# Carbon Dioxide and Earth's Future

## *Pursuing the Prudent Path*

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## Executive Summary

As presently constituted, earth's atmosphere contains just slightly less than 400 ppm of the colorless and odorless gas we call carbon dioxide or $CO_2$. That's only *four-hundredths* of *one percent*. Consequently, even if the air's $CO_2$ concentration was *tripled*, carbon dioxide would still comprise only a little over *one tenth* of one percent of the air we breathe, which is far less than what wafted through earth's atmosphere eons ago, when the planet was a virtual garden place. Nevertheless, a small increase in this minuscule amount of $CO_2$ is frequently predicted to produce a suite of dire environmental consequences, including dangerous global warming, catastrophic sea level rise, reduced agricultural output, and the destruction of many natural ecosystems, as well as dramatic increases in extreme weather phenomena, such as droughts, floods and hurricanes.

As strange as it may seem, these frightening future scenarios are derived from a single source of information: the ever-evolving computer-driven *climate models* that presume to reduce the important physical, chemical and biological processes that combine to determine the state of earth's climate into a set of mathematical equations out of which their forecasts are produced. But do we really *know* what all of those complex and interacting processes are? And even if we *did* -- which we *don't* -- could we correctly reduce them into manageable computer code so as to produce reliable forecasts 50 or 100 years into the future?

Some people answer these questions in the affirmative. However, as may be seen in the body of this report, *real-world observations* fail to confirm essentially *all* of the alarming predictions of significant increases in the frequency and severity of droughts, floods and hurricanes that climate models suggest should occur in response to a global warming of the magnitude that was experienced by the earth over the past two centuries as it gradually recovered from the much-lower-than-present temperatures characteristic of the depths of the Little Ice Age. And other observations have shown that the rising atmospheric $CO_2$ concentrations associated with the development of the Industrial Revolution have actually been *good* for the planet, as they have significantly enhanced the plant productivity and vegetative water use efficiency of earth's natural and agro-ecosystems, leading to a significant "greening of the earth."

In the pages that follow, we present this oft-neglected evidence via a review of the pertinent scientific literature. In the case of the biospheric benefits of atmospheric $CO_2$ enrichment, we find that with more $CO_2$ in the air, plants grow bigger and better in almost every conceivable way, and that they do it more *efficiently*, with respect to their utilization of valuable natural resources, and more *effectively*, in the face of environmental constraints. And when *plants* benefit, so do all of the animals and people that depend upon them for their sustenance.

Likewise, in the case of *climate model inadequacies*, we reveal their many *shortcomings* via a comparison of their "doom and gloom" *predictions* with real-world *observations*. And this exercise reveals that even though the world has warmed substantially over the past century or more -- at a rate that is claimed by many to have been *unprecedented* over the past one to two *millennia* -- this report demonstrates that *none* of the environmental catastrophes that are predicted by climate alarmists to be produced by such a warming has ever come to pass. And this *fact* -- that there have been no significant increases in either the frequency or severity of droughts, floods or hurricanes over the past two centuries or more of global warming -- poses an important question. What should be easier to predict: the effects of global warming on extreme weather events or the effects of elevated atmospheric $CO_2$ concentrations on global temperature? The first part of this question should, in principle, be answerable; for it is well defined in terms of the small number of known factors likely to play a role in linking the independent variable (global warming) with the specified weather phenomena (droughts, floods and hurricanes). The latter part of the question, on the other hand, is ill-defined and possibly even *unanswerable*; for there are *many* factors -- physical, chemical and *biological* -- that could well be involved in linking $CO_2$ (or causing it *not* to be linked) to global temperature.

If, then, today's climate models cannot correctly predict what should be relatively easy for them to correctly predict (the effect of global warming on extreme weather events), why should we believe what they say about something infinitely more complex (the effect of a rise in the air's $CO_2$ content on mean global air temperature)? Clearly, we should pay the models no heed in the matter of *future* climate -- especially in terms of predictions based on the behavior of a *non*-meteorological parameter ($CO_2$) -- until they can reproduce the climate of the past, based on the behavior of one of the most basic of all *true* meteorological parameters (temperature). And even if the models eventually solve this part of the problem, we should still reserve judgment on their forecasts of global warming; for there will yet be a vast gulf between where they will be at that time and where they will have to go to be able to meet the much greater challenge to which they aspire.

## Introduction

Based on the voluminous periodic reports of the Intergovernmental Panel on Climate Change (IPCC), the ongoing rise in the atmosphere's $CO_2$ concentration has come to be viewed as a monumental danger -- not only to human society, but to the world of nature as well. And the picture is not pretty: *searing heat waves* killing the poor and elderly while drying up precious farmland, *melting polar ice caps* raising sea levels and flooding coastal lowlands, *more frequent and ferocious hurricanes* destroying everything in their paths, *devastating diseases* spreading to regions previously considered immune to them, *migrating plants and animals* unable to move to cooler locations fast enough to avoid extinction, *disappearing coral reefs* dissolving into oblivion as the oceans warm and turn acidic, and *spreading anarchy* within and among nations, as fighting erupts over dwindling water supplies and access to land to grow the food they so desperately need to support their burgeoning populations.

It is no wonder that such people are appropriately referred to en masse as *climate alarmists*, being as alarmed as they are about future climatic conditions on earth. But are these horrific "doomsday scenarios" as set-in-stone as the public is led to believe? Do we really *know* all of the complex and interacting processes that should be included in the models upon which these scenarios are based? And can we properly reduce those processes into manageable computer code so as to produce reliable forecasts 50 or 100 years into the future? At present, the only way to properly answer these questions is to compare climate model *projections* with real-world *observations*. Theory is one thing, but empirical reality is quite another. The former may or may *not* be correct, but the latter is *always* right. As such, the only truly objective method to evaluate climate model projections is by comparing them with real-world data.

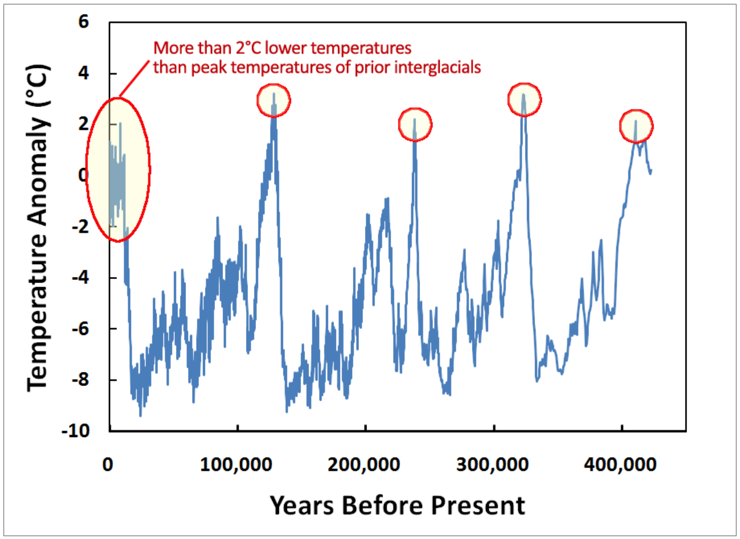
In what follows, we conduct just such an appraisal, comparing against real-world observations ten of the more ominous model-based predictions of what will occur in response to continued business-as-usual anthropogenic $CO_2$ emissions: (1) unprecedented warming of the planet, (2) more frequent and severe floods and droughts, (3) more numerous and stronger hurricanes, (4) dangerous sea level rise, (5) more frequent and severe storms, (6) increased human mortality, (7) widespread plant and animal extinctions, (8) declining vegetative productivity, (9) deadly coral bleaching, and (10) a decimation of the planet's marine life due to ocean acidification. And in conjunction with these analyses, we proffer our view of what the future may hold with respect to the climatic and biological consequences of the ongoing rise in the air's $CO_2$ content, concluding by providing an assessment of what we feel should be done about the situation.

## 1. Unprecedented Warming of the Planet

***The claim:*** *With respect to air temperature, the climate-alarmist contention is multifaceted. It is claimed that over the past several decades: (a) earth's temperature has risen to a* ***level*** *that is unprecedented over the past millennium or more, (b) the world has been warming at a* ***rate*** *that is equally unprecedented, and (c) both of these dubious achievements have been made possible by the similarly unprecedented magnitude of anthropogenic $CO_2$ emissions, due to humanity's ever-increasing burning of fossil fuels such as coal, gas and oil.*

***With respect to the level of warmth the earth has recently attained***, it is important to see how it compares with prior temperatures experienced by the planet, in order to determine the degree of "unprecedentedness" of its current warmth.

Taking a rather lengthy view of the subject, Petit *et al*. (1999) found that peak temperatures experienced during the current interglacial, or Holocene, have been the *coldest* of the last *five* interglacials, with the four interglacials that preceded the Holocene being, on average, more than 2°C warmer (see figure at right). And in a more recent analysis of the subject, Sime *et al*. (2009) suggested that the "maximum interglacial temperatures over the past 340,000 years were between 6.0°C and 10.0°C above present-day values." If anything, therefore, these findings suggest that temperatures of the Holocene, or current interglacial, were indeed unusual, but *not* unusually warm. Quite to the contrary, they have been unusually *cool*.



***Proxy temperature anomalies derived by Petit et al. (1999) from the Vostok ice core in Antarctica..***

But could the higher temperatures of the past four interglacials have been caused by higher $CO_2$ concentrations due to some *non*-human influence? *Absolutely not*, for atmospheric $CO_2$ concentrations during all four prior interglacials never rose above approximately 290 ppm; whereas the air's $CO_2$ concentration today stands at nearly 390 ppm.

Combining these two observations, we have a situation where, compared with the mean conditions of the preceding four interglacials, there is currently 100 ppm *more* $CO_2$ in the air than there was then, and it is currently more than 2°C *colder* than it was then, which adds up to *one huge discrepancy* for the world's climate alarmists and their claim that high atmospheric $CO_2$ concentrations lead to high temperatures. The situation is unprecedented, all right, but *not* in the way the public is being led to believe.

Zooming in a little closer to the present, we compare earth's modern temperatures with those of the past 1000 years, where the IPCC bases its claim for recent heretofore-unreached high temperatures on the infamous “hockey stick” temperature history of Mann *et al*. (1998, 1999). There is a problem with this history, however, in that *reconstructed* temperatures derived from a variety of proxy data (which make up the bulk of the temperature history) are replaced near its end with the historical record of *directly-measured* temperatures, resulting in an “apples vs. oranges” type of comparison, where the latter cannot be validly compared with the former, because the two types of data are not derived in the same way and are, therefore, not perfectly compatible with each other.

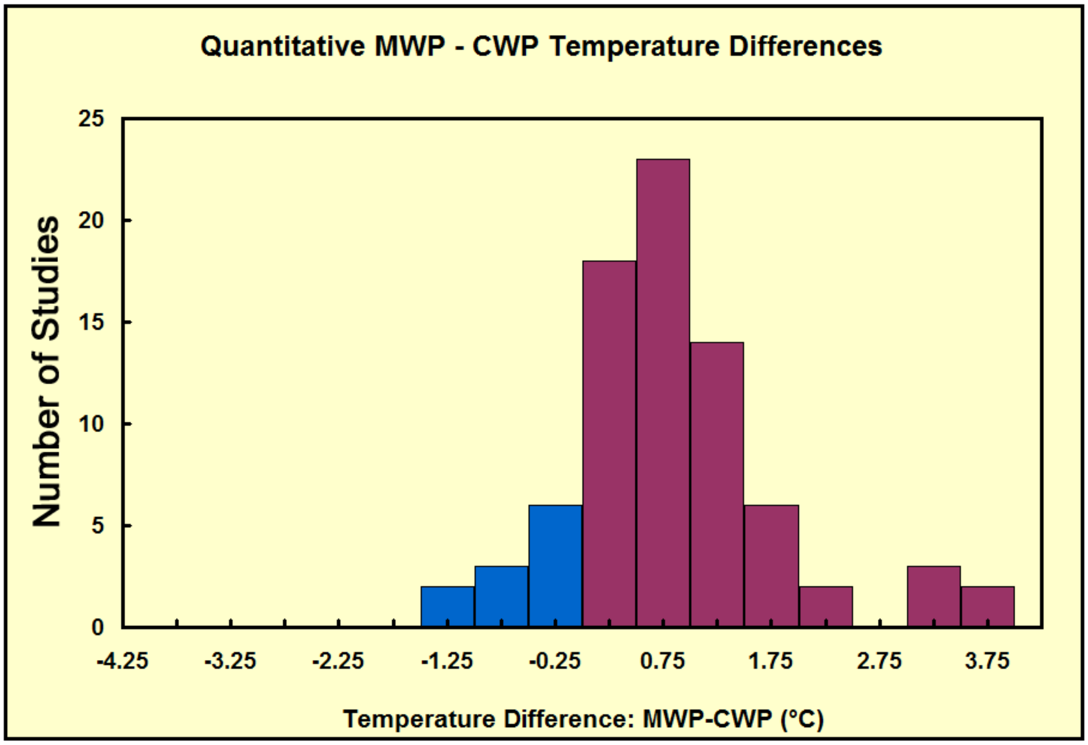
In addition, subsequent evidence indicated that the reconstructed temperatures of some regions did not rise as dramatically as their directly-measured values did over the latter part of the 20th century (Cook *et al*., 2004), demonstrating the importance of the problem and suggesting that if there had been any directly-measured temperatures during the earlier part of the past millennium, they may also have been higher than the reconstructed temperatures of that period. Therefore, due to this *divergence problem*, as D’Arrigo *et al*. (2008) have described it, reconstructions based on tree-ring data from certain regions “cannot be used to directly compare past natural warm periods (notably, the Medieval Warm Period) with recent 20th century warming, making it more difficult to state unequivocally that the recent warming is unprecedented.”

In a much improved method of temperature reconstruction based on tree-ring analysis, Esper *et al*. (2002) employed an analytical technique that allows accurate long-term climatic trends to be derived from individual tree-ring series that are of much shorter duration than the potential climatic oscillation being studied; and they applied this technique to over 1200 individual tree-ring series derived from fourteen different locations scattered across the extratropical region of the Northern Hemisphere. This work revealed, as they describe it, that “past comparisons of the Medieval Warm Period with the 20th-century warming back to the year 1000 have not included all of the Medieval Warm Period and, perhaps, not even its warmest interval.” And in further commenting on this important finding, Briffa and Osborn (2002) revealed that “an early period of warmth in the late 10th and early 11th centuries is more pronounced than in previous large-scale reconstructions.” In addition, the Esper *et al*. record made it abundantly clear that the peak warmth of the Medieval Warm Period was *fully equivalent* to the warmth of the present.

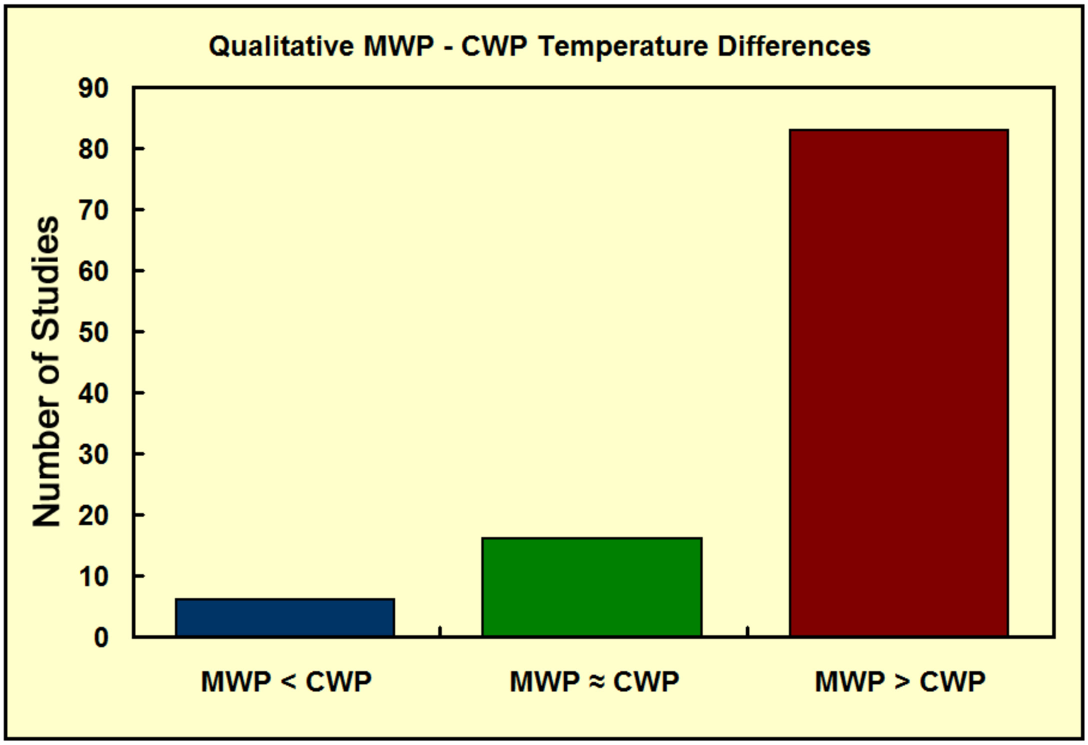
In another important study, von Storch *et al*. (2004) demonstrated that past variations in real-world temperature “may have been at least a factor of two larger than indicated by empirical reconstructions,” and in commenting on their findings, Osborn and Briffa (2004) stated that “if the true natural variability of Northern Hemisphere temperature is indeed greater than is currently accepted,” which they appeared to suggest is likely the case, “the extent to which recent warming can be viewed as ‘unusual’ would need to be reassessed.” And more recently, Mann *et al*. (2009) have had to admit that even using the “apples vs. oranges” approach, the warmth over a large part of the North Atlantic, Southern Greenland, the Eurasian Arctic, and parts of North America during the Medieval Warm Period was "comparable to or exceeds that of the past one-to-two decades in some regions."

So what happens when reconstructed temperature data are employed all the way from the beginning to the end of the past millennium or so? In the data section of our website (www.co2science.org), within what we call our Medieval Warm Period Project, we report the results of a new and properly-prepared millennial temperature reconstruction for a different part of the globe *every single week*. Some of these studies allow actual numerical values of reconstructed temperature differentials between the peak warmth of the Medieval Warm Period (MWP) and the peak warmth of the Current Warm Period (CWP) to be determined, while others merely enable one to determine which of these periods was the warmer of the two.

The results of these two sets of analyses are depicted in the two figures below, representing many more locations than were employed by Mann *et al*. in deriving their original "hockey stick" graph.



***The distribution, in 0.5°C increments, of studies that allow one to identify the degree by which peak Medieval Warm Period temperatures either exceeded (positive values, red) or fell short of (negative values, blue) peak Current Warm Period temperatures.***

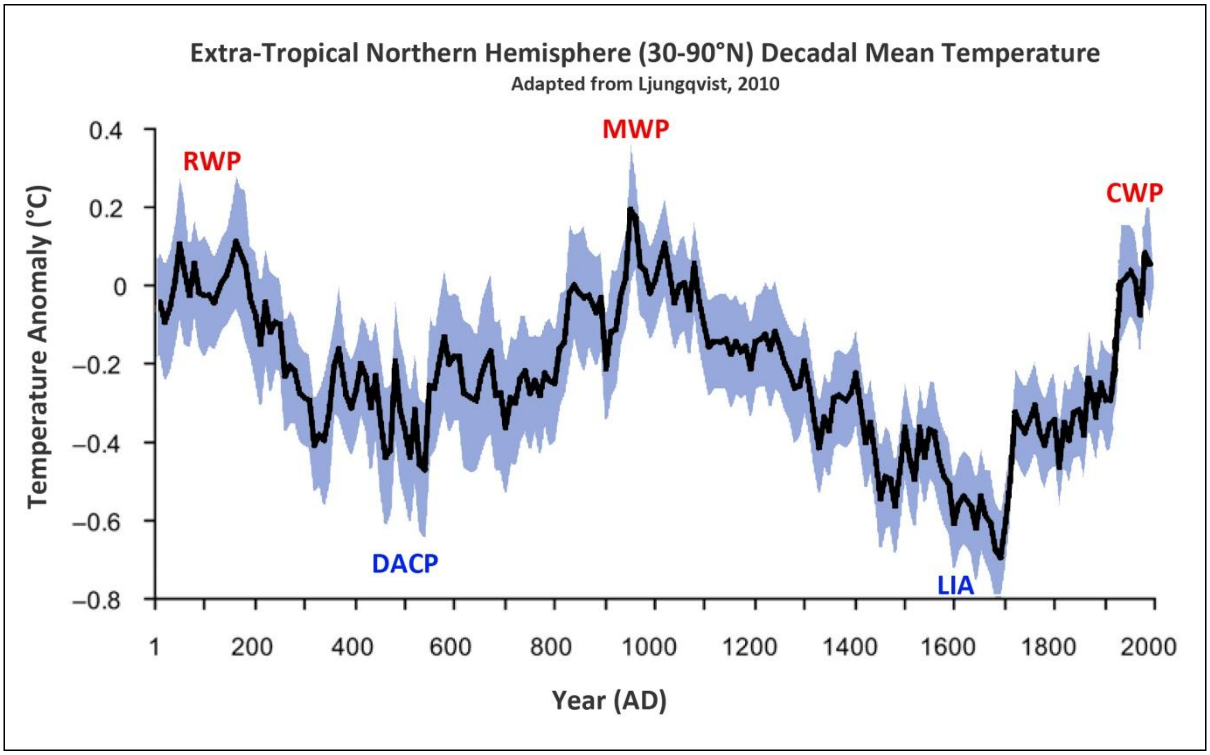


***The distribution of studies that allow one to determine whether peak Medieval Warm Period temperatures were warmer than (red), equivalent to (green), or cooler than (blue), peak Current Warm Period temperatures. These studies do not include those of the preceding figure, the blue ones of which should be added to the blue ones of this figure, and the red ones of which should be added to the red ones of this figure, if true totals of these two result categories are desired.***

The story told by the two figures above seems pretty clear: the peak warmth of the MWP was typically, but not universally, greater than the peak warmth of the CWP has been to date. And that earlier period of greater warmth occurred at a time when the atmosphere's $CO_2$ concentration was fully 100 ppm *less* than it is today, indicative of the fact that the earth has experienced equivalent or warmer temperatures than those of the present when there was *much less* $CO_2$ *in the air*, which suggests that whatever was responsible for the greater warmth of the MWP could easily be responsible for the *lesser* warmth of the CWP.

In discussing one final large-scale study that did *not* mix apples and oranges between its early and later stages, Ljungqvist (2010) developed a 2000-year temperature history of the extra-tropical portion of the Northern Hemisphere (i.e., that part covering the latitudinal range 30-90°N) based on 30 temperature-sensitive proxy records with annual to multi-decadal resolution, including two historical documentary records, three marine sediment records, five lake sediment records, three speleothem $\delta^{18}O$ records, two ice-core $\delta^{18}O$ records, four varved thickness sediment records, five tree-ring width records, five tree-ring maximum latewood density records, and one δ$^{13}$C tree-ring record, but *not* including tree-ring width records from arid and semi-arid regions, since they may have been affected by drought stress, and they may not show a linear response to warming if higher summer temperatures also reduce the availability of water, as suggested by the work of D'Arrigo *et al*. (2006) and Loehle (2009).

The results of Ljungqvist's stellar efforts are depicted in the following figure.



***Reconstructed extra-tropical (30-90°N) mean decadal temperature variations relative to the 1961-1990 mean of the variance-adjusted 30-90°N CRUTEM3+HadSST2 instrumental temperature data of Brohan et al. (2006) and Rayner et al. (2006), showing the approximate locations of the Roman Warm Period (RWP), Dark Ages Cold Period (DACP), Medieval Warm Period (MWP), Little Ice Age (LIA) and Current Warm Period (CEP). Adapted from Ljungqvist (2010).***

In discussing this temperature history, Ljungqvist states that it depicts "a Roman Warm Period *c.* AD 1-300, a Dark Age Cold Period *c.* AD 300-800, a Medieval Warm Period c. AD 800-1300 and a Little Ice Age c. AD 1300-1900, followed by the twentieth-century warming." These alternating warm/cold periods, in his words, "probably represent the much discussed quasi-cyclical *c.* 1470 ± 500-year Bond Cycles (Bond and Lotti, 1995; O'Brien *et al*., 1995; Bond *et al*., 1997, 2001; Oppo, 1997)," which "affected both Scandinavia and northwest North America synchronically (Denton and Karlen, 1973)" and have "subsequently also been observed in China (Hong *et al*., 2009a,b), the mid-latitude North Pacific (Isono *et al*., 2009) and in North America (Viau *et al*., 2006), and have been shown to very likely have affected the whole Northern

Hemisphere during the Holocene (Butikofer, 2007; Wanner *et al*., 2008; Wanner and Butikofer, 2008), or even been global (Mayewski *et al*., 2004)."

Ljungqvist also notes that "decadal mean temperatures in the extra-tropical Northern Hemisphere seem to have equaled or exceeded the AD 1961-1990 mean temperature level during much of the Roman Warm Period and the Medieval Warm Period," and he says that "the second century, during the Roman Warm Period, is the warmest century during the last two millennia," while adding that "the highest average temperatures in the reconstruction are encountered in the mid to late tenth century," which was during the Medieval Warm Period. He warns, however, that the temperature of the last two decades "is possibly higher than during any previous time in the past two millennia," but adds that "this is only seen in the instrumental temperature data and not in the multi-proxy reconstruction itself," which is akin to saying that this possibility only presents itself if one applies Michael Mann's "*Nature* trick" of comparing "apples and oranges," which is clearly not valid, as discussed earlier in this report.

This new study of Ljungqvist is especially important in that it utilizes, in his words, "a larger number of proxy records than most previous reconstructions," and because it "substantiates an already established history of long-term temperature variability." All of these facts, taken together, clearly demonstrate that there is nothing *unusual*, nothing *unnatural* or nothing *unprecedented* about the planet's current level of warmth, seeing it was just as warm as, or even warmer than, it has been recently during *both* the Roman and Medieval Warm Periods, when the atmosphere's $CO_2$ concentration was more than 100 ppm *less* than it is today. And this latter observation, together with the realization that earth's climate *naturally* transits back and forth between cooler and warmer conditions on a millennial timescale, demonstrates that there is absolutely no *need* to associate the planet's current level of warmth with its current higher atmospheric $CO_2$ concentration, in clear contradiction of the worn-out climate-alarmist claim that *the only way* to explain earth's current warmth is to associate it with the greenhouse effect of $CO_2$. That *claim* -- for which there is *no supporting evidence*, other than *misplaced trust* in climate models -- is unsound.

***With respect to the recent rate at which the earth has warmed,*** we examine the results of a number of studies that have investigated recent temperature changes in the Arctic, which Meadows (2001) described as "the place to watch for global warming, the sensitive point, the canary in the coal mine." Here, in comparing the vast array of prior Holocene climate changes with what climate alarmists claim to be the "unprecedented" anthropogenic-induced warming of the past several decades, White *et al*. (2010) recently determined that "the human influence on rate and size of climate change thus far does not stand out strongly from other causes of climate change."

Other scientists preceded White *et al*. with similar conclusions. Chylek *et al*. (2006) studied two century-long temperature records from southern coastal Greenland -- Godthab Nuuk on the west and Ammassalik on the east -- both of which are close to 64°N latitude, concentrating on the period 1915-2005. And in doing so, as they describe it, they determined that "two periods of intense warming (1995-2005 and 1920-1930) are clearly visible in the Godthab Nuuk and

Ammassalik temperature records." However, they state that "the average rate of warming was considerably higher within the 1920-1930 decade than within the 1995-2005 decade." In fact, they report that the earlier warming rate was *50% greater* than the most recent one. And in discussing this fact, they say that "an important question is to what extent can the current (1995-2005) temperature increase in Greenland coastal regions be interpreted as evidence of man-induced global warming?" In providing their own answer, they noted that "the Greenland warming of 1920 to 1930 demonstrates that a high concentration of carbon dioxide and other greenhouse gases is not a necessary condition for [a] period of warming to arise," and that "the observed 1995-2005 temperature increase seems to be within [the] natural variability of Greenland climate."

A similar study was conducted two years later by Mernild *et al*. (2008), who described "the climate and observed climatic variations and trends in the Mittivakkat Glacier catchment in Low Arctic East Greenland from 1993 to 2005 ... based on the period of detailed observations (1993-2005) and supported by synoptic meteorological data from the nearby town of Tasiilaq (Ammassalik) from 1898 to 2004." This work revealed that "the Mittivakkat Glacier net mass balance has been almost continuously negative, corresponding to an average loss of glacier volume of 0.4% per year." And during the past century of general mass loss, they found that "periods of warming were observed from 1918 (the end of the Little Ice Age) to 1935 of 0.12°C per year and 1978 to 2004 of 0.07°C per year," with the former rate of warming being fully 70% greater than the most recent rate of warming.

Last of all, Wood *et al*. (2010) constructed a two-century (1802-2009) *instrumental record* of annual surface air temperature within the Atlantic-Arctic boundary region, using data obtained from recently published (Klingbjer and Moberg, 2003; Vinther *et al*., 2006) and historical (Wahlen, 1886) sources that yielded four station-based composite time series that pertain to Southwestern Greenland, Iceland, Tornedalen (Sweden) and Arkhangel'sk (Russia). This operation added seventy-six years to the previously available record, the credibility of which result, in Wood *et al*.'s words, "is supported by ice core records, other temperature proxies, and historical evidence." And the U.S. and Icelandic researchers determined that their newly extended temperature history and their analysis of it revealed "an irregular pattern of decadal-scale temperature fluctuations over the past two centuries," of which the *early twentieth-century warming* (ETCW) event -- which they say "began about 1920 and persisted until mid-century" -- was *by far* "the most striking historical example."

In further discussing their findings, Wood *et al*. write that "as for the future, with no other examples in the record quite like the ETCW, we cannot easily suggest how often -- much less when -- such a comparably large regional climate fluctuation might be expected to appear." Nevertheless, they say that if past is prologue to the future, "it would be reasonable to expect substantial regional climate fluctuations of either sign to appear from time to time," and, therefore, that "singular episodes of regional climate fluctuation should be anticipated in the future," which also implies that any rapid warming that may subsequently occur within the Atlantic-Arctic boundary region *need not be due to rising greenhouse gas concentrations*, as it could well be caused by the same unknown factor that caused the remarkable ETCW event, which further implies that the Arctic is *not* the “canary in the coal mine” that climate alarmists make it out to be.

***With respect to the cause of earth’s recent warming***, we note that the *truly* unprecedented and increasing magnitude of anthropogenic $CO_2$ emissions over the past few decades has *not* resulted in any similar increase in the rate of Arctic warming. Looking first at three coastal stations in southern and central Greenland that possess almost uninterrupted temperature records between 1950 and 2000, for example, Chylek *et al*. (2004) discovered that “summer temperatures, which are most relevant to Greenland ice sheet melting rates, do not show any persistent increase during the last fifty years.” In fact, working with the two stations with the longest records (both over a century in length), they determined that coastal Greenland’s peak temperatures occurred between 1930 and 1940, and that the subsequent decrease in temperature was so substantial and sustained that then-current coastal temperatures were “about 1°C below their 1940 values.” Furthermore, they noted that at the summit of the Greenland ice sheet the summer average temperature had “decreased at the rate of 2.2°C per decade since the beginning of the measurements in 1987.” Thus, as with the Arctic as a whole, Greenland did not experience *any* net warming over the most dramatic period of atmospheric $CO_2$ increase on record. In fact, it *cooled* during this period ... and cooled *significantly*.

At the *start* of the 20th century, however, Greenland *was* warming, as it emerged, along with the rest of the world, from the depths of the Little Ice Age. What is more, between 1920 and 1930, when the atmosphere’s $CO_2$ concentration rose by a mere 3 to 4 ppm, there was a *phenomenal* warming at all five coastal locations for which contemporary temperature records were available. In fact, in the words of Chylek *et al*., “average annual temperature rose between 2 and 4°C [and by as much as 6°C in the winter] in less than ten years.” And this warming, as they noted, “is also seen in the $^{18}O/^{16}O$ record of the Summit ice core (Steig *et al*., 1994; Stuiver *et al*., 1995; White *et al*., 1997).”

In commenting on this dramatic temperature rise, which they called the *great Greenland warming of the 1920s*, Chylek *et al*. concluded that “since there was no significant increase in the atmospheric greenhouse gas concentration during that time, the Greenland warming of the 1920s demonstrates that a large and rapid temperature increase can occur over Greenland, and perhaps in other regions of the Arctic, due to internal climate variability such as the Northern Annular Mode/North Atlantic Oscillation, without a significant anthropogenic influence.”

Other studies demonstrated pretty much the same thing for the *entire* Arctic, as well as the *Antarctic* region of the globe. Overpeck *et al*. (1997), for example, combined paleoclimatic records from lake and marine sediments, trees and glaciers to develop a 400-year history of circum-Arctic surface air temperature. From this record they determined that the most dramatic warming of the last four centuries (1.5°C) occurred between 1840 and 1955, over which period the air’s $CO_2$ concentration rose from approximately 285 ppm to 313 ppm, or by 28 ppm. Then, from 1955 to the end of the record (about 1990), the mean circum-Arctic air temperature actually *declined* by 0.4°C, while the air’s $CO_2$ concentration rose from 313 ppm to 354 ppm, or by 41 ppm.

On the basis of these observations, which apply to the entire Arctic, it is not possible to assess the influence of atmospheric $CO_2$ on surface air temperature within this region, or even conclude that it has any effect at all. Why? Because over the first 115 years of warming, as the air's $CO_2$ concentration rose by an average of 0.24 ppm/year, the air temperature rose by an average of 0.013°C/year; while over the final 35 years of the record, when the increase in the air's $CO_2$ content *really* began to accelerate, rising at a mean rate of 1.17 ppm/year (nearly *five times* the rate at which it had risen in the prior period), the rate of rise of surface air temperature did not accelerate anywhere *near* that fast. In fact, *it did not accelerate at all*. In fact, it *decelerated*, to a mean rate of change (0.011°C/year) that was nearly the same as the rate at which it had previously risen *but in the opposite direction*, i.e., *downward*. Clearly, there was something that *totally overpowered* whatever effect the rise in the air's $CO_2$ content over the first period may, *or may not*, have had on the temperature of the Arctic, as well as the effect of the nearly five times greater rate of rise in the air's $CO_2$ content over the second period.

Concentrating wholly on *directly-measured* temperatures, as opposed to the *reconstructed* temperatures derived by the proxy approach of Overpeck *et al*. (1997), Polyakov *et al*. (2003) derived a surface air temperature history that stretched from 1875 to 2000 based on data obtained at 75 land stations and a number of drifting buoys located poleward of 62°N latitude. This effort allowed the team of eight U.S. and Russian scientists to determine that from 1875 to about 1917, the surface air temperature of the huge northern region rose hardly at all; but then it took off like a rocket, climbing 1.7°C in just 20 years to reach a peak in 1937 that has yet to be eclipsed. During this 20-year period of rapidly rising air temperature, the atmosphere's $CO_2$ concentration rose by a mere 8 ppm. But then, over the next six decades, when the air's $CO_2$ content rose by approximately 55 ppm, or nearly seven times more than it did throughout the 20-year period of dramatic warming that preceded it, the surface air temperature of the region poleward of 62°N experienced *no net warming* and, in fact, may have actually *cooled* a bit.

In light of these results, it is difficult to claim much about the strength of the warming power of the approximate 75-ppm increase in the atmosphere's $CO_2$ concentration that occurred from 1875 to 2000, other than to say it was *miniscule* compared to whatever other forcing factor, or combination of forcing factors, was concurrently having its way with the climate of the Arctic. One cannot, for example, claim that *any* of the 1917 to 1937 warming was due to the 8-ppm increase in $CO_2$ that accompanied it, even if augmented by the 12-ppm increase that occurred between 1875 and 1917; for the subsequent and much larger 55-ppm increase in $CO_2$ led to *no net warming* over the remainder of the record, which suggests that just a *partial* relaxation of the forces that *totally overwhelmed* the warming influence of the $CO_2$ increase experienced between 1937 and 2000 would have been sufficient to account for the temperature increase that occurred between 1917 and 1937. And understood in this light, the air's $CO_2$ content does not even *begin* to enter the picture.

But what about earth's other polar region: the Antarctic? Here, too, one can conclude nothing about the influence of atmospheric $CO_2$ on surface air temperature. Why? Because *for the* *continent as a whole* (excepting the Antarctic Peninsula), there had been a net cooling over the pre-1990 period, stretching back to at least 1966 (Comiso, 2000; Doran *et al*., 2002; Thompson and Solomon, 2002). And when the real-world air temperature *declines* when the theoretical climate forcing factor is *rising*, one cannot even conclude that the forcing has any positive effect at all, much less determine its magnitude. Hence, there is absolutely no substance to the claim that earth's polar regions are providing evidence for an impending $CO_2$-induced warming of *any* magnitude *anywhere*.

So what does the future hold in terms of global temperature? The answer is anyone's guess. What we ***do*** know, however, is that earth's thermal future can ***not*** be validly described by current state-of-the-art climate models that base their simulations on projections of future anthropogenic $CO_2$ emissions. There is just too much real-world evidence to place any confidence at all in what the climate models suggest.

## 2. More Frequent and Severe Floods and Droughts

***The claim:*** *As a result of the global warming and change in weather patterns that climate models predict will occur in response to the ongoing rise in the air's* $CO_2$ *content, it is claimed that floods and droughts will become both more numerous and severe throughout the world.*

***With respect to current climate model deficiencies***, we note that correctly simulating future extreme weather phenomena such as floods and droughts has proved an extremely difficult task. One reason for the lack of success in this area is inadequate model resolution on both vertical and horizontal spatial scales, which forces climate modelers to *parameterize* the large-scale effects of processes that occur on smaller scales than their models are capable of handling. This is particularly true of physical processes such as cloud formation and cloud-radiation interactions.

A good perspective on the cloud-climate conundrum was provided by Randall *et al*. (2003), who stated at the outset of their review of the subject that "the representation of cloud processes in global atmospheric models has been recognized for decades as the source of much of the uncertainty surrounding predictions of climate variability." However, and despite what they called the "best efforts" of the climate modeling community, they had to acknowledge that "the problem remains largely unsolved." What is more, they suggested that "at the current rate of progress, cloud parameterization deficiencies will continue to plague us for many more decades into the future," which has important implications for correctly predicting precipitation-related floods and drought.

In describing some of these deficiencies, Randall *et al*. stated that "our understanding of the interactions of the hot towers [of cumulus convection] with the global circulation is still in a fairly primitive state," and not knowing all that much about *what goes up*, it's not surprising that we also don't know all that much about *what comes down*, as they report that "downdrafts are either not parameterized or crudely parameterized in large-scale models."

With respect to stratiform clouds, the situation is no better, as their parameterizations were described by Randall *et al*. as "very rough caricatures of reality." As for *interactions* between convective and stratiform clouds, *forget about it* ... which is pretty much what the climate modelers themselves did during the 1970s and 80s, when Randall *et al*. reported that "cumulus parameterizations were extensively tested against observations without even accounting for the effects of the attendant stratiform clouds." Even at the time of their study, in fact, they had to report that the concept of cloud detrainment was "somewhat murky," and that conditions that trigger detrainment were "imperfectly understood." Hence, it should once again come as no surprise that at the time of their review they had to admit that "no existing GCM [included] a satisfactory parameterization of the effects of mesoscale cloud circulations."

Randall *et al*. additionally noted that "the large-scale effects of microphysics, turbulence, and radiation should be parameterized as closely coupled processes acting in concert," but they reported that only a few GCMs had even *attempted* to do so. And why? Because, as they described it, "the cloud parameterization problem is overwhelmingly complicated," and "cloud parameterization developers," as they referred to them, were *still* "struggling to identify the most important processes on the basis of woefully incomplete observations." And to drive this point home, they said "there is little question why the cloud parameterization problem is taking a long time to solve: It is very, very hard." In fact, the four scientists concluded that "a sober assessment suggests that with current approaches the cloud parameterization problem will not be 'solved' in any of our lifetimes."

So is all hope lost with respect to models ever being able to correctly forecast floods and drought if they cannot correctly reproduce clouds and precipitation? Not entirely.

The shining hope of the climate-modeling community resides in something Randall *et al*. called "cloud system-resolving models" or CSRMs, which can be compared with single-column models or SCMs that can be "surgically extracted from their host GCMs." These advanced models, as they describe them, "have resolutions fine enough to represent individual cloud elements, and space-time domains large enough to encompass many clouds over many cloud lifetimes." Of course, these improvements mean that "the computational cost of running a CSRM is hundreds or thousands of times greater than that of running an SCM." Nevertheless, in a few more *decades*, according to Randall *et al*., "it will become possible to use such global CSRMs to perform century-scale climate simulations, relevant to such problems as anthropogenic climate change." In the interim, however, they remain far from ready for prime time, as evidenced in a study conducted four years later by Zhou *et al*. (2007).

Noting that CSRMs "still need parameterizations on scales smaller than their grid resolutions and have many known and unknown deficiencies," and to help stimulate progress in these areas, Zhou *et al*. compared the cloud and precipitation properties observed by instruments deployed in the Clouds and Earth's Radiant Energy System (CERES) and Tropical Rainfall Measuring Mission (TRMM) systems against simulations obtained from the three-dimensional Goddard Cumulus Ensemble (GCE) model during the South China Sea Monsoon Experiment (SCSMEX) field campaign of 18 May-18 June 1998. And as a result of that analysis, the nine researchers reported that: (1) "the GCE rainfall spectrum includes a greater proportion of heavy rains than PR (Precipitation Radar) or TMI (TRMM Microwave Imager) observations," (2) "the GCE model produces excessive condensed water loading in the column, especially the amount of graupel as indicated by both TMI and PR observations," (3) "the model also cannot simulate the bright band and the sharp decrease of radar reflectivity above the freezing level in stratiform rain as seen from PR," (4) "the model has much higher domain-averaged OLR (outgoing longwave radiation) due to smaller total cloud fraction," (5) "the model has a more skewed distribution of OLR and effective cloud top than CERES observations, indicating that the model's cloud field is insufficient in area extent," (6) "the GCE is ... not very efficient in stratiform rain conditions because of the large amounts of slowly falling snow and graupel that are simulated," and finally, in summation, that (7) "large differences between model and observations exist in the rain spectrum and the vertical hydrometeor profiles that contribute to the associated cloud field."

Other studies have continued to demonstrate the difficulties models have in simulating precipitation properties and trends. Kiktev *et al*. (2007), for example, analyzed the abilities of five global coupled climate models that played important roles in the IPCC's Fourth Assessment Report to simulate temporal trends over the second half of the 20th century for five annual indices of precipitation extremes. Their results revealed "low skill" or an "absence" of model skill.

Two years later, Lavers *et al*. (2009) examined the predictive skill of eight seasonal climate forecast models that were developed at various European climate centers. Specifically, they assessed the predictability of monthly precipitation "retrospective forecasts" or *hindcasts*, which were composed of multiple nine-month projections initialized during each month of the year over the period 1981-2001, comparing the projections against *real-world* precipitation values that were obtained from the Global Precipitation Climatology Center data. In addition, they conducted a *virtual-world* analysis, where the output of one of the models was arbitrarily assumed to be the "truth," and where the average of the rest of the models was assumed to be the "predictor."

The results of these exercises indicated that in the *virtual world* of the climate models, there was quite good skill over the first *two weeks* of the forecast, when the spread of ensemble model members was small, but that there was a large drop off in predictive skill in the second 15-day period. Things were even worse in the *real world*, where they say the models had *negligible* skill over land at a 31-day lead time, which they described as being "a relatively short lead time in terms of seasonal climate prediction." In light of these findings, therefore, the three researchers concluded that given the real-world skill -- *or lack thereof!* -- demonstrated by the state-of-the-art models, "it appears that only through significant model improvements can useful long-lead forecasts be provided that would be useful for decision makers," a quest that they quite frankly state "may prove to be elusive."

More of the same was also reported by O'Gorman and Schneider (2009), who assessed "how precipitation extremes change in simulations with 11 different climate models in the World Climate Research Program's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) archive." Based on their findings, as well as those of others, O'Gorman and Schneider reported that "in simulations with comprehensive climate models, the rate of increase in precipitation extremes varies widely among models, especially in the tropics (Kharin *et al*., 2007)." They also noted, in this regard, that "the variations among models in the tropics indicate that simulated precipitation extremes may depend sensitively on the parameterization of *unresolved* and *poorly understood* processes [italics added]," citing the work of Wilcox and Donner (2007). In fact, they state that "climate models do not correctly reproduce the interannual variability of precipitation extremes in the tropics (Allan and Soden, 2008), or the frequency and intensity distribution of precipitation generally (Wilcox and Donner, 2007; Dai, 2006; Sun *et al*., 2006)." Thus, the two researchers concluded that "current climate models cannot reliably predict changes in tropical precipitation extremes," noting that "inaccurate simulation of the upward velocities may explain not only the intermodal scatter in changes in tropical precipitation extremes but also the inability of models to reproduce observed interannual variability."

Most recently, Stephens *et al*. (2010) employed "new and definitive measures of precipitation frequency provided by CloudSat [e.g., Haynes *et al*., 2009]" to assess the realism of global model precipitation via an analysis that employed five different computational techniques representing "state-of-the-art weather prediction models, state-of-the-art climate models, and the emerging high-resolution global cloud 'resolving' models." The results of this exercise indicated that "the character of liquid precipitation (defined as a combination of accumulation, frequency, and intensity) over the global oceans is significantly different from the character of liquid precipitation produced by global weather and climate models," and that "the differences between observed and modeled precipitation are larger than can be explained by observational retrieval errors or by the inherent sampling differences between observations and models."

More specifically, Stephens *et al*. reported that for precipitation over the global ocean as a whole, "the mean model intensity lies between 1.3 and 1.9 times less than the averaged observations," while occurrences "are approximately twice the frequency of observations." They also found that the models "produce too much precipitation over the tropical oceans" and "too little mid-latitude precipitation." And they indicate that the large model errors "are not merely a consequence of inadequate upscaling of observations but indicative of a systemic problem of models more generally."

In concluding their study, the nine US, UK and Australian researchers say their results imply that state-of-the-art weather and climate models have "little skill in precipitation calculated at individual grid points," and that "applications involving downscaling of grid point precipitation to yet even finer-scale resolution has little foundation and relevance to the real earth system," which is not too encouraging a result, considering it is the "real earth system" in which we live and for which we have great concern. Therefore, given these findings, as well as the many others previously cited, it is difficult to conceive how today's state-of-the-art computer models can be claimed to produce reliable flood and drought forecasts decades and centuries into the future.

Fortunately, there exists an *alternative* means by which the claim that global warming will result in more frequent and severe floods and droughts can be evaluated. Since climate alarmists contend the earth has already experienced a warming that has been *unprecedented over the past millennium or more*, we can assess the validity of their claims about the future of floods and droughts by examining to what extent the planet's emergence from the global chill of the Little Ice Age has -- or has not -- impacted the frequency and magnitude of these two extreme and often-deadly forces of nature. Or for records that are long enough, we can compare the characteristics of these phenomena as they were expressed during the cold of the Little Ice Age and the heat of the prior Medieval Warm Period. And as we do so, we find that there does not appear to have been any warming-driven increase in floods or droughts, as demonstrated by the papers reviewed in the following two subsections of this document.

***With respect to prior observed effects of warming on floods***, we focus first on Europe, where Nesje *et al*. (2001) analyzed a sediment core from a lake in southern Norway, attempting to determine the frequency and magnitude of prior floods in that region. The last thousand years of this record, as they describe it, revealed "a period of little flood activity around the Medieval period (AD 1000-1400)," which was followed by a period of *extensive* flood activity associated with the "post-Medieval climate deterioration characterized by lower air temperature, thicker and more long-lasting snow cover, and more frequent storms associated with the 'Little Ice Age'."

Moving on to France, Pirazzoli (2000) analyzed tide-gauge and meteorological data over the period 1951-1997 for the northern portion of the French Atlantic coast, discovering that "ongoing trends of climate variability show a decrease in the frequency and hence the gravity of coastal flooding." A year later, however, on the 8th and 9th of September 2002, extreme flooding of the Gardon River in southern France claimed the lives of a number of people and caused much damage to towns and villages situated adjacent to its channel. This event elicited much coverage in the press; and Sheffer *et al*. (2003) wrote that "this flood is now considered by the media and professionals to be 'the largest flood on record'," which record extends all the way back to 1890. Coincidently, however, Sheffer *et al*. were in the midst of a study of prior floods of the Gardon River when the "big one" hit; and they had data spanning a much longer time period against which to compare its magnitude. Based on their findings, they were able to report that "the extraordinary flood of September 2002 was not the largest by any means," noting that "similar, and even larger floods have occurred several times in the recent past," with three of the five greatest floods they had identified to that point in time occurring over the period AD 1400-1800 during the Little Ice Age.

Five years later, Sheffer *et al*. (2008) had obtained even more data on the subject. Working in two caves and two alcoves of a 1600-meter-long stretch of the Gardon River, they analyzed geomorphic, sedimentologic and hydrologic data associated with both historical and late Holocene floods, which they had hoped would provide a longer and better-defined perspective on the subject. And so it did, as they discovered that "at least five floods of a larger magnitude than the 2002 flood occurred over the last 500 years," all of which took place, as they describe it, "during the Little Ice Age." In addition, they reported that several other studies had also determined that "the Little Ice Age has been related to increased flood frequency in France," citing the work of Guilbert (1994), Coeur (2003) and Sheffer (2003, 2005).

Also working in France at this time were Renard *et al*. (2008), who employed four different procedures for assessing field significance and regional consistency with respect to trend detection in both high-flow and low-flow hydrological regimes of French rivers. This they did using daily discharge data obtained from 195 gauging stations having a minimum record length of 40 years; and in doing so, they determined that "at the scale of the entire country, the search for a generalized change in extreme hydrological events through field significance assessment remained largely inconclusive." In addition, they discovered that at the smaller scale of hydro-climatic regions, there were also no significant results for most such areas.

Working in the Myjava Hill Land of Slovakia, Stankoviansky (2003) employed topographical maps and aerial photographs, field geomorphic investigation, and the study of historical documents, including those from local municipal and church sources, to determine the spatial distribution of gully landforms and the temporal history of their creation. These diverse efforts led to his discovery that "the central part of the area, settled between the second half of the 16th and the beginning of the 19th centuries, was affected by gully formation in two periods, the first between the end of the 16th century and the 1730s and the second roughly between the 1780s and 1840s," and he reports that "the triggering mechanism of gullying was extreme rainfalls during the Little Ice Age." More specifically, he writes that "the gullies were formed relatively quickly by repeated incision of ephemeral flows concentrated during extreme rainfall events, which were clustered in periods that correspond with known climatic fluctuations during the Little Ice Age." Subsequently, from the mid-19th century to the present, he reported there has been a *decrease* in gully growth because of "climatic improvements since the termination of the Little Ice Age."

In Sweden, Lindstrom and Bergstrom (2004) analyzed runoff and flood data from more than 60 discharge stations scattered throughout the country, some of which provided information stretching as far back in time as the early to mid-1800s, when Sweden and the world were still experiencing the cold of the Little Ice Age. This analysis led them to discover that the last 20 years of the past century were indeed unusually wet, with a runoff anomaly of +8% compared with the century average. But they also found that "the runoff in the 1920s was comparable to that of the two latest decades," and that "the few observation series available from the 1800s show that the runoff was even higher than recently." In addition, they determined that "flood peaks in old data [were] probably underestimated," which "makes it difficult to conclude that there has really been a significant increase in average flood levels." Also, they report that "no increased frequency of floods with a return period of 10 years or more could be determined." And with respect to the generality of their findings, the two researchers state that conditions in Sweden "are consistent with results reported from nearby countries: e.g. [Norway] Forland *et al*. (2000), [Denmark] Bering Ovesen *et al*. (2000), [Latvia] Klavins *et al*. (2002) and [Finland] Hyvarinen (2003)," noting that "it has been difficult to show any convincing evidence of an increasing magnitude of floods (e.g. Roald, 1999) in the near region."

Macklin *et al*. (2005) developed what they describe as "the first probability-based, long-term record of flooding in Europe, which spans the entire Holocene and uses a large and unique database of $^{14}$C-dated British flood deposits," after which they compared their reconstructed flood history "with high-resolution proxy-climate records from the North Atlantic region, northwest Europe and the British Isles to critically test the link between climate change and flooding." As a result of this multifaceted endeavor, they determined that "the majority of the largest and most widespread recorded floods in Great Britain occurred during cool, moist periods," and that "comparison of the British Holocene palaeoflood series ... with climate reconstructions from tree-ring patterns of subfossil bog oaks in northwest Europe also suggests that a similar relationship between climate and flooding in Great Britain existed during the Holocene, with floods being more frequent and larger during relatively cold, wet periods."

Three years later, while noting that "recent flood events have led to speculation that climate change is influencing the high-flow regimes of United Kingdom catchments" and that "projections suggest that flooding may increase in [the] future as a result of human-induced warming," Hannaford and Marsh (2008) used the UK benchmark network of 87 near-natural catchments identified by Bradford and Marsh (2003) to conduct a UK-wide appraisal of trends in high-flow regimes unaffected by human disturbances. This work revealed, in their words, that "significant positive trends were observed in all high-flow indicators ... over the 30-40 years prior to 2003, primarily in the maritime-influenced, upland catchments in the north and west of the UK." *However*, they say "there is little compelling evidence for high-flow trends in lowland areas in the south and east." They also found that "in western areas, high-flow indicators are correlated with the North Atlantic Oscillation Index (NAOI)," so that "recent trends may therefore reflect an influence of multi-decadal variability related to the NAOI." In addition, they state that longer river flow records from five additional catchments they studied "provide little compelling evidence for long-term (>50 year) trends but show evidence of pronounced multi-decadal fluctuations." Lastly, they add that "in comparison with other indicators, there were fewer trends in flood magnitude," and that "trends in peaks-over-threshold frequency and extended-duration maxima at a gauging station were not necessarily associated with increasing annual maximum instantaneous flow." All things considered, therefore, Hannaford and Marsh concluded that "considerable caution should be exercised in extrapolating from any future increases in runoff or high-flow frequency to an increasing vulnerability to extreme flood events."

"Starting from historical document sources, early instrumental data (basically, rainfall and surface pressure) and the most recent meteorological information," as they describe it, Llasat *et al*. (2005) analyzed "the temporal evolution of floods in northeast Spain since the 14th century," focusing particularly on the river Segre in Lleida, the river Llobregat in El Prat, and the river Ter in Girona. This work indicated there was "an increase of flood events for the periods 1580-1620, 1760-1800 and 1830-1870," and they report that "these periods are coherent with chronologies of maximum advance in several alpine glaciers." In addition, their tabulated data indicate that for the aggregate of the three river basins noted above, the mean number of what Llasat *et al*. call *catastrophic floods per century* for the 14th through 19th centuries was 3.55 ± 0.22, while the corresponding number for the 20th century was only 1.33 ± 0.33. Thus, the four Spanish researchers concluded their paper by saying "we may assert that, having analyzed responses inherent to the Little Ice Age and due to the low occurrence of frequent flood events or events of exceptional magnitude in the 20th century, the latter did not present an excessively problematic scenario."

Five years later, working in *southeast* Spain, Benito *et al*. (2010) reconstructed flood frequencies of the Upper Guadalentin River using "geomorphological evidence, combined with one-dimensional hydraulic modeling and supported by records from documentary sources at Lorca in the lower Guadalentin catchment." Their efforts revealed that past floods were clustered during particular time periods: AD 950-1200 (10), AD 1648-1672 (10), AD 1769-1802 (9), AD 1830-1840 (6), and AD 1877-1900 (10), where the first time interval coincides with the Medieval Warm Period and the latter four time intervals all fall within the confines of the Little Ice Age; and calculating mean rates of flood occurrence over each of the five intervals, we obtain a value of 0.40 floods per decade during the Medieval Warm Period, and an average value of 4.31 floods per decade over the four parts of the Little Ice Age, which latter value is *more than ten times greater* than the mean flood frequency experienced during the Medieval Warm Period.

In Poland, Cyberski *et al*. (2006) used documentary sources of information (written documents and "flood boards") to develop a reconstruction of winter flooding of the Vistula River all the way back to AD 988; and this work indicated, in their words, that winter floods "have exhibited a decreasing frequency of snowmelt and ice-jam floods in the warming climate over much of the Vistula basin."

Focusing on southwest Germany, Burger *et al*. (2007) reviewed what was known about flooding in this region over the past three centuries, which takes us back well into the Little Ice Age. The six scientists report that the extreme flood of the Neckar River in October 1824 was "the largest flood during the last 300 years in most parts of the Neckar catchment." In fact, they say "it was the highest flood ever recorded in most parts of the Neckar catchment and also affected the Upper Rhine, the Mosel and Saar." In addition, they report that the historical floods of 1845 and 1882 "were among the most extreme floods in the Rhine catchment in the 19th century," which they describe as truly "catastrophic events." And speaking of the flood of 1845, they say it "showed a particular impact in the Middle and Lower Rhine and in this region it was higher than the flood of 1824." Finally, the year 1882 actually saw *two* extreme floods, one at the end of November and one at the end of December. Of the first one, Burger *et al*. say that "in Koblenz, where the Mosel flows into the Rhine, the flood of November 1882 was the fourth-highest of the recorded floods, after 1784, 1651 and 1920," with the much-hyped late-20th-century floods of 1993, 1995, 1998 and 2002 *not even meriting a mention*.

On a broader multi-country scale, Mudelsee *et al*. (2003) analyzed historical documents from the 11th century to 1850, plus subsequent water stage and daily runoff records from then until 2002, for two of the largest rivers in central Europe: the Elbe and Oder Rivers. In doing so, they discovered that for the prior 80 to 150 years, which climate alarmists typically describe as a period of unprecedented global warming, there was actually "a decrease in winter flood occurrence in both rivers, while summer floods show[ed] no trend, consistent with trends in extreme precipitation occurrence." Then, shortly thereafter, Mudelsee *et al*. (2004) wrote that "extreme river floods have had devastating effects in central Europe in recent years," citing as examples the Elbe flood of August 2002, which caused 36 deaths and inflicted damages totaling over 15 billion U.S. dollars, and the Oder flood of July 1997, which caused 114 deaths and inflicted approximately 5 billion dollars in damages.

The researchers then noted that concern had been expressed in this regard "in the Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change," wherein it was stated that "current anthropogenic changes in atmospheric composition will add to this risk." Unconvinced about this contention, however, the four researchers reevaluated the quality of data and methods of reconstruction that had previously produced flood histories of the middle parts of the Elbe and Oder rivers back to AD 1021 and 1269, respectively; and in doing so, they found, for both the Elbe and Oder rivers, "no significant trends in summer flood risk in the twentieth century," but "significant downward trends in winter flood risk," which latter phenomenon -- described by them as "a reduced winter flood risk during the instrumental period" -- they specifically described as "a response to regional warming."

Rounding out the study of Europe, based on information on flood losses obtained from the Emergency Events Database and the Natural Hazards Assessment Network, Barredo (2009) developed a 1970-2006 history of *normalized* monetary flood losses throughout the continent -- including the member states of the European Union along with Norway, Switzerland, Croatia and the former Yugoslav Republic of Macedonia -- by calculating the value of losses that would have occurred if the floods of the past had taken place under the current socio-economic conditions of the continent, while further removing inter-country price differences by adjusting the losses for purchasing power parities.

This work revealed, in the analyst's words, that "there is no evidence of a clear positive trend in normalized flood losses in Europe," and that "changes in population, inflation and per capita real wealth are the main factors contributing to the increase of the original raw losses." Thus, after removing the influence of the stated socio-economic factors, the European Commission researcher declared "there remains no evident signal suggesting any influence of anthropogenic climate change on the trend of flood losses in Europe during the assessed period."

In summation, the studies described above, from locations scattered throughout all of Europe, contradict the climate-alarmist claim that warming results in more frequent and more severe floods. In addition, there do not appear to have been any increases in either floods or properly-adjusted flood damages throughout all of Europe over the period of time the world's climate alarmists contend was the warmest of the past thousand or more years. And Europe is no anomaly is this regard, for things have been found to be largely the same almost everywhere such studies have been conducted; and in light of this fact -- and to not unnecessarily lengthen our report -- in the following two paragraphs we merely cite the journal references to similar investigations that have produced similar findings on earth's other continents.

For *North America*, see Ely (1997), Brown *et al*. (1999), Lins and Slack (1999), Olsen *et al*. (1999), Haque (2000), Knox (2001), Molnar and Ramirez (2001), Campbell (2002), Garbrecht and Rossel (2002), Ni *et al*. (2002), Noren *et al*. (2002), St. George and Nielsen (2002), Fye *et al*. (2003), Schimmelmann *et al*. (2003), Shapley *et al*. (2005), Wolfe *et al*. (2005), Carson *et al*. (2007), Pinter *et al*. (2008), Collins (2009), Cunderlik and Ouarda (2009) and Villarini and Smith (2010).

For *Asia*, see Cluis and Laberge (2001), Jiang *et al*. (2005), Zhang *et al*. (2007), Zhang *et al*. (2009), and Panin and Nefedov (2010), while for *South America*, see Wells (1990), Magillian and Goldstein (2001) and Rein *et al*. (2004), and for *Africa*, see Heine (2004).

***With respect to prior observed effects of warming on drought***, we find that the peer-reviewed scientific literature clearly demonstrates that the climate-model-based claim of more frequent and severe droughts being induced by global warming is also false. And we begin our review of the evidence that makes this conclusion very clear by scrutinizing recent research work that has been conducted in North America.

Confining themselves to the continental United States, Andreadis and Lettenmaier (2006) examined 20th-century trends in soil moisture, runoff and drought with a hydro-climatological model forced by real-world data for precipitation, air temperature and wind speed over the period 1915-2003. This work revealed, in their words, that “droughts have, for the most part, become shorter, less frequent, less severe, and cover a smaller portion of the country over the last century.” And it would seem to be nigh unto impossible to contemplate a more *stunning rebuke* of climate-alarmist claims concerning global warming and drought than that provided by this study.

Working within the conterminous United States and part of Mexico (20-50°N, 130-60°W), Van der Schrier *et al*. (2006) constructed maps of summer moisture availability for the period 1901-2002 with a spatial resolution of 0.5° latitude x 0.5° longitude; and as a result of their efforts, they were able to report that over the area as a whole, “the 1930s and 1950s stand out as times of persistent and exceptionally dry conditions, whereas the 1970s and the 1990s were generally wet.” However, they say that “no statistically significant trend was found in the mean summer PDSI over the 1901-2002 period, nor in the area percentage with moderate or severe moisture excess or deficit.” In fact, they could not find *a single coherent area* within the PDSI maps that “showed a statistically significant trend over the 1901-2002 period.”

Expanding their scope still further, Cook *et al*. (2004) developed a 1200-year drought history for the western half of the United States and adjacent parts of Canada and Mexico (hereafter referred to as the 'West'), based on their analysis of annually-resolved tree-ring records of summer-season Palmer Drought Severity Index that were derived for 103 points on a 2.5° x 2.5° grid, 66% of which possessed data that extended back to AD 800. This reconstruction, in their words, revealed “some remarkable earlier increases in aridity that dwarf the comparatively short-duration current drought in the 'West'.” Interestingly, they report that the four driest epochs (centered on AD 936, 1034, 1150 and 1253) all occurred during an approximate 400-year interval of overall elevated aridity from AD 900 to 1300, which they describe as being “broadly consistent with the Medieval Warm Period.”

Commenting further on their findings, the five researchers stated that “the overall coincidence between our megadrought epoch and the Medieval Warm Period suggests that anomalously warm climate conditions during that time may have contributed to the development of more frequent and persistent droughts in the ‘West’,” as well as to the megadrought that was discovered by Rein *et al*. (2004) to have occurred in Peru at about the same time (AD 800-1250); and after citing nine other studies that provide independent evidence of drought during this time period for various sub-regions of the West, they warn that “any trend toward warmer temperatures in the future could lead to a serious long-term increase in aridity over western North America,” noting that “future droughts in the ‘West’ of similar duration to those seen prior to AD 1300 would be disastrous.”

We certainly agree with Cook *et al*.'s analysis, noting that such an unfortunate fate could well befall the western United States, *even in the absence of $CO_2$-induced global warming*; for the millennial-scale oscillation of climate that brought the world the Medieval Warm Period (which was obviously *not* $CO_2$-induced) could well be in process of repeating itself during the possibly still-ongoing development of the Current Warm Period. And if the association between global warmth and drought in the western United States is robust, it additionally suggests that current world temperatures are still *far below* those experienced during much of the Medieval Warm Period.

At about the same time, Woodhouse (2004) reported what was then known about *natural* hydroclimatic variability throughout the United States via descriptions of several major droughts that had occurred there over the past three millennia, all but the last century of which had experienced atmospheric $CO_2$ concentrations that never varied by more than about 10 ppm from a mean value of 280 ppm. For comparative purposes, Woodhouse began by noting that "the most extensive U.S. droughts in the 20th century were the 1930s Dust Bowl and the 1950s droughts." The first of these droughts lasted "most of the decade of the 1930s" and "occurred in several waves," while the latter "also occurred in several waves over the years 1951-1956." Far more severe than either of these two droughts, however, was what has come to be known as the *16th-Century Megadrought*, which lasted from 1580 to 1600 and included northwestern Mexico in addition to the southwestern United States and the western Great Plains. Then there was what is simply called *The Great Drought*, which spanned the last quarter of the 13th century and was actually the last in a series of *three* 13th-century droughts, the first of which may have been even more severe than the last. In addition, Woodhouse notes there was a period of remarkably sustained drought in the second half of the 12th century.

It is evident from these observations, according to Woodhouse, that "the 20th century climate record contains only a subset of the range of natural climate variability in centuries-long and longer paleoclimatic records." It is also obvious that this subset, as it pertains to water shortage, does not even *begin* to approach the level of drought severity and duration experienced in prior centuries and millennia. This being the case, it is also clear that it would take a drought *much* more extreme than the most extreme droughts of the 20th century to propel the western United States and adjacent portions of Canada and Mexico into a truly unprecedented state of dryness.

Three years later, Seager (2007) studied the global context of the drought that affected nearly the entire United States, northern Mexico and the Canadian Prairies between 1998 and 2004. On the basis of atmospheric reanalysis data and ensembles of climate model simulations forced by global or tropical Pacific sea surface temperatures over the period January 1856 to April 2005, he compared the climatic circumstances of the recent drought with those of five prior great droughts of North America: (1) the Civil War drought of 1856-65, (2) the 1870s drought, (3) the 1890s drought, (4) the great Dust Bowl drought, and (5) the 1950s drought. And in doing so, he found that the 1998-2002 drought "was most likely caused by multiyear variability of the tropical Pacific Ocean," noting that the recent drought "was the latest in a series of six persistent global hydroclimate regimes, involving a persistent La Niña-like state in the tropical

Pacific and dry conditions across the midlatitudes of each hemisphere." In fact, there was no aspect of this study that implicated global warming, either $CO_2$-induced or otherwise, as a cause of -- or contributor to -- the great turn-of-the-20th-century drought that affected large portions of North America. Seager noted, for example, that "although the Indian Ocean has steadily warmed over the last half century, this is not implicated as a cause of the turn of the century North American drought because the five prior droughts were associated with cool Indian Ocean sea surface temperatures." In addition, the five earlier great droughts occurred during periods when the mean global temperature was also significantly cooler than what it was during the last great drought.

Another far-ranging study was that of Cook *et al*. (2007), who discussed the nature of a number of megadroughts that occurred over the past millennium and clearly exceeded in all aspects all droughts of the instrumental period. Indeed, they state that "these past megadroughts dwarf the famous droughts of the 20th century, such as the Dust Bowl drought of the 1930s, the southern Great Plains drought of the 1950s, and the current one in the West that began in 1999," all of which dramatic droughts fade into almost *total insignificance* when compared to the granddaddy of them all, which they describe as "an epoch of significantly elevated aridity that persisted for almost 400 years over the AD 900-1300 period."

Of central importance to North American drought formation, in the words of the four researchers, "is the development of cool 'La Niña-like' SSTs in the eastern tropical Pacific." *Paradoxically*, as they describe the situation, "warmer conditions over the tropical Pacific region lead to the development of cool La Niña-like SSTs there, which is drought inducing over North America." And in further explaining the mechanics of this phenomenon, on which they say both "model and data agree," Cook *et al*. state that "if there is a heating over the entire tropics then the Pacific will warm more in the west than in the east because the strong upwelling and surface divergence in the east moves some of the heat poleward," with the result that "the east-west temperature gradient will strengthen, so the winds will also strengthen, so the temperature gradient will increase further ... leading to a more La Niña-like state." What is more, they add that "La Niña-like conditions were apparently the norm during much of the Medieval period when the West was in a protracted period of elevated aridity and solar irradiance was unusually high."

In light of these several observations, it would appear that throughout the AD 900-1300 period of what Cook *et al*. call "significantly elevated aridity" in North America, the tropical Pacific Ocean likely experienced *significantly elevated temperature*, which may well have been far greater than anything experienced over the course of the 20th century, because there was no period of time over the last several hundred years when North America experienced anything like the seemingly endless aridity of that *400-year megadrought* that coincided with the great central portion of the Medieval Warm Period. And in light of *this* observation, we conclude that much of the Medieval Warm Period *had* to have been *much* warmer than even the *warmest* portion of the 20th century, or any time since. In fact, there is reason to believe that the world *as a whole* may well have been warmer during the bulk of the Medieval Warm Period than it is currently, for Cook *et al*. write that "the persistent droughts over North America all arose as part of the response of the global climate to persistent La Niña-like conditions in the tropical Pacific Ocean." And this conclusion contradicts the climate-alarmists' primary but unfounded claim that the world is currently warmer than it has been at any other time over the past two millennia or more.

It is instructive to learn how Native Americans were impacted by different dry phases of the Medieval Warm Period, which was the subject of the study of Benson *et al*. (2007), who reviewed and discussed possible impacts of early-11th-, middle-12th-, and late-13th-century droughts on three Native American cultures that occupied parts of the western United States (Anasazi, Fremont, Lovelock) plus another culture that occupied parts of southwestern Illinois (Cahokia). They report, in this regard, that "population declines among the various Native American cultures were documented to have occurred either in the early-11th, middle-12th, or late-13th centuries" -- AD 990-1060, 1135-1170, and 1276-1297, respectively -- and that "really extensive droughts impacted the regions occupied by these prehistoric Native Americans during one or more of these three time periods." In particular, they say the middle-12th-century drought "had the strongest impact on the Anasazi and Mississippian Cahokia cultures," noting that "by AD 1150, the Anasazi had abandoned 85% of their great houses in the Four Corners region and most of their village sites, and the Cahokians had abandoned one or more of their agricultural support centers, including the large Richland farming complex." In addition, they write that "the sedentary Fremont appear to have abandoned many of their southern area habitation sites in the greater Unita Basin area by AD 1150 as well as the eastern Great Basin and the Southern Colorado Plateau," so that "in some sense, the 13th century drought may simply have 'finished off' some cultures that were already in decline." Lastly, they state that these "major reductions in prehistoric Native American habitation sites/population" occurred during "anomalously warm" climatic conditions, which characterized the Medieval Warm Period throughout much of the world at that particular time. And the fact that the deadly North American droughts of the MWP have *never been equaled* throughout *all the ensuing years* argues strongly that what Benson *et al*. call the *anomalous warmth* of that period has *also* "never been equaled throughout all the ensuing years," which further suggests (since the air's $CO_2$ content was so much less during the MWP than it is now) that the considerably lesser warmth of today need not in any way be related to the much higher $CO_2$ concentration of earth's current atmosphere.

At this point, we have covered large portions of the United States plus other parts of North America; and we will discuss a few additional studies that consider this larger area, beginning with that of Stahle *et al*. (2000). This team of eight researchers developed a long-term history of drought over North America from reconstructions of the Palmer Drought Severity Index (PDSI), based on analyses of many lengthy tree-ring records; and in doing so, they found that the 1930s Dust Bowl drought in the United States -- which was the nation's most severe, sustained, and wide-spread drought of the past 300 years -- was eclipsed in all three of these categories by a 16th-century "megadrought." Although this drought has been mentioned in some of the prior studies we have reviewed, it is worth noting the additional information that Stahle *et al*. present.

The 16th-century *megadrought*, as they describe it, persisted "from the 1540s to 1580s in Mexico, from the 1550s to 1590s over the [U.S.] Southwest, and from the 1570s to 1600s over Wyoming and Montana," and it "extended across most of the continental United States during the 1560s." It also recurred with greater intensity over the Southeast during the 1580s to 1590s; and so horrendous was this climatic event, that the researchers unequivocally stated that "the 'megadrought' of the 16th century far exceeded any drought of the 20th century." In fact, they said that "precipitation reconstruction for western New Mexico suggests that the 16th century drought was the most extreme prolonged drought in the past 2000 years."

To put these various sets of droughts in perspective, we turn to the study of Stahle *et al*. (2007), who used an expanded grid of tree-ring reconstructions of summer Palmer Drought Severity Indices covering the United States, southern Canada, and most of Mexico to examine the timing, intensity, and spatial distribution of decadal to multidecadal moisture regimes over North America. This work revealed that during the Current Warm Period, "the Dust Bowl drought of the 1930s and the Southwestern drought of the 1950s were the two most intense and prolonged droughts to impact North America," as did the studies of Worster (1979), Diaz (1983) and Fye *et al*. (2003). During the Little Ice Age, on the other hand, they report the occurrence of three *megadroughts*, which they define as "very large-scale drought[s] more severe and sustained than any witnessed during the period of instrumental weather observations (e.g., Stahle *et al*., 2000)." However, they report that still "stronger and more persistent droughts have been reconstructed with tree rings and other proxies over North America during the Medieval era (e.g., Stine, 1994; Laird *et al*., 2003; Cook *et al*., 2004)." In fact, they say that these latter megadroughts were so phenomenal that they decided to refer to them as "no-analog Medieval megadroughts."

So with *megadroughts* occurring at *cooler*-than-present temperatures and with *no-analog megadroughts* occurring at *warmer*-than-present temperatures, one must consider the possibility that something *other than temperature* is the driving force behind their occurrence. And there are a number of scientists who feel that that "something other" is *solar variability*, such as Black *et al*. (1999), who stated that "small changes in solar output may influence Atlantic variability on centennial time scales," Yu and Ito (1999), who felt forced "to consider solar variability as the major cause of century-scale drought frequency in the northern Great Plains," Dean and Schwalb (2000), who concluded "it seems reasonable that the cycles in aridity and eolian activity over the past several thousand years recorded in the sediments of lakes in the northern Great Plains might also have a solar connection," Verschuren *et al*. (2000), who indicated that variations in solar activity "may have contributed to decade-scale rainfall variability in equatorial east Africa," Hodell *et al*. (2001), who wrote that "a significant component of century-scale variability in Yucatan droughts is explained by solar forcing," Mensing *et al*. (2004), who concluded that "changes in solar irradiance may be a possible mechanism influencing century-scale drought in the western Great Basin" of the United States, Asmerom *et al*. (2007), who suggest that a solar link to Holocene climate operates "through changes in the Walker circulation and the Pacific Decadal Oscillation and El Niño-Southern Oscillation systems of the tropical Pacific Ocean," Garcin *et al*. (2007), who emphasize that the positive correlation of Lake Masoko hydrology with various solar activity proxies "implies a forcing of solar activity on the atmospheric circulation and thus on the regional climate of [a] part of East Africa," and Springer *et al*. (2008), who say their findings "corroborate works indicating that millennial-scale solar-forcing is responsible for droughts and ecosystem changes in central and eastern North America,"

In one final and exceptionally perceptive paper dealing with North American droughts, Cook *et al*. (2009) wrote that "IPCC Assessment Report 4 model projections suggest that the subtropical dry zones of the world will both dry and expand poleward in the future due to greenhouse warming," and that "the US southwest is particularly vulnerable in this regard and model projections indicate a progressive drying there out to the end of the 21st century." *However*, they then wrote that "the USA has been in a state of drought over much of the West for about 10 years now," and that "while severe, this turn of the century drought has not yet clearly exceeded the severity of two exceptional droughts in the 20th century," so that "while the coincidence between the turn of the century drought and projected drying in the Southwest is cause for concern, it is premature to claim that the model projections are correct."

We begin to understand this fact when we compare the "turn of the century drought" with the two "exceptional droughts" that preceded it by a few decades. Based on gridded instrumental Palmer Drought Severity indices for tree ring reconstruction that extend back to 1900, Cook *et al*. calculated that the turn-of-the-century drought had its greatest Drought Area Index value of 59% in the year 2002, while the Great Plains/Southwest drought covered 62% of the US in its peak year of 1954, and the Dust Bowl drought covered 77% of the US in 1934. In terms of *drought duration*, however, things are not quite as clear. Stahle *et al*. (2007) estimated that the first two droughts lasted for 12 and 14 years, respectively; Seager *et al*. (2005) estimated them to have lasted for 8 and 10 years; and Andreadis *et al*. (2005) estimated them to have lasted for 7 and 8 years, yielding means of 9 and 11 years for the two exceptional droughts, which durations are to be compared to 10 or so years for the turn-of-the-century drought, which again makes the latter drought *not unprecedented* compared to those that occurred earlier in the 20th century.

*Real* clarity, however, comes when the turn-of-the-century drought is compared to droughts of the prior *millennium*. Cook *et al*. write that "perhaps the most famous example is the 'Great Drouth' (sic) of AD 1276-1299 described by A.E. Douglass (1929, 1935)." Yet this 24-year drought was eclipsed by the 38-year drought that was found by Weakley (1965) to have occurred in Nebraska from AD 1276 to 1313, which Cook *et al*. say "may have been a more prolonged northerly extension of the 'Great Drouth'." But even these *multi-decade* droughts truly pale in comparison to the "two extraordinary droughts discovered by Stine (1994) in California that lasted more than two centuries before AD 1112 and more than 140 years before AD 1350." And each of these *megadroughts*, as Cook *et al*. describe them, occurred, in their words, "in the so-called Medieval Warm Period." And they add that "all of this happened *prior to the strong greenhouse gas warming that began with the Industrial Revolution* [authors' italics]."

In further ruminating about these facts in the "Conclusions and Recommendations" section of their paper, Cook *et al*. again state that the medieval megadroughts "occurred without any need for enhanced radiative forcing due to anthropogenic greenhouse gas forcing." And, therefore, they go on to say "there is no guarantee that the response of the climate system to greenhouse gas forcing will result in megadroughts of the kind experienced by North America in the past."

In summation, these and *many other studies* conducted at various locations throughout North America -- Laird *et al*. (1998), Woodhouse and Overpeck (1998), Cronin *et al*. (2000), Fritz *et al*. (2000), Hidalgo *et al*. (2000), Benson *et al*. (2002), Knapp *et al*. (2002), Ni *et al*. (2002), Gray *et al*. (2003), Gedalof *et al*. (2004), Gray *et al*. (2004a,b), Mauget (2004), Mensing *et al*. (2004), Quiring (2004), Daniels and Knox (2005), Forman *et al*. (2005), Shapley *et al*. (2005), Rasmussen *et al*. (2006), Malamud-Roam *et al*. (2006), Tian *et al*. (2006), Woodhouse *et al*. (2006), Woodhouse and Lukas (2006), MacDonald and Tingstad (2007), Meko *et al*. (2007), MacDonald *et al*. (2008) and Springer *et al*. (2008) -- dispute the climate-alarmist claim that warming must always result in more frequent and more severe drought, while studies conducted on other continents have led to the same conclusion. However, to not unnecessarily lengthen this section of our report, we conclude it by merely providing the journal references to some of these studies in the following paragraph.

For *Africa*, see Holmes *et al*. (1997), Verschuren *et al*. (2000), Nicholson *et al*. (2001), Russell and Johnson (2005), Lau *et al*. (2006), Therrell *et al*. (2006) and Esper *et al*. (2007); for *Asia*, see Cluis and Laberge (2001), Paulson *et al*. (2003), Touchan *et al*. (2003), Kalugin *et al*. (2005), Davi *et al*. (2006), Sinha *et al*. (2007), Kim *et al*. (2009) and Zhang *et al*. (2009); for *Europe*, see Hisdal *et al*. (2001), Ducic (2005), Linderholm and Chen (2005), Linderholm and Molin (2005), van der Schrier et al. (2006), Wilson *et al*. (2005), Pfister *et al*. (2006) and Renard *et al*. (2008); and for *South America*, see Marengo (2009).

## 3. More Frequent and Severe Hurricanes

***The claim:*** *$CO_2$-induced global warming will increase the frequency, intensity and duration of hurricanes.*

How do hurricanes respond to global warming? A popular book and award-winning film (Gore, 2006) suggest that global warming is leading to "an increased frequency of hurricanes," and that rising temperatures are also linked to "a significant increase in both the duration and intensity of hurricanes."

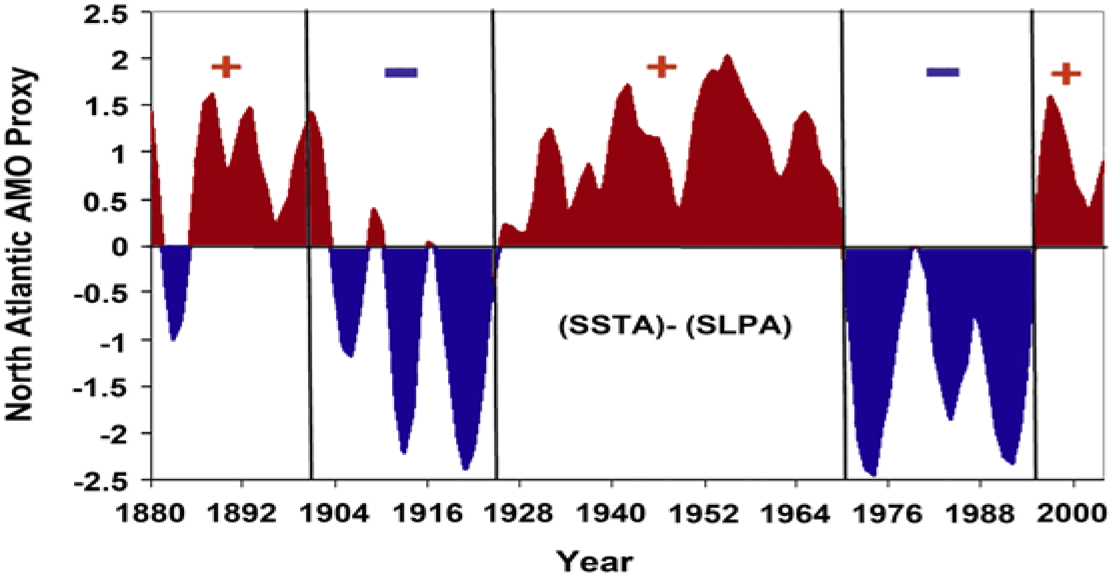
This view of the subject received significant early support in the scientific literature, especially within the climate modeling community. Free *et al*. (2004), for example, wrote that "increases in hurricane intensity are expected to result from increases in sea surface temperature and decreases in tropopause-level temperature accompanying greenhouse warming (Emanuel, 1987; Henderson-Sellers *et al*., 1998; Knutson *et al*., 1998)." In fact, Knutson and Tuleya (2004) stated that "nearly all combinations of climate model boundary conditions and hurricane model convection schemes show a $CO_2$-induced increase in both storm intensity and near-storm precipitation rates."

To test this climate-model-based hypothesis, we examine the pertinent scientific literature to determine how much more frequent, powerful and longer-lasting hurricanes may -- or may *not* -- have become over the course of earth's recovery from the cooler temperatures of the Little Ice Age, or how hurricanes of the Medieval Warm Period may have differed from those of the Little Ice Age. An analysis of this subject was presented by Idso and Singer (2009) in *Climate Change Reconsidered: The Report of the Nongovernmental International Panel on Climate Change (NIPCC)*, where in examining the peer-reviewed scientific literature up through 2007 they found "little or no support for these predictions and considerable evidence to support an opposite prediction." Therefore, we confine ourselves here to an analysis of scientific papers published *after* 2007, in order to see if Idso and Singer's conclusion still holds.

***With respect to hurricanes occurring over the Atlantic Ocean***, we begin with the study of Chylek and Lesins (2008), who applied simple statistical methods to the NOAA HURDAT record of storm activity in the North Atlantic basin between 1851 and 2007 in order to investigate a possible linear trend, periodicity and other features of interest. Using what they describe as "a hurricane activity index that integrates over hurricane numbers, durations, and strengths," the two researchers reported discovering "a quasi-periodic behavior with a period around 60 years superimposed upon a linearly increasing background." However, they noted that "the linearly increasing background [was] significantly reduced or removed when various corrections were applied for hurricane undercounting in the early portion of the record." And further noting that "the last minimum in hurricane activity occurred around 1980," they stated that in comparing the two 28-year-long periods on either side of this date, they found "a modest increase of minor hurricanes, no change in the number of major hurricanes, and a decrease in cases of rapid hurricane intensification."

As a result of these findings, the two researchers concluded that "if there is an increase in hurricane activity connected to a greenhouse gas induced global warming, it is currently obscured by the 60-year quasi-periodic cycle." Consequently, and in spite of the fact that (1) the hurricane record they analyzed started during the final stages of the Little Ice Age (which was the coldest period of the current interglacial), and that (2) the planet experienced a subsequent warming that has been declared by climate alarmists to have been unprecedented over the past millennium or more, they could still find no convincing real-world evidence that global warming enhances either the frequency or intensity of hurricanes occurring over the Atlantic Ocean.

Contemporaneously, Klotzbach and Gray (2008) employed *sea surface temperature* (SST) data for the *far* North Atlantic (50-60°N, 50-10°W) and *sea level pressure* (SLP) data for the North Atlantic (0-50°N, 70-10°W) to construct an index of the *Atlantic Multidecadal Oscillation* (AMO), which they defined as the difference between the standardized SST and SLP anomalies (SST-SLP) for the hurricane season of June-November, and which they evaluated for the period 1878-2006, after which they compared their results (to which they applied a 1-2-3-2-1 filter) with a number of hurricane or *tropical cyclone* (TC) properties. And this work revealed the existence of three positive and two negative AMO phases over the period of their study, as may be seen in the figure below.



***North Atlantic AMO Index. Adapted from Klotzbach and Gray (2008).***

In comparing *annually-averaged* results for TC characteristics between the positive and negative AMO phases indicated in the above graph, it can be calculated from the TC data of the two researchers that the positive AMO phase-to-negative AMO phase *ratios* of hurricane numbers, hurricane days, major hurricane numbers and major hurricane days were 1.53, 1.89, 2.00 and 2.46, respectively, over the entire period studied, while for the 20 *most positive* and 20 *most negative* AMO years the values of the same ratios, in the same order, were 1.73, 2.41, 2.80 and 4.94. Clearly, therefore, the state of the North Atlantic AMO is *tremendously* important to hurricane genesis and development; and this striking natural variability makes it impossible to determine if there is any long-term trend in the TC data that might possibly be due to 20th-century global warming.

One year later, Zeng *et al*. (2009), as they describe it, “synthesized field measurements, satellite image analyses, and empirical models to evaluate forest and carbon cycle impacts for historical tropical cyclones from 1851 to 2000 over the continental U.S.” In doing so, they determined “there were more forest impacts and greater biomass loss between 1851 and 1900 than during the 20th century.” On average, for example, they found that “147 million trees were affected each year between 1851 and 1900,” which led to “a 79-Tg annual biomass loss.” Average annual forest impact and biomass loss between 1900 and 2000, on the other hand, “were 72 million trees and 39 Tg, which were only half of the impacts before 1900,” which results they say are in “accordance with historical records showing that Atlantic tropical cyclones were more active during the period from 1870 to 1900.” In addition, they note that the amount of carbon released from the downed and damaged trees “reached a maximum value in 1896, after which it continuously decreased until 1978,” whereupon it leveled off for the remaining two decades of the 20th century.

Taking a longer look at the subject, Chenoweth and Divine (2008) examined newspaper accounts, ships’ logbooks, meteorological journals and other documents in order to reconstruct a history of tropical cyclones passing through the 61.5°W meridian between the coast of South America (~9.7°N) and 25.0°N over the period 1690-2007, which they describe as “the longest and most complete record for any area of the world.” This work, however, was inconclusive for most of the time period, as the two researchers say they could find “no evidence of statistically significant trend in the number of tropical cyclones passing through the region on any time scale.” But they did note that “hurricane frequency is down about 20% in the 20th century compared to earlier centuries,” and that “this decline is consistent with the 20th century observed record of decreasing hurricane landfall rates in the U.S. (Landsea *et al*., 1999; Elsner *et al*., 2004) and proxy reconstruction of higher tropical cyclone frequency in Puerto Rico before the 20th century (Nyberg *et al*., 2007), as well as model-simulated small changes in Atlantic basin tropical cyclone numbers in a doubled $CO_2$ environment (Emanuel *et al*., 2008; Knutson *et al*., 2008).” They also report that “the period 1968-1977 was probably the most inactive period since the islands were settled in the 1620s and 1630s,” which finding “supports the results of Nyberg *et al*. (2007) of unprecedented low frequency of major hurricanes in the 1970s and 1980s.” In addition, it strongly suggests that the subsequent short-term increase in cyclone numbers has had absolutely nothing to do with the supposedly unprecedented concurrent warming of the globe, as it appears to be nothing more than a simple recovery from a short-term dip (within a century-scale lull) that reduced yearly cyclone numbers to their lowest levels of the past three centuries.

Going still further back in time, Wallace and Anderson (2010) collected a total of 37 sediment cores along eight transects within Laguna Madre, an elongate water body located behind the narrow low-elevation barrier that is Texas (USA’s) South Padre Island; and based on the vertical distribution and grain size of storm over-wash sediments contained within four of those cores from two transects -- which were most ideally positioned -- they were able to construct a detailed history of intense hurricane strikes from 5300 to 900 years *before present* (BP). Based on their analyses, the two scientists determined that "there has been no notable variation in intense storm impacts across the northwestern Gulf of Mexico coast during this time interval," i.e., 5300-900 yr BP, "implying no direct link between changing climate conditions and annual hurricane impact probability." In addition, they report that "there have been no significant differences in the landfall probabilities of storms between the eastern and western Gulf of Mexico during the late Holocene, suggesting that storm steering mechanisms have not varied during this time."

In discussing their findings -- as well as the similar results obtained by others for Western Lake, Florida (USA), and Lake Shelby, Alabama (USA) -- the two researchers concluded that current rates of intense hurricane impacts "do not seem unprecedented when compared to intense strikes over the past 5000 years," while noting that "similar probabilities in high-intensity hurricane strikes for the eastern and western Gulf of Mexico do not show any clear-cut out-of-phase relationship that would enlighten us as to climate controls on storm pathways." Thus, they reiterated their conclusion that "in the northern Gulf of Mexico, there have been no significant variations in storm impact probabilities and/or storm steering mechanisms from ca. 5300-900 yr BP."

***With respect to hurricanes occurring over the Pacific Ocean***, there are a number of recent studies, including that of Chan (2008), who investigated possible causes of the multi-decadal variability in intense TC (category 4 and 5) occurrence in the western North Pacific (WNP), which basin generally has the largest number of TCs every year. And based on data for the period 1960-2005, the Hong Kong researcher determined that decadal variations in intense typhoon activity largely result from a combination of the behavior of the El Niño-Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO).

In discussing this finding, Chan said that "the view that global warming would lead to more intense TCs owing to the enhancement of thermodynamic factors ignores the fact that for TCs to intensify significantly, the dynamic factors must 'cooperate'," and he added that "the latter have not been demonstrated to be enhanced basin wide." Thus, he suggested "the more likely conclusion is that the major low-frequency variations in the frequency of intense TC occurrence is probably a multi-decadal one in response to similar variations in the factors that govern the formation, intensification and movement of TCs," and he noted that "such variations largely result from modifications of the atmospheric and oceanographic conditions in response to ENSO and PDO." Thus, and "at least for the WNP," Chan stated "it is not possible to conclude that the variations in intense typhoon activity are attributable to the effect of global warming."

Defining *rapid intensification* (RI) of a tropical cyclone as occurring when the maximum wind speed of a TC reaches at least 5 knots in the first 6 hours, 10 knots in the first 12 hours, and 30 knots in 24 hours, Wang and Zhou (2008) determined that "all category 4 and 5 hurricanes in the Atlantic basin and 90% of the equivalent-strength typhoons in the western North Pacific experience at least one RI process in their life cycles." Thus, using best-track TC data obtained from the Joint Typhoon Warning Center for the 40-year period 1965-2004, the two researchers determined the climatic conditions that are most critical for the development of RI in TCs of the Western North Pacific on annual, intra-seasonal, and inter-annual time scales; and this work revealed, as they describe it, that "over the past 40 years, the annual total of RI in the western North Pacific shows pronounced interdecadal variation but no significant trend," and they say that this fact "implies that the super typhoons had likely no upward trend in the last 40 years." In addition, they found that when there was a southward shift in the mean latitude of where the tropical storms form (either seasonally or from year to year), the proportion of super typhoons or major hurricanes would increase; and they state that "this finding contrasts [with] the current notion that higher sea surface temperature leads to more frequent occurrence of category 4 or 5 hurricanes."

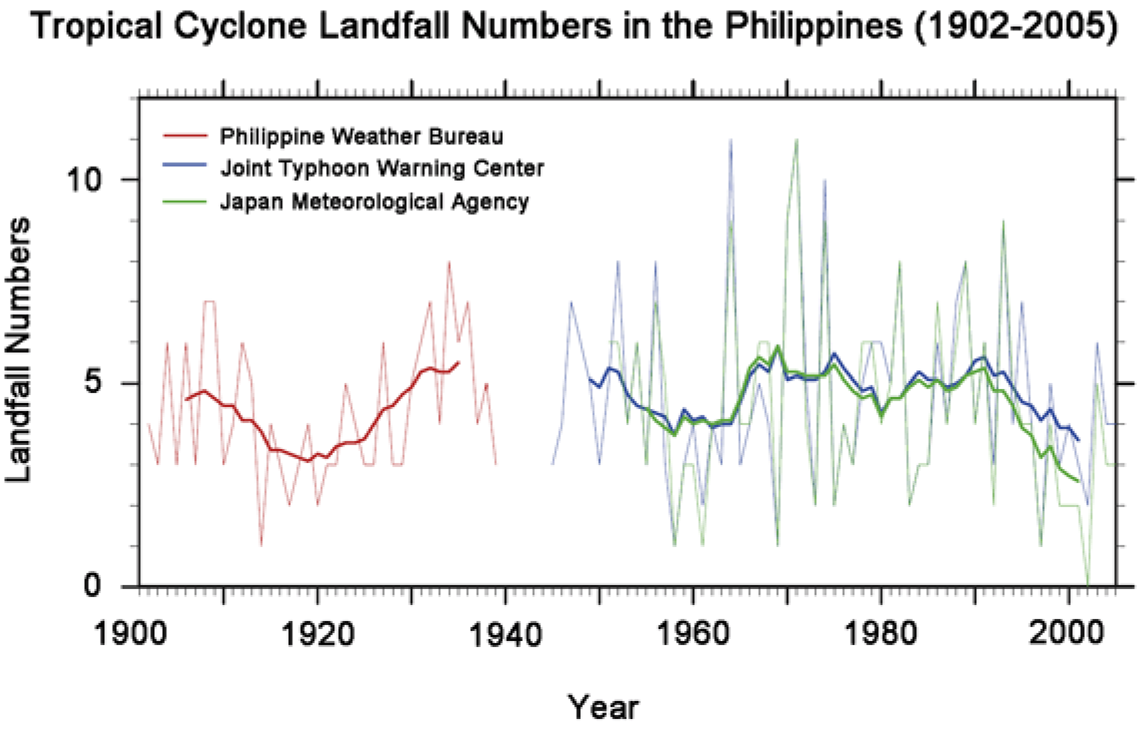
Contemporaneously, Englehart *et al*. (2008) developed a "first cut" data set pertaining to the area immediately adjacent to Mexico's Pacific coast. Although only 54% of Eastern Pacific storms reached TC status within this near-shore area over the period 1967-2005, they report that "near-shore storm activity is fairly well correlated with total basin TC activity, a result which suggests that over the longer period (i.e., 1921-onward), changes in near-shore activity can provide some sense of the broader basin activity." Thus, they proceeded with their analysis, discovering significant decadal variability in annual eastern Pacific near-shore TC frequency of occurrence. Also, they found that "long-term TC frequency exhibits a significant negative trend," which -- as best can be determined from their graph of the data -- declines by approximately 23% over the 85-year period 1921-2005. And this result was driven *solely* by an approximate 30% drop in TC frequency during the *late* (August-November) TC season, with essentially *no* long-term trend in the *early* (May-July) TC season.

Englehart *et al*. additionally presented a graph of the maximum wind speed associated with each TC, which revealed an approximate 20% decline in this intensity-related parameter over the period of their study. Consequently, although their work was acknowledged by them to be but a "first cut" at trying to determine how North Pacific TCs might have varied in frequency of occurrence and intensity over the prior 85 years, it clearly provided *no support* for the climate-alarmist claim that global warming increases both the frequency and intensity of TCs and/or hurricanes. In fact, the data from this part of the world appear to suggest just the *opposite*.

Also publishing in the same year, Wang *et al*. (2008) analyzed climatic characteristics of China-influencing typhoons over the period 1951-2004, *finding* that "the frequency of affecting typhoons has been declining since 1951 at a rate of 0.9 typhoon per decade, which passes the test of 0.05 significance level," and *emphasizing* that "the past 10 years is the time that sees the least frequency." In addition, they determined that "super-typhoons have the largest drop in the frequency, showing a tendency of decreasing 0.7 typhoon per decade, which passes the test of 0.001 significance level."

Moving ahead one year, Zhang *et al*. (2009) examined cyclone-generated economic losses and human casualties in China, as well as their changes in space and time; and in doing so, they determined that “direct economic losses trended upward significantly over the past 24 years,” but that “the trend disappears if considering the rapid increase of the annual total gross domestic product of China, suggesting that the upward trend in direct economic losses is a result of Chinese economic development.” They also stated that “there is no significant trend in tropical cyclone casualties over the past 24 years,” and that it is only because “the Chinese economy has been booming since the early 1980s” that there has been an increasing trend in typhoon-caused economic losses between 1983 and 2006. And they additionally noted that “after adjusting for inflation, wealth, and population," Pielke and Landsea (1998) and Pielke *et al*. (2008) also "found no significant trend in economic losses caused by landfalling tropical cyclones.”

Contemporaneously, Kubota and Chan (2009) created a unique dataset of TLP (*tropical* cyclone *landfall* numbers in the *Philippines*) based on historical observations of TC tracks during the period 1901-1940, which were obtained from Monthly Bulletins of the Philippine Weather Bureau along with TLP data obtained from the Joint Typhoon Warning Center for the period 1945-2005, which they used to investigate the TC-global warming hypothesis. And by these means the two researchers discovered, via the data plotted in the figure below, that “the TLP has an apparent oscillation of about 32 years before 1939 and an oscillation of about 10-22 years after 1945.” Most important of all, they reported that “no long-term trend is found.” In addition, they determined that “natural variability related to ENSO and PDO phases appears to prevail in the interdecadal variability of TLP.”



***Philippine tropical cyclone landfall numbers vs. year. Adapted from Kubota and Chan (2009).***

Working nearby, Ma and Chen (2009) used NCEP/NCAR reanalysis data to determine the SST distribution over the Western North Pacific (WNP) and to evaluate its temporal variability, while they employed TC frequency data obtained from the Joint Typhoon Warning Center, the *Tropical Cyclone Year Book* of the China Meteorological Administration, and the Tokyo-Typhoon Center of the Japanese Meteorological Agency to characterize TC frequency over the period 1949-2007. This work indicated, in their words, that "SSTs over the WNP have been gradually increasing during the past 60 years ... with a maximum increment of 1°C around the central equatorial Pacific for the last 10 years," and they found that "the warm pool, which is defined to be enclosed by a critical temperature of 28°C, has expanded eastward and northward in recent years," noting further that "there has been remarkable warming in the last decade, more than 0.8°C in some local areas." *Nevertheless*, and in spite of this "remarkable warming," they determined that "the frequency of TC against the background of global warming has decreased with time."

Contemporaneously, Chan and Xu (2009) studied landfalling tropical cyclones of East Asia, based on TC data obtained from the Joint Typhoon Warning Center for the period 1945-2004 and the Annual Tropical Cyclone Data Book (edited by the Shanghai Typhoon Institute) for the period 1951-2000, conducting a comprehensive study of variations in the annual number of landfalling TCs in three sub-regions of East Asia: South (south China, Vietnam and the Philippines), Middle (east China), and North (Korean Peninsula and Japan). As might have been expected, the two researchers discovered that "wavelet analyses of each time series show that the landfalling frequencies go through large inter-annual (2-8 years), inter-decadal (8-16 years) and even multi-decadal (16-32 years) variations, with the inter-annual being the most dominant, and the multi-decadal explaining most of the rest of the variance." And in what they call "an important finding," they state that "none of the time series shows a significant linear temporal trend, which suggests that global warming has not led to more landfalls in any of the regions in Asia."

Last of all, with respect to the Pacific Ocean, Song *et al*. (2010) write that "in recent years, there has been increasing interest in whether global warming is enhancing tropical cyclone activity," as has been claimed by Emanuel (2005) and Webster *et al*. (2005). One of the main sources of contention over this matter has been the fact that Wu *et al*. (2006) and Yeung (2006) examined best track data from the Regional Specialized Meteorological Center (RSMC), Tokyo, Japan, as well as that of the Hong Kong Observatory of China (HKO), and that "in contrast to Webster *et al*. (2005)," as Song *et al*. describe it, they found "there was no increase in category 4-5 typhoon activity in the western North Pacific basin." In addition, they report that "neither RSMC nor HKO best track data suggest an increase in TC destructiveness." And they further state that "other studies also examined the differences in TC data sets from the Joint Typhoon Warning Center (JTWC) of the U.S. Naval Pacific Meteorology Oceanography Center in Hawaii, the RSMC, and the Shanghai Typhoon Institute (STI) of [the] China Meteorological Administration in Shanghai (Lei, 2001; Kamahori *et al*., 2006; Ott, 2006; Yu *et al*., 2007)," and they indicate that "so far, the reported trends in TC activity in the WNP basin have been detected mainly in the JTWC best track data set," which anomalous data set was employed by Emanuel (2005) and Webster *et al*. (2005) in drawing their anomalous conclusions.

To help resolve the discrepancies exhibited by the JTWC typhoon database, Song *et al*. analyzed differences of track, intensity, frequency and the associated long-term trends of those TCs that were *simultaneously recorded* and *included within* the best track data sets of the JTWC, the RSMC and the STI from 1945 to 2007. This work revealed, according to them, that "though the differences in TC tracks among these data sets are negligibly small, the JTWC data set tends to classify TCs of category 2-3 as category 4-5, leading to an upward trend in the annual frequency of category 4-5 TCs and the annual accumulated power dissipation index reported by Webster *et al*. (2005) and Emanuel (2005)." And they add that "this trend and potential destructiveness over the period 1977-2007 are found only with the JTWC data set," while noting that actual *downward* trends "are apparent in the RSMC and STI data sets." In light of their findings, therefore, plus those of the other scientists they cite, there would appear to be little doubt that the studies of Emanuel (2005) and Webster *et al*. (2005) provide *no evidence* for what climate alarmists long hailed as *proof positive* of their claim that global warming leads to more intense tropical cyclones or hurricanes.

***With respect to hurricanes occurring over the Indian Ocean***, there are but two studies to report. In the first, Harper *et al*. (2008) analyzed several "potential influences on the accuracy of estimating TC intensity over time due to increasing technology, methodology, knowledge and skill" for TCs that occurred off the coast of northwestern Australia, primarily in a band between 5 and 25°S, over the period 1968/69 to 2000/01. This work revealed, in their words, that "a bias towards lower intensities likely exists in earlier (mainly pre-1980) TC central pressure deficit estimates of the order of at least 20 per cent in 1970, reducing to around ten per cent by 1980 and to five per cent in 1985," and they say that "inferred temporal trends in the estimated intensity from the original data-sets are therefore significantly reduced in the objectively reviewed data-set." In fact, when all was said and done, they concluded "there is no prima facie evidence of a potential climate-change induced trend in TC intensity in northwestern Australia over the past 30 years."

Also working out of Australia, but only partly in the Indian Ocean, Hassim and Walsh (2008) analyzed tropical cyclone best track data pertaining to severe storms of the Australian region (5-30°S) forming off Western Australia and the Northern Territory (the western sector: 90-135°E, Indian Ocean) and off Queensland and the Gulf of Carpentaria (the eastern sector: 135-160°E, Pacific Ocean) for the presence of systematic intensity and duration trends over the cyclone season periods running from 1969/1970 through 2004/2005; and in doing so, in the words of the two Australian researchers, "substantial differences in trends [were] found between the two sub-regions, with the number, average maximum intensity, and duration at the severe category intensities of tropical cyclones increasing since 1980 in the west but decreasing (in number) or exhibiting no trend (in intensity, severe category duration) in the east."

As Hassim and Walsh concluded, however, more study of Australian-region TCs will be required "to unravel the causes of the clear differences between cyclone trends in the eastern and western portions of the Australian basin." Until then, it will remain unclear what the overall data really suggest, and, of course, *why*. And even when these questions are answered, the temporal length of the underlying database will still be far too short to differentiate between a long-term trend that might possibly be tied to the warming that produced the Little Ice Age-to-Current Warm Period transition and a shorter-term cyclical regime shift. However, it is worth noting that in reporting results described at the *International Summit on Hurricanes and Climate Change* that was held on the Greek island of Crete in May of 2007, Elsner (2008) indicates that what he calls *paleotempestology* -- which he defines as the study of prehistoric storms based on geological and biological evidence -- indicates that “sedimentary ridges in Australia left behind by ancient tropical cyclones indicate that activity from the last century under-represents the continent’s stormy past.”

***With respect to hurricanes occurring over multiple ocean basins***, Fan and Liu (2008), who also focused on paleotempestology, conducted a brief review and synthesis of major research advances and findings in this emerging field of work, which they describe as “a young science” that “studies past typhoon activity spanning several centuries to millennia before the instrumental era through the use of geological proxies and historical documentary records.” And this analysis indicated, as they describe it, that “there does not exist a simple linear relationship between typhoon frequency and Holocene climate (temperature) change,” especially of the type suggested by climate alarmists. They report, for example, that “typhoon frequency seemed to have increased at least regionally during the coldest phases of the Little Ice Age,” and they also note that there are typically “more frequent typhoon landfalls during La Niña years than during El Niño years.”

In the realm of *theoretical modeling*, Nolan and Rappin (2008) extended the methodology of Nolan *et al*. (2007) to include a prescribed wind as a function of height that remains approximately constant during the genesis of tropical cyclones in environments of radiative-convective equilibrium that are partially defined by sea surface temperature, which they then employed to explore what happens when SSTs rise. And when subsequently running the adjusted model, they report that “an unexpected result has been obtained, that increasing sea surface temperature does not allow TC genesis to overcome greater shear.” In fact, they say that “the opposite trend is found,” and that “the new and surprising result of this study is that the effect of shear in suppressing TC genesis actually increases as the SST of the radiative-convective equilibrium environment is increased.”

This new *model*-based result is eerily analogous to the recent *observation*-based result of Vecchi and Knutson (2008), who found that as the SST of the main development region of North Atlantic TCs had increased over the past 125 years, certain aspects of climate changed in ways that may have made the North Atlantic, in their words, “more favorable to cyclogenesis, while at the same time making the overall environment less favorable to TC maintenance.” Hence, it is *doubly* interesting that Nolan and Rappin conclude their paper with the intriguing *question*: “Do these results explain recent general circulation modeling studies predicting fewer tropical cyclones in a global warming world,” citing the work of Bengtsson *et al*. (2007).”

Focusing on five ocean basins -- the Atlantic (1960-2007), the Western North Pacific (1960-2007), the Eastern North Pacific (1960-2007), the South Indian Ocean (1981-2007), and the South Pacific (1981-2007) -- Chan (2009) examined (1) the relationship between the seasonally averaged *maximum potential intensity* (MPI, an index of thermodynamic forcing) over each basin where TCs typically form and (2) the seasonal frequency of occurrence of intense TCs. In doing so, he determined that "only in the Atlantic does the MPI have a statistically significant relationship with the number of intense TCs, explaining about 40% of the variance," while "in other ocean basins, there is either no correlation or the correlation is not significant." The People's Republic of China's researcher thus states that "even in the Atlantic, where a significant correlation between the thermodynamic factors and the frequency of intense TCs exists, it is not clear whether global warming will produce a net increase in such a frequency, because model projections suggest an increase in vertical wind shear associated with an increase in sea surface temperature," which phenomenon tends to work *against* intense TC development. As a result, Chan concludes that "it remains uncertain whether the frequency of occurrence of intense TCs will increase under a global warming scenario."

In a concomitant two-ocean-basin study, Wang and Lee (2009) noted that in the Western Hemisphere, tropical cyclones "can form and develop in both the tropical North Atlantic (NA) and eastern North Pacific (ENP) Oceans, which are separated by the narrow landmass of Central America," and that "in comparison with TCs in the NA, TCs in the ENP have received less attention although TC activity is generally greater in the ENP than in the NA (e.g., Maloney and Hartmann, 2000; Romero-Vadillo *et al*., 2007)." So, in exploring how the TC activities of the NA and ENP basins might be related to each other over the period 1949-2007, as well as over the shorter period of 1979-2007, Wang and Lee employed a number of different datasets to calculate the index of *accumulated cyclone energy* (ACE), which accounts for the number, strength and duration of all TCs in a given season.

The results of this exercise led the two U.S. scientists to state that "TC activity in the NA varies out-of-phase with that in the ENP on both *interannual* and *multidecadal* timescales," so that "when TC activity in the NA increases (decreases), TC activity in the ENP decreases (increases)." And they found that "the out-of-phase relationship seems to [have] become stronger in the recent decades," as evidenced by the fact that the interannual and multidecadal correlations between the NA and ENP ACE indices were -0.70 and -0.43, respectively, for the period 1949-2007, but -0.79 and -0.59, respectively, for the period 1979-2007. In terms of the *combined* TC activity over the NA and ENP ocean basins *as a whole*, however, there was little variability on either interannual or multidecadal timescales; and real-world empirical data suggest that the variability that does exist over the *conglomerate* of the two basins has grown slightly *weaker* as the earth has *warmed* over the past six decades, which runs counter to climate-alarmist claims that earth's hurricanes or tropical cyclones should become more numerous, stronger and longer-lasting as temperatures rise.

Most recently, Wang *et al*. (2010) examined cross-basin spatial-temporal variations of TC storm days for the Western North Pacific (WNP), the Eastern North Pacific (ENP), the North Atlantic (NAT), the North Indian Ocean (NIO), and the Southern Hemisphere Ocean (SHO) over the period 1965-2008, for which time interval pertinent satellite data were obtained from the U.S. Navy's Joint Typhoon Warning Center for the WNP, NIO and SHO, and from NASA's (USA) National Hurricane Center for the NAT and ENP. And as a result of their efforts, they were able to report that "over the period of 1965-2008, the global TC activity, as measured by storm days, shows a large amplitude fluctuation regulated by the El Niño-Southern Oscillation and the Pacific Decadal Oscillation, but has no trend, suggesting that the rising temperature so far has not yet [had] an impact on the global total number of storm days."

So what does the future hold for us in terms of hurricanes? Based on the numerous empirical observations from the ocean basins described above, it is clear that there is *no support* for the climate-alarmist claim that global warming increases both the frequency and intensity of hurricanes. In fact, the data seem to suggest just the *opposite*. Thus, if the world warms any further in the future, for whatever reason (anthropogenic or natural), we would expect to see fewer and less intense hurricanes than have occurred recently.

## 4. Rising Sea Levels Inundating Coastal Lowlands

***The claim:*** *Anthropogenic-induced global warming will lead to rapidly melting polar ice sheets, rapidly rising sea levels and catastrophic coastal flooding.*

***With respect to the melting of earth's polar ice sheets,*** we begin in the Northern Hemisphere with the review of Alley *et al*. (2005), who claimed that "the Greenland Ice Sheet may melt entirely from future global warming," which contention they buttressed with the statement that "recently detected rapid ice-marginal changes contributing to sea-level rise may indicate greater ice-sheet sensitivity to warming than previously considered." Between the periods of 1993-94 and 1998-99, for example, they report that "the ice sheet was losing 54 ± 14 gigatons per year (Gt/year) of ice, equivalent to a sea-level rise of ~0.15 mm/year," adding that despite excess snowfall in the southeast in 2002 and 2003, "net mass loss over the 1997-to-2003 interval was higher than the loss between 1993 and 1999, averaging 74 ± 11 Gt/year or ~0.21 mm/year sea-level rise."

Just *one day* before Alley *et al*.'s paper appeared in print, however, Johannessen *et al*. (2005), working with satellite-altimeter data from Greenland, reported in a *Sciencexpress* paper posted online that although *below* 1500 meters the mean change of the ice sheet height with time was a decline of 2.0 ± 0.9 cm/year over the 11-year period 1992-2003, *above* 1500 meters there was a *positive* growth rate of fully 6.4 ± 0.2 cm/year due to snow accumulation; and averaged over the entire ice sheet the mean result was also positive, with a mean growth rate of 5.4 ± 0.2 cm/year, which when adjusted for an isostatic uplift of about 0.5 cm/year yielded a mean growth rate of approximately 5 cm/year, for a total *increase* in the mean thickness of the Greenland Ice Sheet of about 55 cm over the 11-year period, a result that was just the *opposite* of that suggested by Alley *et al*.

Then, like a pendulum changing direction yet again, came the study of Rignot and Kanagaratnam (2005), who used satellite radar interferometry observations of Greenland to detect "widespread glacier acceleration." Calculating that this phenomenon had led to a doubling of the ice sheet's mass deficit in the last decade and, therefore, to a comparable increase in Greenland's contribution to rising sea levels, they went on to claim that as more glaciers accelerate, "the contribution of Greenland to sea-level rise will continue to increase." Hard on the heels of *their* paper, however, came the satellite radar altimetry study of Zwally *et al*. (2005), which once again sent the pendulum swinging in the opposite direction in response to their finding that "the Greenland ice sheet is thinning at the margins (-42 ± 2 Gt/year below the equilibrium-line altitude) and growing inland (+53 ± 2 Gt/year above the equilibrium-line altitude) with a small overall mass gain (+11 ± 3 Gt/year; -0.03 mm/year sea-level equivalent)."

But Chen *et al*. (2006) soon after pushed the pendulum *way* back in the *other* direction with their Gravity Recovery and Climate Experiment (GRACE) study, wherein they concluded that satellite-measured gravity variations suggested that the Greenland Ice Sheet was currently disappearing at a rate of some 240 cubic kilometers per year. However, the many problems with which they had to contend in reaching this conclusion were complex enough to make the effort nearly intractable and render their end result highly questionable.

In ruminating about this confusing situation, Cazenave (2006) described the many knotty problems that have beset the GRACE technique and led to the disturbingly large scatter in Greenland ice loss calculations (50 to 250 Gt/year) among the several studies that have employed it. Almost contemporaneously, however, a new approach to the analysis of GRACE data was developed by Luthcke *et al*. (2006); and it would appear to have greatly improved the fidelity of their findings, which suggested that there has been a mean ice mass loss of only 101 ± 16 Gt/year from Greenland over the period 2003 to 2005. Nevertheless, because of the short time span involved, and the fact that "over Greenland," as Cazenave describes it, "ice mass varies widely from year to year," little could be concluded from the GRACE data that had been accumulated to date; and she stated that because the different analyses "do not overlap exactly in time, different trend estimates are to be expected."

Two years later, Das *et al*. (2008) established observation sites at two large supraglacial lakes on the western margin of the Greenland Ice Sheet atop approximately 1000-meter-thick sub-freezing ice. One of the lakes rapidly drained on 29 July 2006 in a dramatic event that was monitored by local GPS, seismic and water-level sensors, which indicated that the entire lake drained in approximately 1.4 hours, with a mean drainage rate exceeding the average rate of water flow over Niagara Falls. One consequence of this event was a westward surface displacement of 0.5 meter in excess of the average daily displacement of 0.25 meter. However, pre- and post-drainage lateral speeds did not differ appreciably, leading the researchers to conclude that "the opening of a new moulin draining a large daily melt volume (24 $m^3$/sec) had little apparent lasting effect on the local ice-sheet velocity."

But what might be the effect of *multiple* lake drainages?

In a second study that addressed *this* question, Joughin *et al*. (2008) assembled a comprehensive set of interferometric synthetic aperture radar (InSAR) and GPS observations over the period September 2004 to August 2007. These data allowed the construction of 71 InSAR velocity maps along two partially overlapping RADARSAT tracks that included Jakobshavn Isbrae (western Greenland's largest outlet glacier), several smaller marine-terminating outlet glaciers, and a several-hundred-kilometer-long stretch of the surrounding ice sheet. The data thereby obtained revealed summer ice-sheet speedups of 50+% in some places. However, the researchers noted that "the melt-induced speedup averaged over a mix of several tidewater outlet glaciers is relatively small (<10 to 15%)." And when factoring in the short melt-season duration, they found that "the total additional annual displacement attributable to surface melt amounts to a few percent on glaciers moving at several hundred meters per year." In addition, they reported that "the limited seasonal observations elsewhere in Greenland suggest a low sensitivity to summer melt similar to that which we observe."

In concluding, Joughin *et al*. wrote that "surface-melt-enhanced basal lubrication has been invoked previously as a feedback that would hasten the Greenland Ice Sheet's demise in a warming climate." However, their *real-world observations* of this phenomenon showed that "several fast-flowing outlet glaciers, including Jakobshavn Isbrae, are relatively insensitive to this process."

To the *south* of Jakobshavn Isbrae, however, Joughin *et al*. noted that the ice sheet's western flank is relatively free of outlet glaciers and that ice loss there is primarily due to melt; and they say that "numerical models appropriate to this type of sheet flow and that include a parameterization of surface-melt-induced speedup predict 10-to-25% more ice loss in the 21st Century than models without this feedback." This estimate, of course, is based on a model parameterization of surface-melt-induced speedup that may or may not be an adequate representation of reality. Nevertheless, it can probably safely be concluded, as Joughin *et al*. expressed it, that the phenomenon of *surface-melt-enhanced basal lubrication* likely will *not* have a "catastrophic" effect on the Greenland Ice Sheet's future evolution.

Studying the subject contemporaneously were van de Wal *et al*. (2008), who acquired ice velocity measurements from the major ablation area along the western margin of the Greenland Ice Sheet and determined that "the englacial hydraulic system adjusts constantly to the variable meltwater input, which results in a more or less constant ice flux over the years," such that the phenomenon "may have only a limited effect on the response of the ice sheet to climate warming over the next decades," with their data suggesting that that "limited effect" might actually be to *slow* rather than *hasten* ice flow to the sea.

Shortly thereafter, Nick *et al*. (2009) developed "a numerical ice-flow model that reproduced the observed marked changes in Helheim Glacier," which they described as "one of Greenland's largest outlet glaciers," after which they used the model to study the glacier's dynamics and determine what they might imply about the future mass balance of the Greenland Ice Sheet and subsequent global sea levels. The four researchers reported that their model simulations showed that "ice acceleration, thinning and retreat begin at the calving terminus and then propagate upstream through dynamic coupling along the glacier." What is more, they found that "these changes are unlikely to be caused by basal lubrication through surface melt propagating to the glacier bed." And, therefore, Nick *et al*. concluded that "tidewater outlet glaciers adjust extremely rapidly to changing boundary conditions at the calving terminus," stating that their results implied that "the recent rates of mass loss in Greenland's outlet glaciers are transient and should not be extrapolated into the future."

About the same time, Wake *et al*. (2009) reconstructed the 1866-2005 surface mass-balance (SMB) history of the Greenland ice sheet on a 5 x 5-km grid using a runoff-retention model based on the positive degree-day method that accounts "for the influence of year-on-year surface elevation changes on SMB estimates," which was "forced with new datasets of temperature and precipitation patterns dating back to 1866." This they did in order to compare "the response of the ice sheet to a recent period of warming and a similar warm period during the 1920s to examine how exceptional the recent changes are within a longer time context." And in doing so, the six scientists determined that present-day SMB changes "are not exceptional within the last 140 years." In fact, they found that the SMB decline over the decade

1995-2005 was no different from that of the decade 1923-1933. Therefore, "based on the simulations of these two periods," according to Wake *et al*., "it could as well be stated that the recent changes that have been monitored extensively (Krabill *et al*., 2004; Luthcke *et al*., 2006; Thomas *et al*., 2006) are representative of natural sub-decadal fluctuations in the mass balance of the ice sheet and are not necessarily the result of anthropogenic-related warming."

Contemporaneously, Ettema *et al*. (2009) applied a regional atmospheric climate model over a domain that included the Greenland Ice Sheet and its surrounding oceans and islands at what they described as an "unprecedented high horizontal resolution (~11 km)," which for use over Greenland was coupled to a physical snow model that treated surface albedo as a function of snow/firn/ice properties, meltwater percolation, retention and refreezing. The atmospheric part of this model was forced at the lateral boundaries and the sea surface by the global model of the European Centre for Medium-Range Weather Forecasts for the period September 1957 to September 2008. This work revealed the "total annual precipitation in the Greenland ice sheet for 1958-2007 to be up to 24% and surface mass balance up to 63% higher than previously thought," with the largest differences occurring in coastal southeast Greenland, where the seven scientists said that the much higher-resolution facilitates captured snow accumulation peaks that past five-fold coarser resolution regional climate models missed.

Averaged over the entire study period, the total ice sheet's SMB was 469 ± 41 Gt per year; and before 1990 none of the mass balance components exhibited a significant trend. Since 1990, however, there has been a slight downward trend in Greenland's SMB of 12 ± 4 Gt per year, which is probably not all that significant, considering the fact that over the one-year-period 1995 to 1996 its SMB rose by a whopping 250%. With respect to the stability/longevity of the Greenland Ice Sheet, therefore, Ettema *et al*. state that "considerably more mass accumulates on the Greenland Ice Sheet than previously thought, adjusting upwards earlier estimates by as much as 63%," which suggests that the Northern Hemisphere's largest ice sheet may well hang around a whole lot longer than many climate alarmists have been willing to admit.

In the *Southern Hemisphere*, Cofaigh *et al*. (2001) analyzed five sediment cores from the continental rise west of the Antarctic Peninsula and six from the Weddell and Scotia Seas for their *ice rafted debris* (IRD) content in an attempt to determine if there are Antarctic analogues of the Heinrich layers of the North Atlantic Ocean, which testify of the repeated collapse of the eastern margin of the Laurentide Ice Sheet and the concomitant massive discharge of icebergs. This they did because if such IRD layers exist around Antarctica, they reasoned they would be evidence of "periodic, widespread catastrophic collapse of basins within the Antarctic Ice Sheet," which could obviously occur again. After carefully analyzing their data, however, they concluded that "the ice sheet over the Antarctic Peninsula did not undergo widespread catastrophic collapse along its western margin during the late Quaternary," and that this evidence "argues against pervasive, rapid ice-sheet collapse around the Weddell embayment over the last few glacial cycles." Therefore, if there was no dramatic break-up of the Antarctic Ice Sheet "over the last few glacial cycles," there's a good chance there will also be none before the current interglacial ends. And since the data of Petit *et al*. (1999) indicate that *each* of the last *four* interglacials were *warmer* than the current one -- and by an average of *more than 2°C* -- we can make that good chance an *extremely* good chance.

Two years later, Stone *et al*. (2003) collected and determined cosmogenic $^{10}$Be exposure dates of glacially-transported cobbles in elevation transects on seven peaks of the Ford Ranges that are located between the present grounding line of the West Antarctic Ice Sheet (WAIS) and the Clark Mountains some 80 km inland. Based on these ages and the elevations at which the cobbles were found, they determined a history of ice-sheet thinning over the past 10,000-plus years. This work revealed, in their words, that "the exposed rock in the Ford Ranges, up to 700 meters above the present ice surface, was deglaciated within the past 11,000 years" and that "several lines of evidence suggest that the maximum ice sheet stood considerably higher than this." They also report that the consistency of the exposure age versus elevation trends of their data "indicates steady deglaciation since the first of these peaks emerged from the ice sheet some time before 10,400 years ago" and that the mass balance of the region "has been negative throughout the Holocene."

Continuing, Stone *et al*. remarked that their results "add to the evidence that West Antarctic deglaciation continued long after the disappearance of the Northern Hemisphere ice sheets and may still be under way," and they report that the ice sheet in Marie Byrd Land "shows the same pattern of steady Holocene deglaciation as the marine ice sheet in the Ross Sea," where ice "has thinned and retreated since 7000 years ago," noting further that "there is strong evidence that the limit of grounded ice in both regions -- and in Pine Island Bay -- is still receding." Thus, they concluded that "the pattern of recent change is consistent with the idea that thinning of the WAIS over the past few thousand years is continuing," and in a commentary on Stone *et al*.'s work, Ackert (2003) makes this point even plainer, when he says that "recent ice sheet dynamics appear to be dominated by the ongoing response to deglacial forcing thousands of years ago, rather than by a recent anthropogenic warming or sea level rise."

After three more years, using measurements of time-variable gravity from the GRACE satellites, Velicogna and Wahr (2006) determined mass variations of the Antarctic Ice Sheet for the 34 months between April 2002 and August 2005. This work suggested that "the ice sheet mass decreased significantly, at a rate of 152 ± 80 km$^3$/year of ice, equivalent to 0.4 ± 0.2 mm/year of global sea level rise," all of which mass loss came from the West Antarctic Ice Sheet, since they calculated the East Antarctic Ice Sheet mass balance to be 0 ± 56 km$^3$/year. What these results imply about the real world, however, is highly dependent upon their ability to truly represent what they presume to describe; and in this regard Velicogna and Wahr say there is "geophysical contamination ... caused by signals outside Antarctica," including "continental hydrology ... and ocean mass variability." And in addition to these problems, they note that the GRACE mass solutions "do not reveal whether a gravity variation over Antarctica is caused by a change in snow and ice on the surface, a change in atmospheric mass above Antarctica, or *post-glacial rebound* (PGR: the viscoelastic response of the solid Earth to glacial unloading over the last several thousand years)."

Estimates and adjustments to deal with these several problems are convoluted and complex, as well as highly dependent upon various *models*. In addition, the estimates and adjustments concern some huge entities, as Velicogna and Wahr acknowledge that "the PGR contribution is much larger than the uncorrected GRACE trend." In fact, their calculations indicate that the PGR contribution exceeds that of the signal being sought *by nearly a factor of five!* And they are forced to admit that "a significant ice mass trend does not appear until the PGR contribution is removed."

In light of the latter *humungously* confounding problem, Velicogna and Wahr rightly state that "the main disadvantage of GRACE is that it is more sensitive than other techniques to PGR." In fact, considering the many other adjustments they had to make, based upon *estimations* utilizing *multiple models* and *databases with errors* that had to be *further estimated*, one can have little confidence in their final result, particularly in light of the fact that it did not even cover a full three-year period. Much more likely to be much more representative of the truth with respect to Antarctica's mass balance are the findings of Zwally *et al*. (2005), who determined Antarctica's contribution to mean global sea level over a recent *nine*-year period to be only 0.08 mm/year compared to the five-times-greater value of 0.4 mm/year calculated by Velcogna and Wahr.

A few months later, Ramillien *et al*. (2006) derived new estimates of the mass balances of the East and West Antarctic Ice Sheets that were also based on GRACE data, but which pertained to the somewhat shorter period of July 2002 to March 2005, obtaining some significantly different ice sheet mass balances than those obtained by Velicogna and Wahr: a loss of 107 ± 23 km$^{3}$/year for West Antarctica and a gain of 67 ± 28 km$^{3}$/year for East Antarctica, which results yielded a net ice loss for the entire continent of only 40 km$^{3}$/year (which translates to a mean sea level rise of 0.11 mm/year), as opposed to the 152 km$^{3}$/year ice loss calculated by Velicogna and Wahr (which translates to a nearly four times larger mean sea level rise of 0.40 mm/year). Thus, the Ramillien *et al*. mean sea level rise of 0.11 mm/year was much less ominous and of the same order of magnitude as the 0.08 mm/year Antarctic-induced mean sea level rise calculated by Zwally *et al*. (2005), which was derived from ice surface elevation changes based on *nine* years of satellite *radar altimetry data* obtained from the European Remote-sensing Satellites ERS-1 and -2.

In an attempt to bring together much of this information, plus the findings of still other studies that pertain to *both* polar regions of the planet, as well as to determine what it all implies about sea level globally, Shepherd and Wingham (2007) reviewed what was known about sea-level contributions arising from the wastage of the Greenland and Antarctic Ice Sheets, concentrating on the results of 14 satellite-based estimates of the imbalances of the polar ice sheets that had been derived since 1998. These studies were of three major types -- standard mass budget analyses, altimetry measurements of ice-sheet volume changes, and measurements of the ice sheets' changing gravitational attraction -- and they yielded a diversity of values, ranging from a sea-level rise equivalent of 1.0 mm/year to a sea-level *fall* equivalent of 0.15 mm/year.

Of the three major approaches, the results of the latter technique were said by Shepherd and Wingham to be “more negative than those provided by mass budget or altimetry.” And why is that? It is *because*, as they describe it, the gravity-based technique “is [1 ] new, and [2] a consensus about the measurement errors has yet to emerge, [3] the correction for postglacial rebound is uncertain, [4] contamination from ocean and atmosphere mass changes is possible, and [5] the results depend on the method used to reduce the data.” In addition, they say that (6) the GRACE record is only three years long, and that (7) it is thus particularly sensitive to short-term fluctuations in ice sheet behavior that may not be indicative of what is occurring over a much longer timeframe. Even including these likely ice-wastage-inflating properties and phenomena, however, the two researchers concluded that the current “best estimate” of the contribution of polar ice wastage to global sea level change was a rise of 0.35 millimeters per year, which over a *century* amounts to only 35 millimeters or *a little less than an inch and a half*.

Yet even this unimpressive sea level increase may be too large, for although two of Greenland’s largest outlet glaciers doubled their rates of mass loss in less than a year back in 2004, causing many climate alarmists to claim that the Greenland Ice Sheet was responding much more rapidly to global warming than anyone had ever expected, Howat *et al*. (2007) reported that the two glaciers’ rates of mass loss “decreased in 2006 to near the previous rates.” And these observations, in their words, “suggest that special care must be taken in how mass-balance estimates are evaluated, particularly when extrapolating into the future, because short-term spikes could yield erroneous long-term trends.”

Consequently, the most reliable data related to losses of ice from Greenland and Antarctica suggest that the global sea level rise over the current century should be a whole lot smaller than the “meters” predicted by the U.S. National Oceanic and Atmospheric Administration’s James Hansen in testimony presented to the Select Committee of Energy Independence and Global Warming of the U.S. House of Representatives on 26 April 2007, which in turn implies that resultant *coastal flooding* around the world may not even be considered “flooding” -- *if it ever occurs at all!* -- based on the best science of our day.

## 5. More Frequent and Severe Storms

***The claim:*** *Among the many highly-publicized catastrophic consequences that climate alarmists contend will attend the ongoing rise in the air's $CO_2$ content are predicted increases in the frequency and severity of a variety of different types of storms.*

In an effort to determine if this contention has any validity, many scientists have examined historical and proxy storm records in an attempt to determine how temperature changes of the past millennium may have impacted the storminess of earth's climate. Noting that the planet's mean temperature had risen by about 0.6 °C over the 20th century, for example, Easterling *et al*. (2000) looked for possible impacts of this warming on extreme weather events that they said "would add to the body of evidence that there is a discernable human affect on the climate." In doing so, however, they found few changes of significance, and -- as might have been expected -- that "in some areas of the world increases in extreme events are apparent, while in others there appears to be a decline," so that the overall global response was pretty much of a wash.

In another study of multiple severe weather phenomena, Khandekar (2003) briefly reviewed what he had learned about extreme weather events in Canada in the course of conducting a study of the subject for the government of Alberta. This review revealed that "extreme weather events such as heat waves, rain storms, tornadoes, winter blizzards, etc., [were] not increasing anywhere in Canada at [that] time," while noting that a contemporary special issue of *Natural Hazards* (Vol. 29, No. 2, June 2003) concluded much the same thing about other parts of the world, citing in this context a survey article by Balling and Cerveny (2003) that concluded "there is no significant increase in overall severe storm activity (hurricanes, thunderstorms/tornadoes, winter blizzards) across the conterminous United States," as well as an article by Changnon (2003a), which concluded that "increasing economic loss due to weather extremes in the conterminous United States is a result of societal change and not global warming."

More specifically, Changnon determined that various U.S. weather extremes over the last 50 years of the 20th century were mixed, reporting that "one trend is upwards (heavy rains-floods), others are downward (hail, hurricanes, tornadoes, and severe thunderstorms), and others are unchanging flat trends (winter storms and wind storms)." It should be added, however, that had the analysis of heavy rains-floods been extended back to the *beginning* of the 20th century, the *longer*-term behavior of this phenomenon would have been found to have been indicative of *no net change* over the past hundred years, as demonstrated by Kunkel (2003).

Down in New Zealand, De Lange and Gibb (2000) analyzed trends in sea level derived from several tide gauges located within Tauranga Harbor over the period 1960-1998. And in an examination of seasonal, interannual and decadal distributions of storm surge data, they discovered a considerable decline in their annual numbers in the latter half of the record, while a similar trend was observed in the *magnitude* of storm surges.

Also working “down under” -- with sediment cores extracted from Lake Tutira on New Zealand's North Island -- were Page *et al*. (2010), who developed a 7200-year history of the frequency and magnitude of storm activity, based on analyses of (1) sediment grain size, (2) diatom, pollen and spore types and concentrations, plus (3) carbon and nitrogen concentrations, together with (4) tephra and radiocarbon dating. This work revealed, as they describe it, that “the average frequency of all storm layers is one in five years,” but that “for storm layers >= 1.0 cm thick, the average frequency is every 53 years.” And in this regard, they report that over the course of their record, “there are 25 periods with an increased frequency of large storms,” the onset and cessation of which stormy periods “was usually abrupt, occurring on an inter-annual to decadal scale.” They also note that the duration of these stormy periods “ranged mainly from several decades to a century,” but that “a few were up to several centuries long,” while “intervals between stormy periods range from about thirty years to a century.” Most importantly of all, however, they found that millennial-scale *cooling* periods tended to “coincide with periods of increased storminess in the Tutira record, while warmer events match less stormy periods.”

Studying the entire Southern Hemisphere were Simmonds and Keay (2000), who employed a new cyclone finding and tracking scheme to conduct what they said was “arguably the most reliable analysis of Southern Hemisphere cyclone variability undertaken to date.” This work revealed that the annual average number of cyclones in the Southern Hemisphere experienced a steady increase from the start of the assessment period. After peaking in 1972, however, there was an overall decline; and they stated that “the counts in the 1990s have been particularly low.” Simultaneously, they detected a small increase in mean cyclone radius; but they noted that this effect only served to “partially offset the effect of the remarkable decrease in cyclone numbers,” which they said was “associated with a warming Southern Hemisphere.”

Moving back north, and realizing that “understanding the behavior and frequency of severe storms in the past is crucial for the prediction of future events,” Yu *et al*. (2004) devised a way to decipher the history of severe storms in the southern South China Sea. Working at Youngshu Reef (9°32’-9°42’N, 112°52 -113°04’E), they used both standard radiocarbon dating and TIMS U-series dating to determine the times of occurrence of storms that were strong enough to actually “relocate” large *Porites* coral blocks that are widespread on the reef flats there. And in doing so, they determined that “during the past 1000 years, at least six exceptionally strong storms occurred,” yet *none* of them occurred during the past millennium’s last century, which climate alarmists claim to have been the warmest of that period.

Up in the North Atlantic, Dawson *et al*. (2003) developed relationships between temperature and storminess from Greenland ice-core $\delta^{18}O$ data (which correlate with temperature) and $Na^+$ (sea-salt) concentration data (which correlate with North Atlantic winter storminess) over the period AD 1000 to 1987. And as a result of their efforts, they discovered “it is extremely rare to find any year during the last thousand when high $Na^+$ concentrations coincided with extremely warm years,” additionally noting that “the highest $Na^+$ values are associated with years that were exceptionally cold.”

Also working in the North Atlantic, and employing the dp(abs)24 *pressure-variability index*, which is defined as “the absolute 24-hourly atmospheric surface pressure variation at a location,” Hanna *et al*. (2008) studied its temporal variability over the past 160 years via data obtained from long-running meteorological stations in Denmark, the Faroe Islands, Greenland, Iceland, the United Kingdom, and Ireland, after first showing that the index is “significantly related to wind speed and is therefore a good measure of Atlantic and Northwest European storminess and climatic variation.” This work showed, as they describe it, “periods of relatively high dp(abs)24 and enhanced storminess around 1900 and the early to mid-1990s, as well as a relatively quiescent period from about 1930 to the early 1960s.” And they add that “there is no sign of a sustained enhanced storminess signal associated with ‘global warming’,” stating that their analysis “lends a cautionary note to those who suggest that anthropogenic greenhouse warming probably results in enhanced extratropical storminess, as this is indicated neither by our own nor existing published observational results for the northeast Atlantic for the last ~150 years.”

In yet another study pertaining to this region, which was based on surface pressure data from January of 1874 to January of 2008 that were obtained from eleven sites scattered throughout the northeast Atlantic, Wang *et al*. (2009) computed trends in storm conditions characterized by the 95th and 99th percentiles of geostrophic wind speeds, which they calculated from 3-hourly sea level pressure data over this important period of time, when the earth recovered from the global chill of the Little Ice Age and transited into the Current Warm Period, when the world’s climate alarmists contend it experienced a warming that was *unprecedented over the prior one to two millennia*. If this was truly the case, that warming should have provided a good test of the ancillary climate-alarmist claim that such warming should produce a significant increase in storminess. But it did not. In fact, the four researchers report that for the entire study region, there was “a downward trend of at least 5% significance in both the 99th and 95th percentile series.”

Numerous other studies pertaining to the subject of global warming effects on storminess have been conducted throughout North America, Europe and Asia; and they all reach pretty much the same conclusions. Hence, in what follows, we report the key findings of these studies in much abbreviated fashion, beginning with *North America*.

Changnon and Changnon (2000) analyzed hail-day and thunder-day occurrences over the 100-year period 1896-1995 in terms of 20-year averages obtained from records of 66 first-order weather stations distributed across the United States, finding that the frequency of thunder-days peaked in the second of the five 20-year intervals, while hail-day frequency peaked in the third or middle interval. Thereafter, both parameters declined to their lowest values of the century in the final 20-year period. Hail-day occurrence, in fact, decreased to only 65% of what it was at mid-century. Three years later, Changnon (2003b) expanded on this work to 110 first-order weather reporting stations finding that “the 1936-1955 period was the nation’s peak of storm activity during the 100-year period ending in 1995.” During this central 20-year period, 40% of the 110 first-order weather stations experienced their greatest level of storm activity, whereas during the final 20-year period from 1976-1995, only 15% of the stations experienced their greatest level of storm activity.

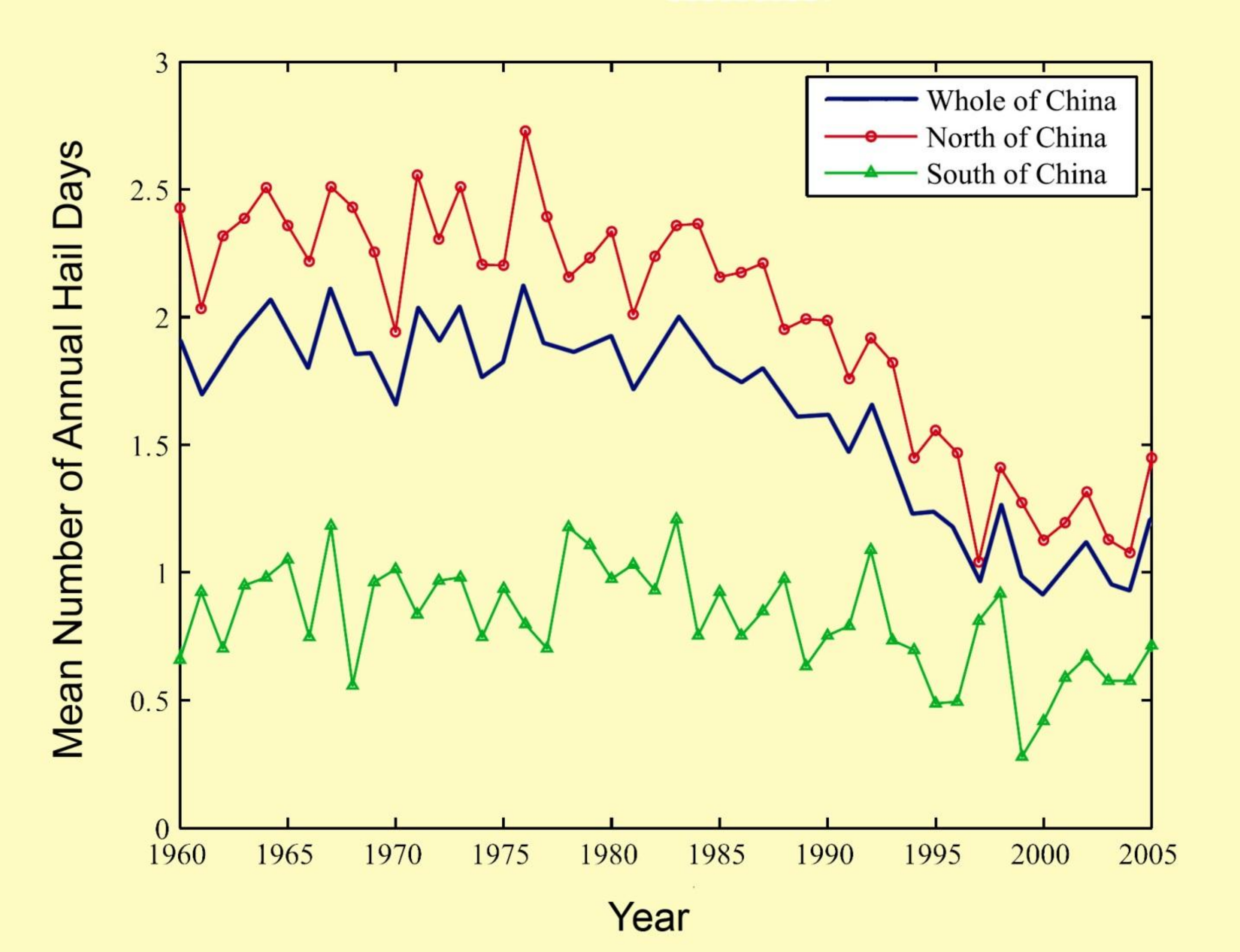
Over the period 1885-1996, Hayden (1999) determined that for the entire continent "no net climate change in storminess [was] found," while along the U.S. East Coast, Zhang *et al*. (2000) could not find "any discernible long-term secular trend in storm activity during the twentieth century." In the Prairie Ecozone of western Canada, Lawson (2003) likewise could find no significant trends in blizzard frequency in eastern and central locations over the period 1953-1997; but there was a significant *downward* trend in blizzard occurrence in the more westerly part, with "no trend in the severity of individual weather elements."

Similarly, in the prairie provinces of Alberta and Saskatchewan in western Canada over the period 1882 to 2001, Hage (2003) found that "all intense storms ["primarily thunderstorm-based tornadoes and downbursts"] showed no discernible changes in frequency after 1940," while *prior* to that time they had exhibited minor *maxima*. With respect to United States snowstorms, on the other hand, Changnon and Changnon (2006) determined that "the incidence of storms peaked in the 1976-1985 period," but they report that snowstorm incidence "exhibited no up or down trend during 1949-2000." And in a similar finding related to windstorm damages in the United States, Changnon (2009) found that "the peak of incidences came during 1977-1991," but that "the fit of a linear trend to the annual data showed no upward or downward trend."

With respect to Asia, and in prefacing their work, Zhu *et al*. (2008) noted that "a number of studies have shown that the spring dust storm frequency (DSF) bears a negative correlation with the local surface air temperature, and exhibits a downward trend over the past 50 years," citing the studies of Qian *et al*. (2002), Zhou and Zhang (2003), Zhai and Li (2003), Zhao *et al*. (2004), Fan *et al*. (2006) and Gong *et al*. (2006, 2007) in support of this statement, after which they explored the long-term variation of Chinese DSF in spring (March to May) and its possible linkage with global warming and its related circulation changes in the Northern Hemisphere, using data from 258 stations within the region surrounding Lake Baikal (70-130°E, 45-65°N) over the period 1954 to 2007. And in doing so, they identified a "prominent warming" in recent decades, as well as "an anomalous dipole circulation pattern" in the troposphere that "consists of a warm anti-cyclone centered at 55°N and a cold cyclone centered around 30°N," that leads to "a weakening of the westerly jet stream and the atmospheric baroclinicity in northern China and Mongolian regions, which suppress the frequency of occurrence and the intensity of the Mongolian cyclones and result in the decreasing DSF in North China." Similar findings were also reported in the earlier study of Liu *et al*. (2004), who concluded that if global warming increases temperatures in the northern part of China and Mongolia as predicted by climate models, "the China-Mongolia ridge will continue to rise and suppress Mongolian cyclones and dust storm activities in Western China-Mongolia."

Also working in China, Xie *et al*. (2008) studied annual variations and trends of hail frequency at 523 stations over the period 1960-2005. And as is clearly evident in the following figure, they report that the results of their study "show no trend in the mean Annual Hail Days (AHD) from

1960 to [the] early 1980s but a significant decreasing trend afterwards," which latter downturn was concomitant with a warming of the globe that the world's climate alarmists have long claimed was *unprecedented* over the past one to two *millennia*.



***Mean Annual Hail Day variations and trends in northern China, southern China and the whole of China. Adapted from Xie et al. (2008).***

Consequently, although climate alarmists continue to claim the world will experience more extreme weather as the planet warms, this study clearly suggests -- as the three researchers who conducted it conclude -- that, in China, global warming may actually imply "a possible reduction of hail occurrence."

In a slight twist on the Xie *et al*. study, Xie and Zhang (2010) focused their research on the extremeness of hailstone *size*, noting that "changes in hail size are also an important aspect of hail climatology," and they went on to study the long-term trend of hail size in four regions of China over the period 1980-2005, using *maximum hail diameter* data. Their work revealed an *uptrend* in maximum hail diameter in Hebei, a *flat trend* in XUAR, and a slight *downtrend* in both Guizhou and IMAR; but they add that "none of the trends is statistically significant." And in light of these several findings, it seems pretty clear that the highly-hyped global warming of the past few decades has led to no significant increase in the extremeness of Chinese hail storms.

Turning to *Europe*, Bijl *et al*. (1999) reported that at several northwest coastal stations, they could find "no sign of a significant increase in storminess" over the prior century, while over the period 1951-1997 along the northern portion of the Atlantic coast of France, Pirazzoli (2000) found that the number of atmospheric depressions (storms) and strong surge winds for this region "are becoming less frequent." Likewise, Clarke *et al*. (2002) determined that massive wind-induced movements of sand in the Aquitaine region of southwest France have been most common during cooler climatic intervals; and based on data pertaining to gale-force winds over northern and northwestern Scotland, Dawson *et al*. (2002) discovered that "storminess in the North Atlantic region was considerably more severe during parts of the nineteenth century than in recent decades." Contemporaneously, Woodworth and Blackman (2002) determined that the annual maximum wind-driven surge-at-high-water measured at Liverpool, England, declined at a rate of 0.11 ± 0.04 meters per century over the prior 232 years, indicative of a long-term reduction of regional storm winds. Similarly, for the period 1 July 1939 to 30 June 2001 at Trieste on the Northern Adriatic, Raicich (2003) found that strong positive surges clearly became *less* frequent over the period of study, *even in the face of a gradually rising sea level.*

Bielic (2001) analyzed thunderstorm records obtained at Cracow, Poland for the period 1896-1995. Close analyses of these data revealed a slight but non-significant linear increase of 1.6 storms from the beginning to the end of the record; but from 1930 onward, the trend was negative, revealing a linear *decrease* of 1.1 storms per year from 1930 to 1996. In addition, Bielic determined that there had been a *decrease* in the annual number of thunderstorms with hail over the period of record, and that there had also been a *decrease* in the frequency of storms producing precipitation greater than 20 mm. Two years later, Bielec-Bakowska (2003) analyzed thunderstorm occurrences at *seven* Polish synoptic weather stations over the period 1885-2000, determining that "over an annual period of 116 years, no clear trends of changes in the number of days with thunderstorms in Poland were found," noting also that "interannual variability of days with thunderstorms in individual seasons did not show any specific trend."

Studying winter wind climate based on counts of quartz grains of different diameters obtained from peat bogs in Southwest Sweden, Bjorck and Clemmensen (2004) found that centennial-scale changes with *high* peaks during the Little Ice Age and *low* peaks during the Medieval Warm Period "seem to record longer-scale climatic variation in the frequency and severity of cold and stormy winters." Similarly, but studying a variety of air pressure indices for Lund (since 1780) and Stockholm (since 1823) in Sweden, Barring and von Storch (2004) found that their storminess proxies "show no indication of a long-term robust change towards a more vigorous storm climate." In fact, during "the entire historical period," in their words, storminess was "remarkably stable, with no systematic change and little transient variability." Likewise, working on the Scottish Outer Hebrides, Dawson *et al*. (2004a) employed similar techniques to construct a local chronology of strong windstorms, which indicated that the majority occurred "during episodes of climate deterioration both prior to and after the well-known period of Medieval warmth," further reporting that "dated inferred sand drift episodes across Europe show synchroneity with increased sand mobilization in SW France, NE England, SW Ireland and the Outer Hebrides, implying a regional response to storminess with increased sand invasion during the cool periods of the Little Ice Age," citing the corroborative works of Lamb (1995), Wintle *et al*. (1998), Gilbertson *et al*. (1999) and Wilson *et al*. (2001).

Continuing, for five locations scattered across Scotland, northwest Ireland and Iceland, Dawson *et al*. (2004b) found a greater frequency of storminess in the cooler 1800s and early 1900s than throughout the remainder of the warmer 20th century; and they report that "considered over the last ca. 2000 years, it would appear that winter storminess and climate-driven coastal erosion was at a minimum during the Medieval Warm Period." Likewise, based on hourly records of 10-m wind speed observations made at thirteen meteorological stations scattered across the country for the time period 1962-2002, Smits *et al*. (2005) found "a decrease in storminess over the Netherlands [of] between 5 and 10% per decade." And in studying two cores of the Pierre Blanche lagoon just south of Montpellier, France, Sabatier *et al*. (2008) determined that washover deposits "provided evidence of three main storms," which they identified as occurring in 1742, 1839 and 1893, all of which were deemed to have been *much* stronger than any of the 20th century.

Similarly, while working on the Danish island of Anholt, Clemmensen *et al*. (2007) found that a "period of sand drift and dune formation took place during the latter part of the Little Ice Age, which is characterized by increased (summer) storminess in large parts of NW Europe." And focusing on sub-Mediterranean Slovenia, while speaking of "violent storms" and "the periods in which these phenomena were more frequent and reached, as to the costs of damage caused, the level of natural disasters or even catastrophes," Ogrin (2007) reported that "the 17th and 18th centuries were undoubtedly such periods, particularly their first halves," when "the frequency of violent storms in that time was comparable to the incidence towards the end of the 20th century."

In an interim review of the subject, Clarke and Rendell (2009) concluded that "the most notable Aeolian sand drift activity was concentrated in the historic period 0.5-0.1 ka (AD 1500-1900) which spans the Little Ice Age." And they stated that "within this period, low solar activity, during the Maunder (AD 1645-1715) and Dalton (AD 1790-1830) Minima, has been related to changes in Atlantic storm tracks (van der Schrier and Barkmeijer, 2005), anomalously cold winter and summer temperatures in Scandinavia (Bjerknes, 1965), and the repositioning of the polar front and changing sea ice cover (Ogilive and Jonsson, 2001)." In addition, they indicated that "the Holocene record of sand drift in western Europe includes episodes of movement corresponding to periods of Northern Hemisphere cooling (Bond *et al*., 1997) ... and provides the additional evidence that these periods, like the Little Ice Age, were also stormy."

Publishing in the same year, and using "the series of thrice-daily sea level pressure observations at Lund and Stockholm," Barring and Fortuniak (2009) determined that "there is no significant overall long-term trend common to all indices in cyclone activity in the North Atlantic and European region since the Dalton minimum," that "the marked positive trend beginning around

1960 ended in the mid-1990s and has since then reversed," and that "this positive trend was more an effect of a 20th-century minimum in cyclone activity around 1960, rather than extraordinary high values in [the] 1990s." Likewise, Sorrel *et al*. (2009) linked high-resolution sediment and rock properties of materials found in cores collected from the Seine estuary in northwest France to climatic conditions of the past few thousand years, finding that "increased removal and transport of estuarine sediments occurred when winter storm activity greatly intensified over northwestern France," and they reported on "four prominent centennial-scale periods of stronger storminess, occurring with a pacing of ~1500 years," which they opined were "likely to be related to the last four [of] Bond's [1997, 2001] Holocene cold events," the most recent of which was the Little Ice Age.

Most recently, Barredo (2010) published a paper entitled *No upward trend in normalized windstorm losses in Europe: 1970-2008*, which is probably all we need to say about it, while Sorell *et al*. (2010) documented the depositional history of the inner Bay of Vilaine in south Brittany along the French Atlantic coast. Their work, with sediment cores, indicated that "during ca. 880-1050 AD ... the influence of winter storminess was minimal," in accordance with the findings of Proctor *et al*. (2000) and Meeker and Mayewski (2002). Thereafter, however, noting that the Medieval Warm Period "is recognized as the warmest period of the last two millennia (Mayewski *et al*., 2004; Moberg *et al*., 2005)," they report that the upper successions of the sediment cores "mark the return to more energetic conditions in the Bay of Vilaine, with coarse sands and shelly sediments sealing the medieval clay intervals," and they state that "this shift most probably documents the transition from the Medieval Warm Period to the Little Ice Age," which led to the "increased storminess both in the marine and continental ecosystems (Lamb, 1979; Clarke and Rendell, 2009)" that was associated with "the formation of dune systems over a great variety of coastal environments in northern Europe: Denmark (Aagaard *et al*., 2007; Clemmensen *et al*., 2007, 2009; Matthews and Briffa, 2005), France (Meurisse *et al*., 2005), Netherlands (Jelgersma *et al*., 1995) and Scotland (Dawson *et al*., 2004a)."

In considering all of the above findings, what does the future look like with respect to nearly all types of storms? Clearly, the evidentiary scale tips far, far away from climate-alarmist scenes of "weather gone wild," as there are almost no historical data that suggest that a warmer world experiences any more severe or more frequent storms than a colder world does. In fact, real-world data seem generally to suggest just the *opposite*.

## 6. Increased Human Mortality

***The claim:*** *Human mortality will escalate due to increasingly more severe and frequent heat waves, as well as a result of the enhanced spreading abroad of numerous vector-borne diseases, all brought about by* $CO_2$*-induced global warming.*

In exploring this sixth climate-alarmist claim, we examine the veracity of the prediction that rising temperatures will lead to future increases in human disease and death, beginning first with a discussion of correlations of human mortality with temperature followed by a brief discussion of viral and vector-borne diseases.

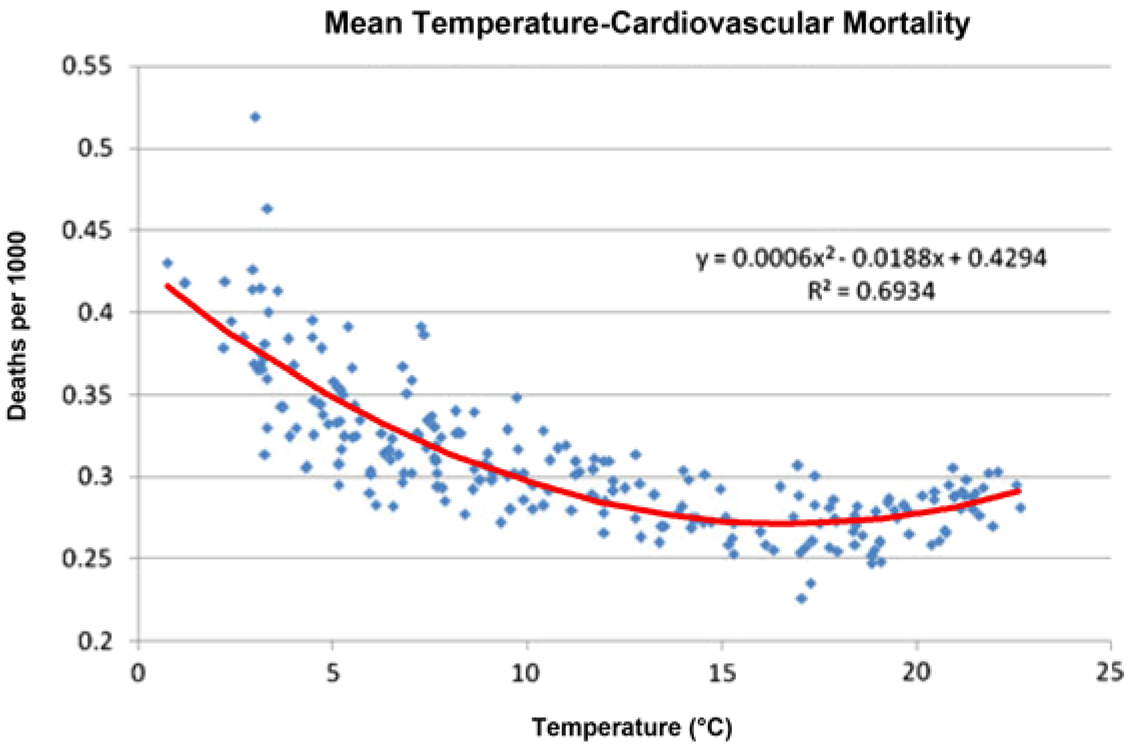
***With respect to correlations of human mortality with temperature***, Christidis *et al*. (2010) have written that "the IPCC AR4 states with very high confidence that climate change contributes to the global burden of disease and to increased mortality," citing the contribution of Confalonieri *et al*. (2007) to that document. In the NIPCC Report *Climate Change Reconsidered* (Idso and Singer, 2009), however, it is concluded that rising temperatures lead to a greater reduction in winter deaths than the increase they cause in summer deaths, resulting in a large net *decrease* in human mortality, based on findings described in the peer-reviewed scientific literature up through 2007. Thus, we here review only studies of the subject that have been published after that time, to see which viewpoint has ultimately prevailed.

In an effort handsomely suited to evaluate the supposedly *very-high-confidence* contention of the IPCC, Christidis *et al*. extracted the numbers of daily deaths from all causes reported on death registration data supplied by the UK Office of National Statistics for men and women fifty years of age or older in England and Wales for the period 1976-2005, which they divided by daily estimates of population that they obtained by fitting a fifth-order polynomial to mid-year population estimates, yielding deaths per million people, after which they compared the results with surface air temperature data that showed a warming trend during the same three-decade period of 0.47°C per decade. In addition, they employed a technique called *optimal detection*, which can be used to estimate the role played by human adaptation in the temperature-related changes in mortality they observed.

As expected, during the *hottest* portion of the year, warming led to *increases* in death rates, while during the *coldest* portion of the year it lead to *decreases* in death rates. But the real story is in the numbers. The three scientists report, for example, that *if no adaptation had taken place*, there would have been 1.6 additional deaths per million people per year due to warming in the hottest part of the year over the period 1976-2005, but there would have been 47 *fewer* deaths per million people per year due to warming in the *coldest* part of the year, for a *lives-saved to life-lost ratio* of 29.4, which represents a *huge* net benefit of the warming experienced in England and Wales over the three-decade period of warming. And when *adaptation* was included in the analysis, as was the case in the data they analyzed, they found there was only 0.7 of a death per million people per year due to warming in the hottest part of the year, but a decrease of fully 85 deaths per million people per year due to warming in the coldest part of the year, for a *phenomenal* lives-saved to life-lost ratio of 121.4. Clearly, therefore, the IPCC's "very-high-confidence" conclusion is *woefully wrong*. Warming is *highly* beneficial to human health, even without any overt adaptation to it. And when adaptations *are* made, warming is *incredibly* beneficial in terms of lengthening human life span.

Working in the Castile-Leon region of Spain -- a plateau in the northwestern part of the country that includes nine provinces with a low population density that can be considered as ageing -- Fernandez-Raga *et al*. (2010) obtained (from the country's National Meteorological Institute) meteorological data from weather stations situated in eight of the provincial capitals that covered the period 1980-1998, while they obtained contemporary mortality data from the country's National Institute for Statistics for deaths associated with cardiovascular, respiratory and digestive system diseases.

Various analyses of the monthly-averaged data revealed a number of interesting results. First, for all three of the disease types studied, the three researchers found that "the death rate is about 15% higher on a winter's day than on a summer's day," which they describe as "a result often found in previous studies," citing the work of Fleming *et al*. (2000), Verlato *et al*. (2002), Grech *et al*. (2002), Law *et al*. (2002) and Eccles (2002). And second, in a finding that helps to explain the first finding, the three researchers discovered that when monthly-averaged human death rates were plotted against monthly-averages of daily *mean*, *maximum* and *minimum* air temperature, the results nearly always took the form of a U-shaped concave parabola, as shown in the figure below.



***Monthly deaths in the Castile-Leon region of Spain attributable to cardiovascular disease vs. mean daily air temperature. Adapted from Fernandez-Raga et al. (2010).***

For all three disease types, they found that all three temperatures (daily mean, maximum and minimum) at which *minimum* death rates occurred -- which they refer to as *ideal* or *comfort* temperatures -- were all within about 1-7°C of the *maximum* values typically reached by those three types of temperature, while they were anywhere from 14-24°C away from their *minimum* values. Consequently, the *ideal* or *comfort* temperatures were always very close to (and sometimes nearly identical to) the *maximum* values reached by the mean, maximum and minimum temperatures experienced in the region, while they were *much* more removed from the *minimum* values of those three temperature parameters, as illustrated in the figure above.

The data of this figure clearly demonstrate that the people of the Castile-Leon region of Spain are much more likely to die from a cardiovascular disease in the extreme cold of winter than in the extreme heat of summer. And the same was found to hold true with respect to dying from respiratory and digestive system diseases. Indeed, cold has been found to be a *much* greater killer of people than heat almost everywhere in the world, and in conjunction with almost any type of illness.

In a more broad-based study, Analitis *et al*. (2008) wrote that "in recent years, the effects of meteorologic factors on health have attracted renewed interest because of the observed and predicted climate change, which is expected to result in a general rise in temperature." And this development, in their words, has led to a "recent focus on heat-wave episodes," which may have fostered the perception that cold-related mortality is not as important a public health concern as is heat-related mortality.

To rectify this situation, the fourteen researchers analyzed short-term effects of cold weather on mortality in 15 European cities (Athens, Greece; Barcelona, Spain; Budapest, Hungary; Dublin, Ireland; Helsinki, Finland; Ljubljana, Slovenia; London, United Kingdom; Milan, Italy; Paris, France; Prague, Czech Republic; Rome, Italy; Stockholm, Sweden; Turin, Italy; Valencia, Spain; and Zurich, Switzerland). More specifically, they assessed the effects of minimum apparent temperature on cause- and age-specific daily mortality over the cold half of the year (October-March), using data from 1990-2000 that they analyzed via "Poisson regression and distributed lag models, controlling for potential confounders."

The international team of scientists -- hailing from Finland, Greece, Ireland, Italy, Slovenia, Spain and Sweden -- found that "a 1°C decrease in temperature was associated with a 1.35% increase in the daily number of total natural deaths and a 1.72%, 3.30% and 1.25% increase in cardiovascular, respiratory, and cerebrovascular deaths, respectively." In addition, they report that "the increase was greater for the older age groups," and that the cold effect "persisted up to 23 days, with no evidence of mortality displacement," which latter finding is extremely important, because in the case of *heat*-related deaths there *is* such a displacement, and its impact is *huge*.

In Germany, for example, Laschewski and Jendritzky (2002) analyzed daily mortality rates in Baden-Wurttemberg (10.5 million inhabitants) over the 30-year period 1958-97 to determine the sensitivity of the population of this moderate climatic zone to long- and short-term episodes of heat and cold. Their research indicated that mortality showed "a marked seasonal pattern with a minimum in summer and a maximum in winter." With respect to short-term exposure to heat and cold, however, they found that "cold spells lead to excess mortality to a relatively small degree, which lasts for weeks," and that "the mortality increase during heat waves is more pronounced, but is followed by lower than average values in subsequent weeks," which suggests, in their words, that people who died from short-term exposure to heat "would have died in the short term anyway."

With respect to this short-term *mortality displacement* that occurs in conjunction with *heat*-related deaths, Laschewski and Jendritzky's data demonstrate that it is precisely that, i.e., merely a *displacement* of deaths and not an overall increase. They found, for example, that the mean duration of above-normal mortality for the 51 heat episodes that occurred from 1968 to 1997 was 10 days, with a mean increase in mortality of 3.9%, after which there was a mean decrease in mortality of 2.3% for 19 days. Hence, the *net* effect of the two perturbations was actually an overall *decrease* in mortality of 0.2% over the full 29-day period. Consequently, it should be abundantly clear that cold spells are *much* more deadly than heat waves, and that we could thus expect global warming to confer significant benefits upon mankind by significantly reducing the very real killing power of routine bouts of colder-than-normal weather. And thus it was that Analitis *et al*. concluded their paper by stating that their results "add evidence that cold-related mortality is an important public health problem across Europe and should not be overlooked by public health authorities because of the recent focus on heat-wave episodes."

In providing some background for another recent study of the subject, Young and Kakinen (2010) write that "Arctic populations, especially indigenous people, could be considered as 'vulnerable,' because their health status generally shows disparities when compared to the national or more southern populations," and they say that "it is not known if the harsh climate, and especially cold temperatures, could be a contributing or causative factor of the observed health inequalities." Thus, to seek answers relative to this uncertainty, the two researchers determined mean January and July temperatures for 27 Arctic regions, based on weather station data for the period 1961-1990, as well as their association with a variety of health outcomes assessed by correlation and multiple linear regression analyses.

Following this protocol, the two researchers found that mean January temperature correlated *negatively* with several health outcomes, including infant mortality rate, age-standardized mortality rates (all causes), perinatal mortality rate and tuberculosis incidence rate, but that it correlated *positively* with life expectancy. That is to say, as mean January temperature rose, the *desirable* metric of life expectancy at birth rose right along with it, while all of the *undesirable* health metrics (such as mortality and disease incidence) declined. For example, they report that "for every 10°C increase in mean January temperature, the life expectancy at birth among males increased by about six years," while "infant mortality rate decreased by about four deaths per thousand live births."

As a result of their several findings, Young and Kakinen concluded that the cold climate of the Arctic is "significantly associated with higher mortality" and "should be recognized in public health planning," noting that "within a generally cold environment, colder climate results in worse health." For people living in these regions, therefore, a little global warming could go a long way towards improving their quality of life ... as well as the length of time they have to enjoy it!

In another impressive study, Deschenes and Moretti (2009) analyzed the relationship between weather and mortality, based on data that included the universe of deaths in the United States over the period 1972-1988, wherein they matched each death to weather conditions on the day of death and in the county of occurrence. These high-frequency data and the fine geographical detail then allowed them to estimate with precision the effect of cold and hot temperature shocks on mortality, as well as the dynamics of such effects, most notably, the existence or non-existence of a "harvesting effect," whereby the temperature-induced deaths either are or are not subsequently followed by a drop in the normal death rate, which could either partially or fully compensate for the prior extreme temperature-induced deaths.

The two researchers stated that their results "point to widely different impacts of cold and hot temperatures on mortality." In the latter case, they discovered that "hot temperature shocks are indeed associated with a large and immediate spike in mortality in the days of the heat wave," but that "almost all of this excess mortality is explained by near-term displacement," so that "in the weeks that follow a heat wave, we find a marked *decline* in mortality hazard, which *completely offsets* the increase during the days of the heat wave," such that "there is virtually no lasting impact of heat waves on mortality."

In the case of *cold* temperature days, they also found "an immediate spike in mortality in the days of the cold wave," but they report that "there is no offsetting decline in the weeks that follow," so that "the cumulative effect of *one day* of extreme cold temperature during a thirty-day window is an increase in daily mortality by as much as 10%." In addition, they say that "this impact of cold weather on mortality is significantly larger for females than for males," but that "for both genders, the effect is mostly attributable to increased mortality due to cardiovascular and respiratory diseases."

In further discussing their findings, Deschenes and Moretti state that "the aggregate magnitude of the impact of extreme cold on mortality in the United States is large," noting that it "roughly corresponds to 0.8% of average annual deaths in the United States during the sample period." And they estimate that "the average person who died because of cold temperature exposure lost in excess of ten years of potential life," whereas the average person who died because of hot temperature exposure likely lost no more than a few days or weeks of life. Hence, it is clear that climate-alarmist concerns about temperature-related deaths are *wildly misplaced*, and that halting global warming -- if it could ever be done -- would lead to *more* thermal-related deaths, because continued warming, which is predicted to be greatest in earth's *coldest* regions, would lead to *fewer* such fatalities.

Interestingly, the two scientists additionally report that many people in the United States have actually taken advantage of these evident facts by moving "from cold northeastern states to warm southwestern states." Based on their findings, for example, they calculate that "each year 4,600 deaths are delayed by the changing exposure to cold temperature due to mobility," and that "3% to 7% of the gains in longevity experienced by the U.S. population over the past three decades are due to the secular movement toward warmer states in the West and the South, away from the colder states in the North."

Working in the Southern Hemisphere, Bi *et al*. (2008) used correlation and autoregressive integrated moving average regression analyses to derive relationships between various aspects of weather and mortality in the general population and elderly (65 years of age and older) of Brisbane, Australia -- which they describe as having a subtropical climate -- over the period 1986-1995. In doing so, they determined that "death rates were around 50-80 per 100,000 in June, July, and August [winter], while they were around 30-50 per 100,000 in the rest of the year, including the summer," and that "this finding applied both to the general population and to the elderly population, and to deaths from various causes."

In discussing the fact that "more deaths occurred in the winter than during other seasons of the year, although winter in Brisbane is very mild," the researchers noted that "it is understandable that more deaths would occur in winters in cold or temperate regions, but even in a subtropical region, as indicated in this study, a decrease in temperatures (in winters) may increase human mortality." Consequently, the evidence continues to grow that extremes of cold lead to the deaths of many more people than extremes of heat in both cold *and* warm climates.

In a study with a slightly different take on the subject, Tam *et al*. (2009) studied daily mortality data from 1997 to 2002, which they obtained from the Hong Kong Census and Statistics Department, examining the association between *diurnal temperature range* (DTR = daily maximum temperature minus daily minimum temperature), while focusing on cardiovascular disease among the elderly (people aged 65 and older). And in doing so, they discovered "a 1.7% increase in mortality for an increase of 1°C in DTR at lag days 0-3," which results they describe as being "similar to those reported in Shanghai."

In discussing their findings, the four Hong Kong researchers stated that "a large fluctuation in the daily temperature -- even in a tropical city like Hong Kong -- has a significant impact on cardiovascular mortality among the elderly population." In addition, *we* note that it has long been known that the DTR has declined significantly over many parts of the world as mean global temperature has risen over the past several decades (Easterling *et al*., 1997), which is perhaps *another* reason why *colder temperatures are a much greater risk to human life than are warmer temperatures*, i.e., because as the planet warms, local DTRs tend to decline, which leads to a corresponding decline in human death rates.

Turning to the Shanghai study mentioned by Tam *et al*., we find that Cao *et al*. (2009) -- working within the nine urban districts of Shanghai, China -- used time-series and case-crossover approaches to assess the relationship between DTR and *coronary heart disease* (CHD) deaths that occurred between 1 January 2001 and 31 December 2004, based on mortality data for elderly people (66 years of age or older) that they obtained from the Shanghai Municipal Center of Disease Control and Prevention, plus temperature data they obtained from a fixed-site station in the Xuhui District of Shanghai, which they adjusted to account for the mortality impacts of long-term and seasonal trends in CHD mortality, day of week, temperature, relative humidity and concomitant atmospheric concentrations of $PM_{10}$, $SO_2$, $NO_2$ and $O_3$, which they obtained from the Shanghai Environmental Monitoring Center.

This work revealed, in Cao *et al*.'s words, that "a 1°C increase in DTR (lag = 2) corresponded to a 2.46% increase in CHD mortality on time-series analysis, a 3.21% increase on unidirectional case-crossover analysis, and a 2.13% increase on bidirectional case-crossover analysis," and that "the estimated effects of DTR on CHD mortality were similar in the warm and cool seasons." Thus, the seven scientists concluded that their data suggested that even "a small increase in DTR is associated with a substantial increase in deaths due to CHD." And since the DTR has declined significantly over most of the world as mean global air temperature has risen over the past several decades, it can be appreciated that the global warming with which this DTR decrease is associated (which is driven by the fact that global warming is predominantly caused by an increase in daily *minimum* temperature) has likely helped to significantly reduce the CHD-induced mortality of elderly people worldwide.

In one final study dealing with the heart, and employing a generalized additive statistical model that blends the properties of generalized linear models with additive models, Bayentin *et al*. (2010) analyzed the standardized daily hospitalization rates for *ischemic heart disease* (IHD) and their relationship with climatic conditions up to two weeks prior to the day of admission -- controlling for time trends, day of the season, and gender -- in order to determine the short-term effects of climate conditions on the incidence of IHD over the 1989-2006 time period for 18 different health regions of Quebec. Perhaps the most interesting and important finding of this study was, as they describe it, the fact that "a decline in the effects of meteorological variables on IHD daily admission rates was observed over the period of 1989-2006," which response, in their words, "can partly be explained by the changes in surface air temperature," which they describe as *warming* "over the last few decades," as is further described by Bonsal *et al*. (2001) and Zhang *et al*. (2000) for the 20th-century portion of the study's duration. In addition, they note that "winters have been steadily warmer," while "summers have yet to become hotter for most regions," which is another beneficial characteristic of the warming that was experienced over most of the planet throughout the latter part of the 20th century: a gradual reduction in DTR, as confirmed by the work of Easterling *et al*. (1997).

***With respect to viral and vector-borne diseases***, in a review of the pertinent literature that describes "those mechanisms that have led to an increase of virus activity in recent years," Zell *et al*. (2008) say "it is assumed that global warming is forced by the anthropogenic release of 'greenhouse gases'," and that a further "consistent assumption" has been a consequent "increased exposure of humans to tropical pathogens and their vectors." However, they note "there is dissent about this hypothesis (Taubes, 1997; Reiter, 2001; Hay *et al*., 2002; Reiter *et al*., 2003; Randolph, 2004; Zell, 2004; Halstead, 2008)," and they thus go on to explore it in more detail, ultimately concluding that "only very few examples point toward global warming as a cause of excess viral activity." Instead, they find that "coupled ocean/atmosphere circulations and continuous anthropogenic disturbances (increased populations of humans and domestic animals, socioeconomic instability, armed conflicts, displaced populations, unbalanced ecosystems, dispersal of resistant pathogens etc.) appear to be the major drivers of disease variability," and that global warming "at best" merely "contributes."

Also exploring this issue about the same time were Gage *et al*. (2008), who reviewed what was then known about it; and in doing so, the four researchers -- all of whom hail from the U.S. Centers for Disease Control's National Center for Zoonotic, Vector-Borne, and Enteric Diseases -- concluded that "the precise impacts" of the various climatic changes that are typically claimed to occur in response to rising atmospheric $CO_2$ concentrations "are difficult to predict." Indeed, they say that "in some areas, climate change could increase outbreaks and the spread of some vector-borne diseases while having quite the opposite effect on other vector-borne diseases."

In further discussing this complex situation, they also wrote that "the mere establishment of suitable vectors for a particular agent does not necessarily mean that spread to humans will commonly occur, as indicated by the limited transmission of dengue and malaria in the southern U.S.," *because*, as they continue, "local transmission has been limited by factors unrelated to the climatic suitability of the areas for the relevant vector species." And they add that "in instances where a vector-borne disease is also zoonotic, the situation is even more complex, because not only must the vector and pathogen be present, but a competent vertebrate reservoir host other than humans must also be present."

So what are some of the *non*-climatic factors that impact the spread of vector-borne diseases of humans? Gage *et al*. list "many other global changes concurrently transforming the world, including increased economic globalization, the high speed of international travel and transport of commercial goods, increased population growth, urbanization, civil unrest, displaced refugee populations, water availability and management, and deforestation and other land-use changes," as well, we would add, as the many different ways in which these phenomena are dealt with by different societies.

Unfortunately, there is almost no way to correctly incorporate such factors into models to correctly forecast disease incidence in the future. Therefore, in light of the many complex phenomena that concurrently impact the spread of vector-borne diseases, it is clearly unjustified to claim that any future warming of the globe will necessarily lead to a net increase in their global incidence, for just the *opposite* could well be true, depending on the type and degree of a number of current and potential societal impacts on the world of nature, as well as the diverse natures of the evolving states of the planet's multiple human societies.

Contemporaneously -- and noting that "dengue is a spectrum of disease caused by four serotypes of the most prevalent arthropod-borne virus affecting humans today," and that "its incidence has increased dramatically in the past 50 years," to where "tens of millions of cases of dengue fever are estimated to occur annually, including up to 500,000 cases of the lifethreatening dengue hemorrhagic fever/dengue shock syndrome" -- Kyle and Harris (2008) conducted a review of the pertinent scientific literature, exploring "the human, mosquito, and viral factors that contribute to the global spread and persistence of dengue, as well as the interaction between the three spheres, in the context of ecological and climate change." So what did they learn?

With respect to the status of dengue fever within the context of climate change, the two researchers say "there has been a great deal of debate on the implications of global warming for human health," but that "at the moment, there is no consensus." However, in the case of dengue, they say "it is important to note that even if global warming does not cause the mosquito vectors to expand their geographic range, there could still be a significant impact on transmission in endemic regions," as they report that "a 2°C increase in temperature would simultaneously lengthen the lifespan of the mosquito and shorten the extrinsic incubation period of the dengue virus, resulting in more infected mosquitoes for a longer period of time." Nevertheless, they note there are "infrastructure and socioeconomic differences that exist today and already prevent the transmission of vector-borne diseases, including dengue, even in the continued presence of their vectors." Consequently, it would appear that whatever advantages rising temperatures might possibly confer upon the dengue virus vector, they can be more than overcome by proper implementation of modern vector control techniques.

One year later, Russell (2009) -- a Professor in the Department of Medicine of the University of Sydney and founding Director of its Department of Medical Entomology -- reported that "during the past 10 years, there has been increasing concern for health impacts of global warming in Australia, and continuing projections and predictions for increasing mosquito-borne disease as a result of climate change." However, he stated that these claims "are relatively simplistic, and do not take adequate account of the current or historic situations of the vectors and pathogens, and the complex ecologies that might be involved," after which he went on to review the consequences of these several inadequacies for malaria, dengue fever, the arboviral arthritides (Ross River and Barmah Forest viruses) and the arboviral encephalitides (Murray Valley encephalitis and Kunjin viruses). This he did within the context of predictions that have been made for projected climate changes as proposed and modeled by Australia's Commonwealth Scientific and Industrial Research Organization and the Intergovernmental Panel on Climate Change. What he concluded from this review was that "there might be some increases in mosquito-borne disease in Australia with a warming climate, but with which mosquitoes and which pathogens, and where and when, cannot be easily discerned." Therefore, the strongest statement he could make was that "of itself, climate change as currently projected, is not likely to provide great cause for public health concern with mosquito-borne disease in Australia."

In another paper, Russell *et al*. (2009) wrote that "dengue has emerged as a leading cause of morbidity in many parts of the tropics," noting that "Australia has had dengue outbreaks in northern Queensland." In addition, they reported that "substantial increases in distribution and incidence of the disease in Australia are projected with climate change," or, more specifically, "with increasing temperatures." Hence, they explored the soundness of these projections by reviewing pertinent facts about the history of dengue in Australia, determining that the dengue vector (the *Aedes aegypti* mosquito) “was previously common in parts of Queensland, the Northern Territory, Western Australia and New South Wales,” and that it had, “in the past, covered most of the climatic range theoretically available to it,” adding that “the distribution of local dengue transmission has [historically] nearly matched the geographic limits of the vector.”

This being the case, the six scientists concluded that the vector’s current absence from much of Australia, as Russell *et al*. described it, “is not because of a lack of a favorable climate.” Thus, they reasoned that “a temperature rise of a few degrees is not alone likely to be responsible for substantial increases in the southern distribution of *A. aegypti* or dengue, as has been recently proposed.” Instead, they reminded everyone that “dengue activity is increasing in many parts of the tropical and subtropical world as a result of rapid urbanization in developing countries and increased international travel, which distributes the viruses between countries.” Rather than futile attempts to limit dengue transmission by controlling the world’s climate, therefore, the medical researchers recommended that “well resourced and functioning surveillance programs, and effective public health intervention capabilities, are essential to counter threats from dengue and other mosquito-borne diseases.”

Studying dengue simultaneously in three other parts of the world, Johansson *et al*. (2009) wrote that “mosquito-borne dengue viruses are a major public health problem throughout the tropical and subtropical regions of the world,” and that “changes in temperature and precipitation have well-defined roles in the transmission cycle and may thus play a role in changing incidence levels.” Therefore, as they continued, since “the El Niño Southern Oscillation (ENSO) is a multiyear climate driver of local temperature and precipitation world wide,” and since “previous studies have reported varying degrees of association between ENSO and dengue incidence,” as they describe it, they decided to analyze “the relationship between ENSO, local weather, and dengue incidence in Puerto Rico, Mexico, and Thailand, which they did by searching for relationships between ENSO, local weather and dengue incidence in Puerto Rico (1986-2006), Mexico (1985-2006), and Thailand (1983-2006), using wavelet analysis as a tool to identify time- and frequency-specific associations.

As a result of these activities, the three researchers reported that they “did not find evidence of a strong, consistent relationship in any of the study areas,” while Rohani (2009), who wrote a Perspective piece on their study, stated that they found “no systematic association between multi-annual dengue outbreaks and El Niño Southern Oscillation.” Thus, as included in the *Editors’ Summary* of Johansson *et al*.’s paper, their findings provided “little evidence for any relationship between ENSO, climate, and dengue incidence.” And in light of the inconclusive nature of Johansson *et al*.’s analysis, there still remains a lack of substantive real-world support for the climate-alarmist claim that global warming promotes the global intensification and spread of the spectrum of diseases caused by the different serotypes of the family of dengue viruses.

In still another review paper dealing with the possible impacts of climate change on the spread of infectious diseases, Randolph (2009) wrote that it is generally tacitly assumed -- and even explicitly stated -- that climate change will result only in a *worsening* of the situation, with the expansion of vector-borne diseases into higher latitudes and an increased disease incidence. In fact, she states that implicit in almost all of the literature on this subject -- both popular and scientific -- "is an assumption that environmental change is more likely to strengthen the transmission potential and expand the range, rather than to disrupt the delicate balance between pathogen, vector and host upon which these systems depend."

With this background, the zoologist from the UK's University of Oxford explores the evidence for these two opposing world views via an analysis of what the bulk of the accurately-informed scientific literature on the subject seems to suggest. In doing so, she finds that "the mercurial epidemiology of each vector-borne disease is the system-specific product of complex, commonly nonlinear, interactions between many disparate environmental factors," which include "not only climate but also other abiotic conditions (e.g., land cover) and the physical structure of the environment (e.g., water sources), and further biotic factors such as host abundance and diversity." She additionally indicates that a number of socioeconomic factors drive human living conditions and behaviors that determine the degree of exposure to the risk posed to them, and that nutritional status and concomitant immunity also determine the degree of resistance to infection.

In some interesting examples from the past, Randolph notes that the upsurge of tick-borne diseases within preexisting endemic regions in central and Eastern Europe "appears to be an unforeseen consequence of the fall of the iron curtain and the end of the cold war," which she describes as "a sort of political global warming." Also noted is the fact that "the introduction of the mosquito *Aedes aegypti* to the Americas within water containers on board slave ships from Africa was repeated four centuries later by the dispersal of the Asian tiger mosquito, *A. albopictus*, from Japan to the United States within water trapped in used car tires (Hawley *et al*., 1987; Reiter and Sprenger, 1987)."

This phenomenon, according to Randolph, continues today, augmented by trade in other water-carrying goods such as Asian Luck Bamboo plants, which activities have allowed this mosquito species "to establish itself in almost all New World countries, a dozen European countries, parts of West Africa, and the Middle East." All of these disease expansions, in her words, have "nothing to do with climate change," which also holds true for such *chance* events as "the introduction of West Nile virus into New York in 1999, most probably by air from Israel (Lanciotti *et al*., 1999)," and the introduction "of the BTV-8 strain of bluetongue virus into the Netherlands in 2006 from South Africa (Saegerman *et al*., 2008)."

In concluding her brief treatise, Randolph states that the real-world complexity within each disease system *emphasizes* that "any expectation of a simple consistent response to climate change, i.e., a universal worsening of the situation, is ill founded," noting further that "there is no single infectious disease whose increased incidence over recent decades can be reliably attributed to climate change." Consequently, she says that "if the purpose of predictions about the future is to guide policy and therefore government spending, exaggerated simplistic rhetoric about the universality and uniformity of the impact of climate change on infectious disease risk is morally indefensible," especially "if it distracts public health agencies from more effective ameliorative action targeted at the real causes."

Contemporaneously, Harvell *et al*. (2009) stated that "in temperate climates, we might expect the range and activity of mosquitoes and the pathogens they vector, such as malaria and dengue, to increase with warmer temperatures." However, "from a later vantage point in 2009," they indicated that "surprisingly, insect-vectored diseases resoundingly do not show a net expansion in range or increase in prevalence." As for *why* this was so, the five scientists gave three explanations that they attributed to Lafferty (2009a): "(1) anthropogenic activities directly influence the distributions of vectors and infectious disease in ways unrelated to climate, (2) vectors and pathogens are limited by thermal maxima, so that temperature changes lead to shifts rather than expansions in distribution, and (3) other factors such as host acquired immunity and vector or parasite life history traits are linked to habitat suitability in addition to climate." In addition, they noted the important role that may be played by "evolutionary changes in properties of the host or pathogen," and in concluding their paper they therefore wrote that "ecologists need to consider how host biology, including movement behavior and acquired immunity, can mediate the impacts of global change on parasite/pathogen dynamics and disease severity," because, as they concluded, "at present, many of these mechanisms are poorly known."

Turning *directly* to the Lafferty (2009a) paper, we again read that climate-alarmist "wisdom" holds that "global climate change will result in an expansion of tropical diseases, particularly vector-transmitted diseases, throughout temperate areas," examples of which include "schistosomiasis (bilharzia or snail fever), onchocerciasis (river blindness), dengue fever, lymphatic filariasis (elephantiasis), African trypanosomiasis (sleeping sickness), leishmaniasis, American trypanosomiasis (Chagas disease), yellow fever, and many less common mosquito and tick-transmitted diseases of humans," as well as many diseases of "nonhuman hosts." In a critique of this alarmist point of view, based on his review of the scientific literature, he concludes that "while climate has affected and will continue to affect habitat suitability for infectious diseases, climate change seems more likely to shift than to expand the geographic ranges of infectious diseases," and that "many other factors affect the distribution of infectious disease, dampening the proposed role of climate." In fact, he concludes that "shifts in climate suitability might actually reduce the geographic distribution of some infectious diseases." And of perhaps even greater importance (because it is a real-world *observation*), he reports that "although the globe is significantly warmer than it was a century ago, there is little evidence that climate change has already favored infectious diseases."

In a companion paper (Lafferty, 2009b), the U.S. researcher lists a number of ways in which ecologists "can contribute substantially to the general theory of climate and infectious disease," some of the most important of which have to deal with "[1] multiple hosts and parasite species (Dobson, 2009), [2] nonhuman hosts (Harvell *et al*., 2009), [3] accounting for the effects of immunity (Dobson, 2009; Harvell *et al*., 2009; Ostfeld, 2009; Pascual and Bouma, 2009), [4] quality and details of [4a] climatic data and [4b] appropriate measures of disease response (Ostfeld, 2009; Pascual and Bouma, 2009; Randolph, 2009), [5] complex analyses to account for multiple, interdependent covariates (Dobson, 2009; Ostfeld, 2009; Pascual and Bouma, 2009, Randolph, 2009), [6] host movement in response to climate change (Harvell *et al*., 2009), and [7] geographic tools to account for distinctions between fundamental and realized niches (Ostfeld, 2009; Randolph, 2009)." And in light of these many and varied *challenges* that confront the scientific community in this emerging field of study, there is much *unfinished business* that needs to be conducted in researching the several potential relationships that may (or may not) exist between climatic change and the spread of infectious diseases. Hence, it should be abundantly clear that the numerous viral and vector-borne health catastrophes that are routinely predicted to occur by the world's climate alarmists in response to future global warming are definitely not yet ready for prime-time consideration, much less unquestioning acceptance.

Inching one year closer to the present, Reiter (2010) writes that the appearance of the West Nile virus in New York (USA) in 1999, plus the unprecedented panzootic that followed, "have stimulated a major research effort in the Western Hemisphere and a new interest in the presence of this virus in the Old World," which developments have been driven in part by the fact that "a great deal of attention has been paid to the potential impact of climate change on the prevalence and incidence of mosquito-borne disease." Therefore, Reiter reviews what researchers have learned about the subject and reports the worldwide implications for public health, summing things up in his final paragraph, where he states that "one point is clear: the importation and establishment of vector-borne pathogens that have a relatively low profile in their current habitat is a serious danger to Europe and throughout the world," which state of affairs, in his view, "is a direct result of the revolution of transport technologies and increasing global trade that has taken place in the past three decades," modern examples of which include "the global circulation of dengue virus serotypes (Gubler, 1998), the intercontinental dissemination of *Aedes albopictus* and other mosquitoes in used tires (Hawley *et al*., 1987; Reiter, 1998), the epidemic of chikungunya virus in Italy (Angelini *et al*., 2007), and the importation of bluetongue virus and trypanosomiasis into Europe (Meroc *et al*., 2008; Moretti, 1969)." And he further concludes that in view of what his review reveals, "globalization is potentially a far greater challenge to public health in Europe than any future changes in climate (Tatem *et al*., 2006)."

Last of all, writing that "pathogens cause roughly one in five human deaths, are responsible for 51% of years of life lost globally, and have long affected human demographics," Dunn *et al*. (2010) state that pathogens "have also been identified as drivers of human behavior, the politics and political stability of countries, human fertility, global economies, and more generally the course and dynamics of human history." And, somewhat ominously, they report that "researchers have linked the presence and prevalence of some pathogens to climate, as has been highlighted in recent discussions of climate change and disease," where they specifically mention malaria, plague and dengue as examples of the latter. Thus, they conducted, as they describe it, "a global analysis of the relative influence of climate, alternative host diversity and spending on disease prevention on modern patterns in the richness and prevalence of human pathogens."

As a result of their work, the U.S., Canadian and New Zealand researchers found that "pathogen richness (number of kinds) is largely explained by the number of birds and mammal species in a region," and that "the most diverse countries with respect to birds and mammals are also the most diverse with respect to pathogens." And noting, in this regard, that "we are unlikely to be able to change patterns of pathogen richness dramatically," they go on to state that "pathogen richness, even when high, does not guarantee high prevalence, because of the potential impact of disease control effort." In fact, they found that "pathogen prevalence is much more sensitive to variation in health spending among regions," and that "importantly, for human health, the prevalence of key human pathogens is strongly influenced by disease control efforts."

As a consequence of the above observations, Dunn *et al*. conclude that "even where disease richness is high, we might still control prevalence, particularly if we spend money in those regions where current spending is low, prevalence is high and populations are large." And let's be realistic about it: this approach is *infinitely* more likely to succeed in its worthy objectives than is the nebulous idea (i.e., the wishful thinking) of changing the planet's climate. And with all of the *unanticipated consequences* of such an effort -- many of which may be assumed to be *negative* and are almost *assured to occur* with the undertaking of such a huge and complex campaign -- we could well be better off to do *nothing* than to gamble all that the human family has achieved over the millennia, fighting a war against something so ethereal as $CO_2$-induced global warming.

## 7. Widespread Plant and Animal Extinctions

***The claim:*** *With respect to plants and animals, global warming alarmists have long contended that the increase in temperature predicted to result from the ongoing rise in the atmosphere's* $CO_2$ *concentration will be so great and occur so fast that many species of plants and animals will not be able to migrate poleward in latitude or upward in elevation rapidly enough to avoid extinction.*

In his 26 April 2007 testimony to the Select Committee of Energy Independence and Global Warming of the U.S. House of Representatives, entitled "Dangerous Human-Made Interference with Climate," NASA's chief climate alarmist -- James Hansen -- declared that "continued business-as-usual greenhouse gas emissions threaten many ecosystems," as he contended that "very little additional forcing is needed ... to cause the extermination of a large fraction of plant and animal species," while stating that in response to global warming, "polar species can be pushed off the planet, as they have no place else to go," and claiming that "life in alpine regions ... is similarly in danger of being pushed off the planet." So what's the *real* story?

We have already indicated, in earlier sections of this document, that anthropogenic $CO_2$ emissions cannot have been responsible for the 20th-century recovery of the earth from the global chill of the Little Ice Age, and that that warming -- due to *whatever* phenomenon may have caused it -- has not led to catastrophic increases in extreme floods, droughts and hurricanes, nor to increases in heat-induced human mortality and viral diseases. In what follows, therefore, we focus on the *biosphere* or the *world of nature*, investigating the climate-alarmist claim that the warming predicted by current state-of-the-art climate models will drive numerous species of plants and animals to oblivion, consigning them to a vicarious existence that manifests itself only in history books.

***With respect to plants and their amazing resilience***, we begin with the study of Holzinger *et al*. (2008), who revisited areas of twelve mountains having summits located between elevations of 2844 and 3006 meters in the canton of Grisons, Switzerland, where in 2004 they assembled complete inventories of vascular plant species that they compared with similar inventories made by other researchers in 1885, 1898, 1912, 1913 and 1958, following the ascension paths of the earlier investigators "as accurately as possible," where mean summer temperature increased by at least 0.6°C between the time of the first study and their most recent one. This effort revealed upward migration rates on the order of several meters per decade; and the data suggested that vascular plant species richness had *increased*, and by *11% per decade*, over the last 120 years on the mountain *summits* (defined as the upper 15 meters of the mountains) in the alpine-nival ecotone, where *not a single species* had been "pushed off the planet." What is more, *this finding*, in the words of the four researchers, "agrees well with other investigations from the Alps, where similar changes have been detected (Grabherr *et al*., 1994; Pauli *et al*., 2001; Camenisch, 2002; Walther, 2003; Walther *et al*., 2005)."

Contemporaneously, Kelly and Goulden (2008) compared two vegetation surveys (one made in 1977 and the other in 2006-2007) of the Deep Canyon Transect in Southern California's Santa

Rosa Mountains, which spans several plant communities and climates, rising from an elevation of 244 meters to 2560 meters over a distance of 16 km, while "climbing through desert scrub, pinyon-juniper woodland, chaparral shrubland, and conifer forest." This work revealed that "the average elevation of the dominant plant species rose by ~65 meters," when the 30-year mean temperature measured at seven stations around Deep Canyon rose by 0.41°C between 1947-1976 and 1977-2006, and when the same metric rose by 0.63°C in the climate regions straddled by the transect, and by 0.77°C at the two weather stations nearest Deep Canyon. In commenting on their observations, the two researchers said they implied that "surprisingly rapid shifts in the distribution of plants can be expected with climate change," and it should be noted that those *rapid shifts* appear to be fully capable of coping with even the supposedly unprecedented rate of warming climate alarmists have long claimed was characteristic of the last decades of the 20th century.

Also publishing in the same year, Le Roux and McGeoch (2008) examined patterns of altitudinal range changes in the *totality* of the native vascular flora of sub-Antarctic Marion Island (46°54'S, 37°45'E) in the southern Indian Ocean, which warmed by 1.2°C between 1965 and 2003. The work of these South African researchers revealed that between 1966 and 2006, there was "a rapid expansion in altitudinal range," with species expanding their upper-elevation boundaries by an average of 70 meters. And *because*, as they described it, "the observed upslope expansion was not matched by a similar change in lower range boundaries," they emphasized the fact that "the flora of Marion Island has undergone range expansion rather than a range shift." In addition, they appropriately noted that "the expansion of species distributions along their cooler boundaries in response to rising temperatures appears to be a consistent biological consequence of recent climate warming," citing references to several other studies that have observed the same type of response.

Another consequence of the *stability of* ***lower*** *range boundaries* together with *expanding* ***upper*** *range boundaries* is that there is now a *greater* ***overlapping*** *of ranges*, resulting in greater *local species richness* or *biodiversity* everywhere up and down various altitudinal transects of the island. And as a *further* consequence of *this* fact, le Roux and McGeoch indicated that "the present species composition of communities at higher altitudes is not an analogue of past community composition at lower altitudes, but rather constitutes a historically unique combination of species," or what we could truly call a "brave new world," which is significantly *richer* than the one of the recent past.

One year later, Randin *et al*. (2009) wrote that "the mean temperature interpolated from local stations at a 20-meter resolution contains more variability than expressed by the mean temperature within a 50-km x 50-km grid cell in which variation in elevation is poorly represented." Or as they described it in another part of their paper, "climatic differences along elevation gradients, as apparent at 25-m x 25-m resolution, allow plant species to find suitable climatic conditions at higher elevation under climate change," whereas "models at a 10 x 10' resolution [10 minutes of latitude x ten minutes of longitude, which correspond to 16-km x 16-km cells in the Swiss Alps, where they carried out their analyses] reflect the mean climatic conditions within the cell, and thus provide imprecise values of the probability of occurrence of species along a thermal gradient."

In testing this "local high-elevation habitat persistence hypothesis," as they described it, the group of Swiss, French and Danish researchers *assessed* "whether climate change-induced habitat losses predicted at the European scale (10 x 10' grid cells) are also predicted from local-scale data and modeling (25-m x 25-m grid cells)." And in doing so, they found that for 78 mountain species modeled at both European and local scales, the "local-scale models predict persistence of suitable habitats in up to 100% of species that were predicted by a European-scale model to lose all their suitable habitats in the area."

In discussing their findings, Randin *et al*. suggested that the vastly different results they obtained when using fine and coarse grid scales might help to explain what they call the *Quaternary Conundrum*, i.e. "why fewer species than expected went extinct during glacial periods when models predict so many extinctions with similar amplitude of climate change (Botkin *et al*., 2007)." In addition, they noted that "coarse-resolution predictions based on species distribution models are commonly used in the preparation of reports by the Intergovernmental Panel on Climate Change," which are then used by "conservation planners, managers, and other decision makers to anticipate biodiversity losses in alpine and other systems across local, regional, and larger scales," but which, unfortunately, give a highly-warped and erroneous view of the subject.

Moving one year closer to the present, Erschbamer *et al*. (2009) documented and analyzed changes (from 2001 to 2006) in plant species number, frequency and composition along an altitudinal gradient crossing four summits from the treeline ecotone to the subnival zone in the South Alps (Dolomites, Italy), where minimum temperatures increased by 1.1-2.0°C during the past century with a marked rise over the last decades. In describing their findings, the four researchers stated that "after five years, a re-visitation of the summit areas revealed a considerable increase of species richness at the upper alpine and subnival zone (10% and 9%, respectively) and relatively modest increases at the lower alpine zone and the treeline ecotone (3% and 1%, respectively)." In addition, with respect to threats of extinction, they reported that "during the last five years, the endemic species of the research area were hardly affected," while "at the highest summit, one endemic species was even among the newcomers."

The Austrian scientists thus concluded that "at least in short to medium time scales, the southern alpine endemics of the study area should not be seriously endangered." Moreover, they indicated that "the three higher summits of the study area have a pronounced relief providing potential surrogate habitats for these species." And they also reported that "recently published monitoring data from high altitudes indicate a consistent increase of species richness in the Alps," citing the work of Pauli *et al*. (2007) and Holzinger *et al*. (2008).

Working contemporaneously in the nearby Swiss Alps, Stocklin *et al*. (2009) studied the consequences of the highly structured alpine landscape for evolutionary processes in four different plants (*Epilobium fleischeri*, *Geum reptans*, *Campanula thyrsoides* and *Poa alpina*), testing for whether genetic diversity *within* their populations was related to altitude and land use, while seeking to determine whether genetic differentiation *among* populations was more related to different land use or to geographic distances. Their efforts indicated that *within*-population genetic diversity of the four species was high and mostly not related to altitude and population size; and they determined that genetic differentiation *among* populations was pronounced and strongly increasing with distance, implying "considerable genetic drift among populations of alpine plants."

Based on these findings, as well as the observations of others, Stocklin *et al*. remarked that "phenotypic plasticity is particularly pronounced in alpine plants," and that "because of the high heterogeneity of the alpine landscape, the pronounced capacity of a single genotype to exhibit variable phenotypes is a clear advantage for the persistence and survival of alpine plants." Hence, they concluded that "the evolutionary potential to respond to global change is mostly intact in alpine plants, even at high altitude." And this result makes it much easier to understand *why* -- even in the face of significant 20th-century global warming -- there have been no species of plants that have been observed to have been *pushed off the planet* in alpine regions, as has also been demonstrated to be the case by Walther *et al*. (2005), Kullman (2007), Holzinger *et al.* (2008), Randin *et al*. (2009) and Erschbamer *et al*. (2009).

In a somewhat different type of study, De Frenne *et al*. (2010) collected seeds of *Anemone nemorosa* L. (a model species for slow-colonizing herbaceous forest plants) that they found growing along a 2400-km latitudinal gradient stretching from northern France to northern Sweden during three separate growing seasons (2005, 2006 and 2008), after which they conducted sowing trials in incubators, a greenhouse, and under field conditions in a forest, where they measured the effects of different temperature treatments (Growing Degree Hours or GDH) on various seed and seedling traits. In completing these several experiments, the nineteen researchers discovered that "seed mass, germination percentage, germinable seed output and seedling mass all showed a positive response to increased GDH experienced by the parent plant," and that seed and seedling mass increased by 9.7% and 10.4%, respectively, for every 1000 °C-hours increase in GDH, which they say is equivalent to a 1°C rise in temperature over a 42-day period.

As a result of their findings, the team of international scientists -- hailing from Belgium, Estonia, France, Germany and Sweden -- concluded that "if climate warms, this will have a pronounced positive impact on the reproduction of *A. nemorosa*, especially in terms of seed mass, germination percentage and seedling mass," because "if more seeds germinate and resulting seedlings show higher fitness, more individuals may be recruited to the adult stage." In addition, they wrote that since "rhizome growth also is likely to benefit from higher winter temperatures (Philipp and Petersen, 2007), it can be hypothesized that the migration potential of *A. nemorosa* may increase as the climate in NW-Europe becomes warmer in the coming decades." And, as *we* suggest, *increasing* ***migration*** *potential* implies *decreasing* ***extinction*** *potential*.

***With respect to animals facing the challenge of global warming,*** climate alarmists generally characterize the situation as highly dangerous for them, just as they do for plants, suggesting that rising temperatures will also drive many of them to extinction. However, and once again as with plants, most research on the subject suggests otherwise.

A good place to begin a review of this subject is a study on butterflies conducted by a group of thirteen researchers in 1999 (Parmesan *et al*., 1999). These scientists analyzed, over the prior century of global warming, the distributional changes of non-migratory species whose northern boundaries were in northern Europe (52 species) and whose southern boundaries were in southern Europe or northern Africa (40 species). This work revealed that the northern boundaries of the first group shifted northward for 65% of them, remained stable for 34%, and shifted southward for 2%, while the southern boundaries of the second group shifted northward for 22% of them, remained stable for 72%, and shifted southward for 5%, such that "nearly all northward shifts," according to Parmesan *et al*., "involved extensions at the northern boundary with the southern boundary remaining stable."

This behavior is precisely what we would expect to see if the butterflies were responding to shifts in the ranges of the plants upon which they depend for their sustenance, because increases in atmospheric $CO_2$ concentration tend to ameliorate the effects of heat stress in plants and induce an upward shift in the temperature at which they function optimally. These phenomena tend to cancel the impetus for poleward migration at the warm edge of a plant's territorial range, yet they continue to provide the *opportunity* for poleward expansion at the cold edge of its range. Hence, it is possible that the observed changes in butterfly ranges over the past century of concomitant warming and rising atmospheric $CO_2$ concentration are related to matching changes in the ranges of the plants upon which they feed. Or, this similarity could be due to some more complex phenomenon, possibly even some direct physiological effect of temperature and atmospheric $CO_2$ concentration on the butterflies themselves. In any event, and in the face of the 0.8°C of "dreaded" global warming that occurred in Europe over the 20th century, the consequences for European butterflies were primarily *beneficial*, because, as Parmesan *et al*. described the situation, "most species effectively expanded the size of their range when shifting northwards," since "nearly all northward shifts involved extensions at the northern boundary with the southern boundary remaining stable."

A number of other researchers have also studied the relationship between butterflies and temperature. In the British Isles, Thomas *et al*. (2001) documented an unusually rapid expansion of the ranges of two butterfly species (the silver-spotted skipper butterfly and the brown argus butterfly) in response to increasing temperatures. In the United States, Crozier (2004) noted that "*Atalopedes campestris*, the sachem skipper butterfly, expanded its range from northern California into western Oregon in 1967, and into southwestern Washington in 1990," where she reports that temperatures rose by 2-4°C over the prior half-century. And in Canada, White and Kerr (2006) reported butterfly species' range shifts across the country between 1900 and 1990, noting that butterfly species richness increased as "a result of range expansion among the study species" that was "positively correlated with temperature change."

In another intriguing research finding, Gonzalez-Megias *et al*. (2008) investigated species turnover in 51 butterfly assemblages in Britain by examining *regional* extinction and colonization events that occurred between the two periods 1976-1982 and 1995-2002, over which time interval the world's climate alarmists claim the planet experienced a warming they contend was *unprecedented over the past millennium or more*. And in doing so, the five researchers found that regional colonizations exceeded extinctions, as "over twice as many sites gained species as lost species," such that "the average species richness of communities has increased." And they too found that species *abundances* following colonization likewise increased, due to "climate-related increases in the [land's] carrying capacity."

In comparing their results with those of a broader range of animal studies, Gonzalez-Megias *et al*. found that "analyses of distribution changes for a wide range of other groups of animals in Britain suggest that southern representatives of most taxa are moving northwards at a rate similar to -- and in some cases faster than -- butterflies (Hickling *et al*., 2006)," and they report that "as with butterflies, most of these taxonomic groups have fewer northern than southern representatives, so climate-driven colonisations are likely to exceed extinctions." Hence, they suggested that "most of these taxa will also be experiencing slight community-level increases in species richness."

One additional means by which butterflies can cope with high temperatures is through the production of heat-shock proteins (HSPs). According to Karl *et al*. (2008), HSPs "are thought to play an important ecological and evolutionary role in thermal adaptation," where "the upregulation of stress-inducible HSPs may help organisms to cope with stress thus enhancing survival (Sorensen *et al*., 2003; Dahlhoff, 2004; Dahlhoff and Rank, 2007)."

Working with *Lycaena tityrus,* a widespread temperate-zone butterfly that ranges from western Europe to central Asia, Karl *et al*. tested this hypothesis by comparing expression patterns of stress-inducible HSPs across replicated populations originating from different altitudes, as well as across different ambient temperatures. Their observations revealed a significant interaction between altitude and rearing temperature that indicated that "low-altitude animals showed a strongly increased HSP70 expression at the higher compared with at the lower rearing temperature," which is exactly where one would expect to see such a response in light of its obvious utility.

In discussing their findings, Karl *et al*. said their observation that "HSP70 expression increased substantially at the higher rearing temperature in low-altitude butterflies ... might represent an adaptation to occasionally occurring heat spells," which further suggests that this response should serve these organisms well in the days and years to come, especially if the dramatic warming and increase in heat spells predicted by the world's climate alarmists ever come to pass, which still further suggests (in light of the similar findings of others) that more of earth's life forms than many have assumed might be genetically equipped to likewise cope with the future thermal dangers envisioned by those enamored with the climate modeling enterprise and its imagined ramifications.

Birds have also been shown to be capable of dealing with increases in temperature. Thomas and Lennon (1999), for example, analyzed the geographical distributions of a number of British bird species over a 20-year period of global warming, looking for climate-induced changes in their breeding ranges between 1970 and 1990. And, as is the case with butterflies, their work revealed that the northern margins of southerly species' breeding ranges shifted northward by an average of 19 km over their study period; while the mean location of the southern margins of northerly species' breeding ranges shifted *not at all*, which observations are again indicative of *expanding* ranges and a propensity for birds -- like butterflies -- to become more *resistant* to extinction in a warming world.

Additional support for this concept was provided by the study of Brommer (2004) of the birds of Finland, which were categorized as either *northerly* (34 species) or *southerly* (116 species). In this analysis the researcher quantified changes in their range margins and distributions from two atlases of breeding birds, one covering the period 1974-79 and one covering the period 1986-89, in an attempt to determine how the two groups of species responded to what he called "the period of the earth's most rapid climate warming in the last 10,000 years." Once again, it was determined that the southerly group of bird species experienced a mean poleward advancement of their northern range boundaries of 18.8 km over the 12-year period of supposedly unprecedented warming. The *southern* range boundaries of the *northerly* species, on the other hand, were essentially unmoved, leading once again to range *expansions* that should have rendered the Finnish birds *less* subject to extinction than they were before the warming.

In an equally revealing study, Maclean *et al*. (2008) analyzed counts of seven wading bird species -- the Eurasian oystercatcher, grey plover, red knot, dunlin, bar-tailed godwit, Eurasian curlew and common redshank -- made at approximately 3500 different sites in Belgium, Denmark, France, Germany, Ireland, the Netherlands and the United Kingdom on at least an annual basis since the late 1970s. This they did in order to determine what range adjustments the waders may have made in response to concomitant regional warming, calculating the weighted geographical centroids of the bird populations for all sites with complete coverage for every year between 1981 and 2000.

This work revealed, in the words of the seven scientists, that "the weighted geographical centroid of the overwintering population of the majority of species shifted in a northeasterly direction, perpendicular to winter isotherms," with overall 20-year shifts ranging from 30 to 119 km. In addition, they reported that "when the dataset for each species was split into 10 parts, according to the mean temperature of the sites, responses are much stronger at the colder extremities of species ranges." In fact, they found that "at warmer sites, there was no palpable relationship between changes in bird numbers and changes in temperature." Hence, they concluded that "range expansions rather than shifts are occurring" as the planet warms.

In discussing the significance of their findings, the members of the international research team said that the commonly used *climate-envelope approach* to predicting warming-induced species migrations -- which was the one employed by many climate alarmists -- "essentially assumes that as climate alters, changes at one margin of a species' range are mirrored by those at the other, such that approximately the same 'climate space' is occupied regardless of actual climate," but that their work suggests "that this may not be the case: climate space can also change."

In further discussing their important finding, Maclean *et al*. wrote that "it is actually not surprising that responses to temperature appear only to be occurring at the colder extremities of species ranges," for they note that "it has long been known that it is common for species to be limited by environmental factors at one extremity, but by biological interactions at the other," citing the work of Connell (1983) and Begon *et al*. (2005). Thus, they concluded that it is likely that "the warmer extremities of the species ranges examined in this study are controlled primarily by biotic interactions, whereas the colder margins are dependent on temperature."

Similarly, and noting that "climate envelopes (or the climatic niche concept) are the current methods of choice for prediction of species distributions under climate change," Beale *et al*. (2008) remind us that "climate envelope methods and assumptions have been criticized as ecologically and statistically naive (Pearson and Dawson, 2003; Hampe, 2004)," and that "there are many reasons why species distributions may not match climate, including biotic interactions (Davis *et al*., 1998), adaptive evolution (Thomas *et al*., 2001), dispersal limitation (Svenning and Skov, 2007), and historical chance (Cotgreave and Harvey, 1994)." Thus, in an attempt to shed more light on the subject, they evaluated the degree of matchup of species distributions to environment by generating *synthetic* distributions that retained the spatial structure of observed distributions but were randomly placed with respect to climate. More specifically, "using data on the European distribution of 100 bird species, [they] generated 99 synthetic distribution patterns for each species," and "for each of the 100 species, [they] fitted climate envelope models to both the true distribution and the 99 simulated distributions by using standard climate variables," after which they determined the goodness-of-fit of the many distribution patterns, *because*, as they describe it, "there has been no attempt to quantify how often high goodness-of-fit scores, and hence ostensibly good matches between distribution and climate, can occur by chance alone."

In a rather surprising result, the three UK researchers determined that "species-climate associations found by climate envelope methods are no better than chance for 68 of 100 European bird species." And, in their words, "because birds are perceived to be equally strongly associated with climate as other species groups and trophic levels (Huntley *et al*., 2004)," they said that their results "cast doubt on the predictions of climate envelope models for all taxa." And as a result, they concluded that "many, if not most, published climate envelopes may be no better than expected from chance associations alone, questioning the implications of many published studies." The bottom line with respect to our stewardship of the earth is thus well described by their conclusion that "scientific studies and climate change adaptation policies based on the indiscriminate use of climate envelope methods irrespective of species sensitivity to climate may be misleading and in need of revision." And that need for revision is further evidenced by a number of other studies documenting recent range expansions, as opposed to range shifts for bird populations (Thomas and Lennon, 1999; Brommer, 2004; Hitch and Leberg, 2007; Brommer, 2008; Grandegeorge *et al*., 2008).

In considering the above observations, and when contemplating the special abilities of winged creatures, such as butterflies and birds, it does not appear to be much of a problem for them to *compensate* for whatever degree of stress a temperature increase might impose upon them by merely moving to more hospitable living quarters, or to actually *take advantage* of whatever *new opportunities* global warming might present for them. Furthermore, and aside from range expansions, rising temperatures also appear to be helping birds in other ways.

Thomas *et al*. (2010), for example, write that "the timing of annual breeding is a crucial determinant of reproductive success, individual fitness, and population performance, particularly in insectivorous passerine birds," because "by synchronizing hatching with the narrow time window of maximal food abundance, parents can enhance their reproductive success through an increase in offspring growth rate and body condition, survival to fledging, and subsequent recruitment into the breeding population." But many people worry, in this regard, that global warming may upset such biological synchronizations, leading to *downward* trends in the populations of many species of birds and other animals, which is yet another climate-alarmist nightmare. *However*, as many studies have shown, rising temperatures have actually been documented to *benefit* bird breeding performance (Halupka *et al*., 2008; Husek and Adamik, 2008; Monroe *et al*., 2008; Dyrcz and Halupka, 2009; Thomas *et al*., 2010) and population size (Julliard *et al*., 2004; Gregory *et al*., 2005; Raven *et al*., 2005; Lemoine *et al*., 2007; Seoane and Carrascal, 2008).

But what about *non*-winged animals? Are they capable of adapting to rising temperatures? In a word, *yes*, as evidenced by the results of the several research studies highlighted below.

Norment *et al*. (1999) summarized and compared the results of many surveys of mammal populations observed along the Thelon River and its tributaries in the Canadian Northwest Territories from the 1920s through much of the 1990s. Over this time period, red squirrel, moose, porcupine, river otter and beaver were found to have established themselves in the area, significantly increasing its biodiversity. The three researchers stated that these primarily northward range expansions could be explained by either "a recent warming trend at the northern treeline during the 1970s and 1980s" or "increasing populations in more southerly areas." In either case, we have a situation where several types of mammals appear to have fared quite well in the face of increasing temperatures in this forest-tundra landscape.

Chamaille-Jammes *et al*. (2006) studied four unconnected populations of the common lizard (*Lacerta vivipara*), a small live-bearing lacertid that lives in peat bogs and heath lands scattered across Europe and Asia, concentrating on a small region near the top of Mont Lozere in southeast France, at the southern limit of the species' range. More specifically, from 1984 to 2001 they monitored a number of life-history traits of the populations, including body size, reproduction characteristics and survival rates, during which time local air temperatures rose by approximately 2.2°C. In doing so, they found that individual body size increased dramatically in all four lizard populations over the 18-year study period, with snout-vent length expanding by roughly 28%. This increase in body size occurred in all age classes and, as they describe it, "appeared related to a concomitant increase in temperature experienced during the first month of life (August)." As a result, they found that "adult female body size increased markedly, and, as fecundity is strongly dependent on female body size, clutch size and total reproductive output also increased." In addition, for a population where capture-recapture data were available, they learned that "adult survival was positively related to May temperature."

In summarizing their findings, the French researchers stated that since all fitness components investigated responded positively to the increase in temperature, "it might be concluded that the common lizard has been advantaged by the shift in temperature." This finding, in their words, stands in stark contrast to the "habitat-based prediction that these populations located close to mountain tops on the southern margin of the species range should be unable to cope with the alteration of their habitat." Hence, they concluded that "to achieve a better prediction of a species persistence, one will probably need to combine both habitat and individual-based approaches," noting, however, that *individual responses*, such as those documented in their study (which were all positive), represent "the ultimate driver of a species response to climate change."

Out in the watery realm of the world's oceans, Rombouts *et al*. (2008) developed the first global description of geographical variation in the diversity of marine copepods in relation to ten environmental variables; and in doing so, they found that "ocean temperature was the most important explanatory factor among all environmental variables tested, accounting for 54 percent of the variation in diversity." Hence, it was not surprising, as they described it, that "diversity peaked at subtropical latitudes in the Northern Hemisphere and showed a plateau in the Southern Hemisphere where diversity remained high from the Equator to the beginning of the temperate regions," which pattern, in their words, "is consistent with latitudinal variations found for some other marine taxa, e.g. foraminifera (Rutherford *et al*., 1999), tintinnids (Dolan *et al*., 2006) and fish (Worm *et al*., 2005; Boyce *et al*., 2008), and also in the terrestrial environment, e.g. aphids, sawflies and birds (Gaston and Blackburn, 2000)."

"Given the strong positive correlation between diversity and temperature," the six scientists went on to say that "local copepod diversity, especially in extra-tropical regions, is likely to increase with climate change as their large-scale distributions respond to climate warming." This state of affairs is much the same as what has typically been found on land for birds, butterflies and several other terrestrial lifeforms, as their ranges expand and overlap in response to global warming. And with more territory thus available to them, their "foothold" on the planet becomes ever stronger, fortifying them against forces (many of them human-induced) that might otherwise lead to their extinction.

Millar and Westfall (2010) studied American pikas: small generalist herbivores that are relatives of rabbits and hares that inhabit patchily-distributed rocky slopes of western North American mountains and are good at tolerating cold. And as a result of that fact, it is not surprising that pikas are widely believed to have a physiological sensitivity to warming, which when "coupled with the geometry of decreasing area at increasing elevation on mountain peaks," in the words of the two scientists, "has raised concern for the future persistence of pikas in the face of climate change." Therefore, they write that the species "has been petitioned under California [USA] state and federal laws for endangered species listing." And in a study designed to investigate the validity of the basis for that classification, Millar and Westfall developed a rapid assessment method for determining pika occurrence and used it "to assess geomorphic affinities of pika habitat, analyze climatic relationships of sites, and evaluate refugium environments for pikas under warming climates," while working over the course of two field seasons in the Sierra Nevada Mountains of California, the southwestern Great Basin of California and Nevada, and the central Great Basin of Nevada, as well as a small area in the central Oregon Cascades.

In reporting their findings, the two U.S. Forest Service researchers state that "whereas concern exists for diminishing range of pikas relative to early surveys, the distribution and extent in our study, pertinent to four subspecies and the Pacific southwest lineage of pikas, resemble the diversity range conditions described in early 20th-century pika records (e.g., Grinnell and Storer, 1924)." In fact, they say that the lowest site at which they detected the current presence of pikas at an elevation of 1827 meters "is below the historic lowest elevation of 2350 m recorded for the subspecies by Grinnell and Storer (1924) in Yosemite National Park; below the low elevation range limit for the White Mountains populations given by Howell (1924) at 2440 m; and below the lowest elevation described for the southern Sierra Nevada populations of 2134 m (Sumner and Dixon, 1953)." In addition, they say that "a similar situation occurred for another lagomorph of concern, pygmy rabbit (*Brachylagus idahoensis*), where a rapid assessment method revealed much wider distribution than had been implied from historic population databases or resurvey efforts (Himes and Drohan, 2007)."

Millar and Westfall thus conclude that "pika populations in the Sierra Nevada and southwestern Great Basin are thriving, persist in a wide range of thermal environments, and show little evidence of extirpation or decline," which suggests to us that current concerns about the future of American pikas in a warming world may be wildly misplaced. Moreover, the documentation of a similar phenomenon operating among pygmy rabbits suggests that still other animals may also be better able to cope with various aspects of climate change than we have been led to believe possible.

In providing some background for their study of montane rainforest lizards, Bell *et al*. (2010) write that tropical species have long been considered to be "especially sensitive to climatic fluctuations because their narrow thermal tolerances and elevational ranges can restrict their ability to persist in, or disperse across, alternate habitats," a concept that NASA's James Hansen expressed much more bluntly by declaring on 21 November 2006 -- when accepting the World Wildlife Fund's Duke of Edinburgh Conservation Medal at St. James Palace in London -- that "species living on the biologically diverse slopes leading to mountains will be pushed off the planet" as the planet warms, opining -- as we have already noted he also did before the U.S. House of Representatives -- that there will simply be no place else for them to go.

In an empirical probe into the substance of this concept, Bell *et al*. compared "responses to historical climate fluctuation in a montane specialist skink, *Lampropholis robertsi*, and its more broadly distributed congener, *L. coggeri*, both endemic to rainforests of northeast Australia," by combining "spatial modeling of potential distributions under representative palaeoclimates, multi-locus phylogeography, and analyses of phenotypic variation." This work revealed, in the words of the seven scientists, that "both species exhibit pronounced phylogeographic structuring for mitochondrial and nuclear genes, attesting to low dispersal and high persistence across multiple isolated regions." And speaking more specifically about *L. robertsi*, they state that their evidence demonstrates "persistence and isolation" of most populations of the montane species "throughout the strong climate oscillations of the late Pleistocene, and likely extending back to the Pliocene."

Noting that many of the isolated refugia they studied "are particularly rich in narrowly endemic species," Bell *et al*. state that this characteristic has been attributed to "their relative stability during recent episodes of climate change (Williams and Pearson, 1997; Yeates *et al*., 2002; Graham *et al*., 2006; VanDerWal *et al*., 2009)." And they indicate that these observations "support the general hypothesis that isolated tropical montane regions harbor high levels of narrow-range taxa because of their resilience to past climate change," citing the work of Fjeldsa and Lovett (1997) and Jetz *et al*. (2004). Thus, they write that "at first sight, species such as *L. robertsi* would seem especially prone to local extinction and loss of considerable genetic diversity with any further warming; yet, these populations and those of other high-montane endemic species (*Cophixalus* frogs; Hoskin, 2004) have evidently persisted through past warming events." And thus it is likely they will do so again, if similarly stressed in the future, in spite of the overly-confident contentions of James Hansen and company to the contrary.

Last of all (but happening some time ago), Pockley (2001) reported the results of a survey of the plants and animals on Australia's Heard Island, a little piece of real estate located 4,000 kilometers southwest of Perth. Over the prior fifty years this sub-Antarctic island had experienced a local warming of approximately 1°C that had resulted in a modest (12%) retreat of its glaciers; and hence, for the first time in a decade, scientists were attempting to document what this warming and melting had done to the ecology of the island.

Pockley began by stating the scientists' work had unearthed "dramatic evidence of global warming's ecological impact," which obviously consisted of "rapid increases in flora and fauna." He quoted Dana Bergstrom, an ecologist at the University of Queensland in Brisbane, as saying that areas that previously had been poorly vegetated had become "lush with large expanses of plants." And he added that populations of birds, fur seals and insects had also expanded rapidly. One of the real winners in this regard was the king penguin, which, according to Pockley, had "exploded from only three breeding pairs in 1947 to 25,000."

Eric Woehler of Australia's environment department was listed as a source of other equally remarkable information, such as the Heard Island cormorant's comeback from "vulnerable" status to a substantial 1,200 pairs, and fur seals emergence from “near extinction” to a population of 28,000 adults and 1,000 pups.

Yes, the regional warming experienced at Heard Island actually saved these threatened animal populations from the jaws of extinction. So it’s time to celebrate!  Responsibility clearly cuts both ways; and if emitters of $CO_2$ are being *excoriated*, and *in advance*, for presumably promoting future *hypothetical* extinctions, they should surely be *thanked*, even *in retrospect*, for preventing imminent *real-world* extinctions.

## 8. Declining Vegetative Productivity

***The claim:*** *Rising temperatures and increased weather extremes will decimate the productivity of critical earth ecosystems*.

*Climate-model projections* have long suggested that the "twin evils" of the world's radical environmentalist movement (atmospheric $CO_2$ enrichment and global warming) will wreck havoc with earth's natural and agro-ecosystems. However, a vast body of *real-world research* indicates that these two phenomena will likely do just the *opposite*.

Carbon dioxide is one of the two chief constituents of life on earth, the other being water; and the combining of the two of them via the process of *photosynthesis* is the very beginning of the planet's many "food chains," be they aquatic or terrestrial. Fortunately, it is a simple matter to assess the effect of an increase in the air's $CO_2$ content on this phenomenon as it operates in terrestrial plants, for it can be accomplished by merely increasing the $CO_2$ concentration of the air surrounding the plants in question and measuring the $CO_2$ exchange between the air and the plants (in the case of photosynthesis) or the production of biomass (in the case of growth). And there have been literally *thousands* of such experiments performed in both the laboratory and the field, throughout most of the inhabited parts of the planet.

The world's largest repository of the results of such studies is located at the website of the Center for the Study of Carbon Dioxide and Global Change in two huge and ever-expanding databases (http://www.co2science.org/data/plant_growth/plantgrowth.php) to which new results are added weekly: one for photosynthesis and one for biomass or plant dry weight production. In the former category, one could find, at the end of 2010, the results of 71 individual experiments conducted on *rice* (an average increase in the rate of photosynthesis of 48.5% in response to a 300-ppm increase in the air's $CO_2$ concentration), while in the case of biomass production, one could find the results of 178 individual experiments (an average dry weight increase of 34.5% in response to a 300-ppm increase in the air's $CO_2$ concentration). Likewise, in the case of *wheat*, there were 91 individual determinations of the increase in photosynthesis caused by a 300-ppm increase in atmospheric $CO_2$ (an average increase of 62.7%) and 235 individual determinations of the increase in dry weight production (an average increase of 32.1%).

A complete summary listing of such results for all plants in the *$CO_2$ Science* database may be found in Appendix 2 (for dry weight or biomass) and Appendix 3 (for photosynthesis) of *Climate Change Reconsidered* (Idso and Singer, 2009), as things stood as of 23 March 2009. In addition, Idso and Idso (2000), in analyzing how things stood about a decade earlier, had determined the mean percentage yield increases in response to a 300-ppm increase in the atmosphere's $CO_2$ concentration to be approximately 15% for CAM plants, 49% for $C_3$ cereals, 20% for $C_4$ cereals, 25% for fruits and melons, 44% for legumes, 48% for roots and tubers, 36% for vegetables, and 51% for woody crop plants.

In light of this vast array of real-world research, it can be appreciated that the *aerial fertilization effect* of enriching earth's atmosphere with $CO_2$ is a *very* beneficent phenomenon. As Sylvan Wittwer stated in his 1995 book (*Food, Climate, and Carbon Dioxide: The Global Environment and World Food Production*):

> "The rising level of atmospheric $CO_2$ could be the one global natural resource that is progressively increasing food production and total biological output, in a world of otherwise diminishing natural resources of land, water, energy, minerals, and fertilizer. It is a means of inadvertently increasing the productivity of farming systems and other photosynthetically active ecosystems. The effects know no boundaries and both developing and developed countries are, and will be, sharing equally."

A second major benefit that earth's plants experience as a result of the ongoing rise in the air's $CO_2$ content is enhanced *water use efficiency*. As mentioned above, when the atmosphere's $CO_2$ concentration is increased, nearly all plants exhibit increased rates of photosynthesis and biomass production, while simultaneously, on a per-unit-leaf-area basis, they often lose less water via transpiration, as they tend to reduce their stomatal apertures and thereby decrease the rate of water loss from their leaves. Thus, the amount of biomass produced per unit of water lost -- or *plant water use efficiency* -- typically rises significantly as the air's $CO_2$ content rises, which means that plants can produce more biomass while letting less water escape to the air, a phenomenon which, like the *aerial fertilization effect* of $CO_2$, has also been observed in a plethora of agricultural crops in numerous experiments conducted under laboratory conditions (Malmstrom and Field, 1997; De Luis *et al*., 1999; Zhu *et al*., 1999; Gavito *et al*., 2000; Kyei-Boahen *et al*., 2003; Kim *et al*., 2006; Fleisher *et al*., 2008), as well as in greenhouses (Ceusters *et al*., 2008; Sanchez-Guerrero *et al*., 2009) and in the field (Garcia *et al*., 1998; Hakala *et al*., 1999; Hunsaker *et al*., 2000; Conley *et al*., 2001; Olivo *et al*., 2002; Dong-Xiu *et al*., 2002; Leavitt *et al*., 2003; Triggs *et al*., 2004; Yoshimoto *et al*., 2005).

Much the same has been observed in several species of young trees that have been similarly studied (Anderson and Tomlinson, 1998; Beerling *et al*., 1998; Egli *et al*., 1998; Rey and Jarvis, 1998; Tjoelker *et al*., 1998; Wayne *et al*., 1998; Centritto *et al*., 1999; Runion *et al*., 1999; Bucher-Wallin *et al*., 2000; Lodge *et al*., 2001; Tognetti *et al*., 2001; Wullschleger and Norby, 2001; Centritto, 2002; Centritto *et al*., 2002; Gunderson *et al*., 2002; Greenep *et al*., 2003), as well as in many species of older trees that have lived through the historical increase in the air's $CO_2$ content of the past century or so, and whose temporal water use efficiency histories have been determined from dated tree-ring cellulose $\delta^{13}C$ measurements (Bert *et al*., 1997; Duquesnay *et al*., 1998; Feng, 1999; Arneth *et al*., 2002; Saurer *et al*., 2004; Hietz *et al*., 2005; Liu *et al*., 2007; Silva *et al*., 2009), plus a few studies of trees where some of them had spent their entire lifetimes growing within $CO_2$-enriched air close to $CO_2$-emitting springs or vents, while others had grown further away from the springs/vents in normal ambient-$CO_2$ air (Fernandez *et al*., 1998; Tognetti *et al*., 1998; Bartak *et al*., 1999; Blaschke *et al*., 2001).

Grasslands also exhibit the same increased water use efficiency response to atmospheric $CO_2$ enrichment that trees and agricultural crops do, as evidenced by the findings of LeCain and

Morgan (1998), Seneweera *et al*. (1998), Szente *et al*. (1998), Clark *et al*. (1999), Leymarie *et al*. (1999), Adams *et al*. (2000), Roumet *et al*. (2000), Grunzweig and Korner (2001), Engloner *et al*. (2003) and Moore and Field (2006). And all of these findings for all types of vegetation imply that the moisture contained in soils upon which plants are growing can be maintained at increasingly *higher levels* for *longer periods of time* as the air's $CO_2$ content continues its upward climb, as has been shown to be the case in numerous field studies (Owensby *et al*., 1993; Ham *et al*., 1995; Bremer *et al*., 1996; Freden *et al*., 1997; Niklaus *et al*., 1998; Owensby *et al*., 1999; Sindhoj *et al*., 2000; Volk *et al*., 2000; Bunce, 2001; Morgan *et al*., 2001; Reich *et al*., 2001; Higgins *et al*., 2002; Hungate *et al*., 2002; Ferretti *et al*., 2003; Obrist *et al*., 2003; Zavaleta *et al*., 2003; Eguchi *et al*., 2004; Nelson *et al*., 2004; Niklaus and Korner, 2004). And *this* phenomenon reduces the severity and length of time that droughts can negatively affect both crops and natural vegetation, which secondary phenomenon leads to *still greater* season-long plant productivity, which phenomenon has also been observed in desert vegetation (Hamerlynck *et al*., 2002; Housman *et al*., 2006).

Last of all, it should be noted that this "water conservation effect" of atmospheric $CO_2$ enrichment appears to operate *even in the face of rising temperatures*, as was found to be the case in the experimental studies of Dermody *et al*. (2007) and Saleska *et al*. (2007). And in an informative review of the direct and indirect effects of rising air temperature and atmospheric $CO_2$ concentration on plant behavior, Kirschbaum (2004) makes a number of pertinent and revealing observations, the primary ones of which we here briefly summarize.

With respect to rising temperatures and their effect on photosynthesis, Kirschbaum states that "all plants appear to be capable of a degree of adaptation to growth conditions," noting that "photosynthesis in some species can function adequately up to 50°C." In fact, he says that "photosynthesis can acclimate considerably to actual growth conditions," noting that "optimum temperatures for photosynthesis acclimate by about 0.5°C per 1.0°C change in effective growth temperature (Berry and Bjorkman, 1980; Battaglia *et al*., 1996)." This response, wherein plants adjust the workings of their photosynthetic apparatus to perform better at higher temperatures as temperatures rise, would appear to be especially beneficial in a warming world.

With respect to rising $CO_2$ concentrations and their effect on photosynthesis, Kirschbaum notes that $CO_2$ assimilation rates generally rise as the air's $CO_2$ content rises: by 25-75% in $C_3$ plants in response to a doubling of the air's $CO_2$ content, and by something on the order of 25% in $C_4$ grasses, according to the major review of Wand *et al*. (1999). This response, wherein plants adjust the workings of their photosynthetic apparatus to perform better at higher atmospheric $CO_2$ concentrations as atmospheric $CO_2$ concentrations rise, would also appear to be especially beneficial in a $CO_2$-acreting atmosphere.

With respect to the *synergistic* effect of simultaneous increases in *both* atmospheric $CO_2$ concentration and temperature on photosynthesis, Kirschbaum notes that plant growth responses to increasing $CO_2$ are usually much more pronounced for plants grown at higher temperatures," presenting a graph that suggests an approximate *six-fold amplification* of the aerial fertilization effect of atmospheric $CO_2$ enrichment at an air temperature of 35°C compared to one of 5°C. Consequently, in a world where *both* air temperature and $CO_2$ concentration are rising, this response would appear to be *hugely* beneficial.

Nevertheless, according to Robock *et al*. (2005), "most global climate model simulations of the future, when forced with increasing greenhouse gases and anthropogenic aerosols, predict summer desiccation in the midlatitudes of the Northern Hemisphere," and they state that "this predicted soil moisture reduction, the product of increased evaporative demand with higher temperatures overwhelming any increased precipitation, is one of the gravest threats of global warming, potentially having large impacts on our food supply." But inquisitive enough to want to know for themselves *what actually happens in the real world*, they went on to analyze 45 years of gravimetrically-measured plant-available soil moisture in the top one meter of soil for 141 stations from fields with either winter or spring cereals in the Ukraine over the period 1958-2002, *finding*, in their words, "a positive soil moisture trend for the entire period of observation." And they emphasized that "even though for the entire period there is a small upward trend in temperature and a downward trend in summer precipitation, the soil moisture still has an upward trend for both winter and summer cereals."

Two years later, Li *et al*. (2007) compared soil moisture simulations derived from the IPCC's Fourth Assessment climate models (which were driven by *observed climate forcings*) for the period 1958-1999 with actual measurements of soil moisture made at over 140 stations or districts in the mid-latitudes of the Northern Hemisphere, which were averaged in such a way as to yield six regional results: one each for the Ukraine, Russia, Mongolia, Northern China, Central China and Illinois (USA). And in doing so, they found that the models showed realistic seasonal cycles for the Ukraine, Russia and Illinois *but* "generally poor seasonal cycles for Mongolia and China." In addition, they said that the Ukraine and Russia experienced soil moisture increases in summer "that were larger than most trends in the model simulations." In fact, they reported that "only two out of 25 model realizations show trends comparable to those observations," and they noted that the two realistic model-derived trends were "due to internal model variability rather than a result of external forcing," which means that the two reasonable matches were actually *accidental*.

Noting further that "changes in precipitation and temperature cannot fully explain soil moisture increases for [the] Ukraine and Russia," Li *et al*. noted that in response to elevated atmospheric $CO_2$ concentrations, "many plant species reduce their stomatal openings, leading to a reduction in evaporation to the atmosphere," so that "more water is likely to be stored in the soil or [diverted to] runoff," correctly reporting that this phenomenon had recently been detected in continental river runoff data by Gedney *et al*. (2006). In addition, in a free-air $CO_2$-enrichment study conducted in a pasture on the North Island of New Zealand, Newton *et al*. (2003) found there was a significant *reduction* in the *water repellency* of the soil in the elevated $CO_2$ treatment, where they describe water repellency as "a soil property that prevents free water from entering the pores of dry soil," as per Tillman *et al*. (1989). In fact, they wrote that "at field moisture content the repellence of the ambient soil was severe and significantly greater than that of the elevated [$CO_2$] soil," suggesting that the reduction in the repellency of the soil provided by atmospheric $CO_2$ enrichment would allow more water to enter and remain in the soil.

As time goes on, therefore, the multifaceted "water conservation effect" of atmospheric $CO_2$ enrichment is becoming ever more important, as ever more land and water resources are being taken from "wild nature," in order to support the planet's growing human population, with the problem being that there's not much pristine land and water left for us to take. However, this problem, as we have noted, is being significantly mitigated by the continued strengthening of the very *positive* effect of atmospheric $CO_2$ enrichment, in that the yearly upward trend in the air's $CO_2$ content enables plants to yearly grow bigger and better -- and more successfully reproduce – especially where it was previously too dry for them to do so. And there is a large and growing body of real-world empirical evidence that suggests that this phenomenon has been occurring for some time now from arid to moist areas throughout the world, in a gradual transformation of the planet's terrestrial landscape that is frequently referred to as *the greening of planet earth*.

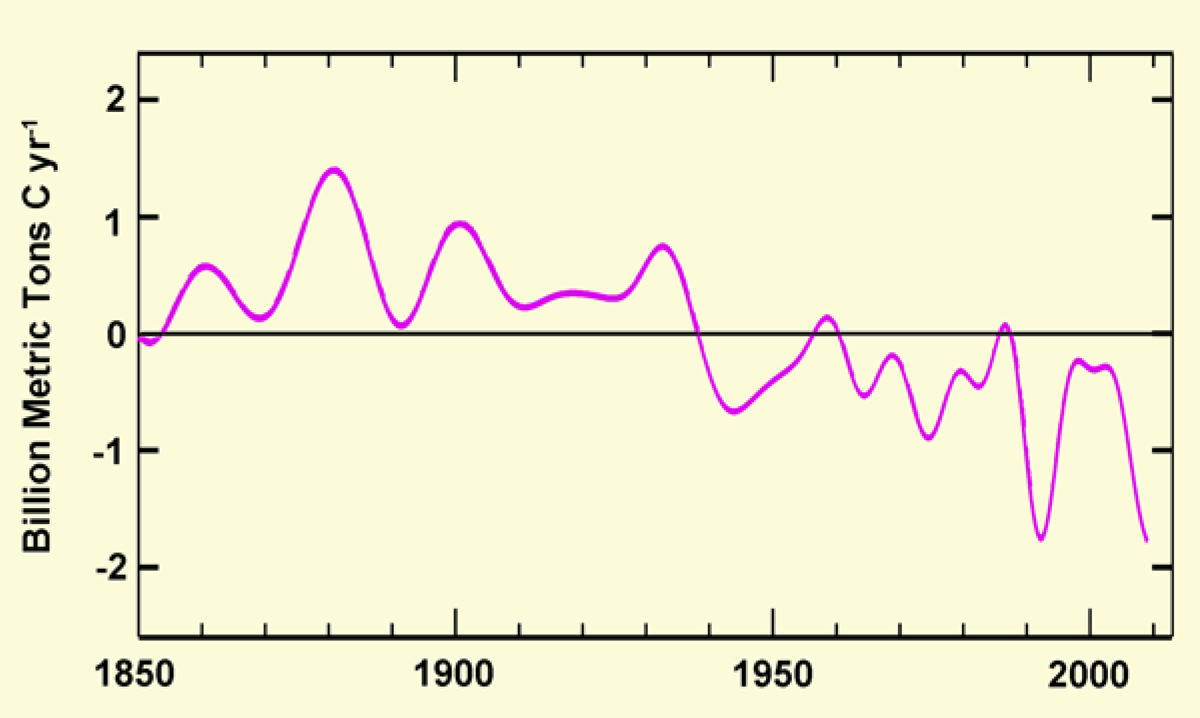
Evaluating this phenomena from a global perspective, Cao *et al*. (2004), in what they called "the first attempt to quantify interannual variations in NPP [net primary production] at the global scale," found that over the last two decades of the 20th century, *when the heat was on*, "there was an increasing trend toward enhanced terrestrial NPP," which they say was "caused mainly by increases in atmospheric carbon dioxide and precipitation." And one year later, Cao *et al*. (2005) calculated -- from real-world data -- that global net ecosystem production increased "from 0.25 Pg C $yr^{-1}$ in the 1980s to 1.36 Pg C $yr^{-1}$ in the 1990s."

In another study, Xiao and Moody (2005) found that the most intense recent greening of the globe was observed in high northern latitudes, portions of the tropics, southeastern North America and eastern China, in harmony with the increases in global vegetative productivity over the latter part of the 20th century that had been detected by Kawabata *et al*. (2001), Ichii *et al*. (2002) and Nemani *et al*. (2003). Working with satellite-derived NDVI data for the period 1982-1999, Young and Harris (2005) obtained similar results, determining that "globally more than 30% of land pixels increased in annual average NDVI greater than 4% and more than 16% *persistently* increased greater than 4%," while "during the same period less than 2% of land pixels declined in NDVI and less than 1% persistently declined," so that "between 1982 and 1999 the general trend of vegetation change throughout the world has been one of increasing photosynthesis."

In a study of tropical forests in the Amazon, Africa and Asia over the period 1982-1999, Ichii *et al*. (2005) reported that "recent changes in atmospheric $CO_2$ and climate promoted terrestrial GPP [gross primary productivity] increases with a significant linear trend in all three tropical regions," such that in the Amazonian region, the rate of GPP increase was 0.67 PgC $year^{-1}$ per decade, while in Africa and Asia it was about 0.3 PgC $year^{-1}$ per decade; and they state that "$CO_2$ fertilization effects strongly increased recent net primary productivity trends in regional totals."

In another study, Lewis, *et al*. (2009a), in a thorough review of the scientific literature, noted that both theory and experiments suggest that over the past several decades "plant photosynthesis should have increased in response to increasing $CO_2$ concentrations, causing increased plant growth and forest biomass," and they did indeed find that "long-term plot data collectively indicate an increase in carbon storage, as well as significant increases in tree growth, mortality, recruitment, and forest dynamism," that satellite measurements "indicate increases in productivity and forest dynamism," and that five Dynamic Global Vegetation Models, incorporating plant physiology, competition, and dynamics, all predict increasing gross primary productivity, net primary productivity, and carbon storage when forced using late-twentieth century climate and atmospheric $CO_2$ concentration data," while noting that "the predicted increases in carbon storage via the differing methods are all of similar magnitude (0.2% to 0.5% per year)." And so they concluded that "these results point toward a widespread shift in the ecology of tropical forests, characterized by increased tree growth and accelerating forest dynamism, with forests, on average, getting bigger (increasing biomass and carbon storage)."

Contemporaneously, Tans (2009) employed measurements of atmospheric and oceanic carbon contents, along with reasonably constrained estimates of global anthropogenic $CO_2$ emissions, to calculate the residual fluxes of carbon (in the form of $CO_2$) from the terrestrial biosphere to the atmosphere (+ values) or from the atmosphere to the terrestrial biosphere (- values), obtaining the results depicted in the following figure.



***Five-year smoothed rates of carbon transfer from land to air (+) or from air to land (-) vs. time. Adapted from Tans (2009).***

As can be seen from this figure, earth's land surfaces were a net *source* of $CO_2$-carbon to the atmosphere until about 1940, primarily due to the felling of forests and the plowing of grasslands to make way for expanded agricultural activities. From 1940 onward, however, the terrestrial biosphere has become, in the mean, an *increasingly greater* ***sink*** for $CO_2$-carbon; and it has done so even in the face of massive global deforestation, for which it has *more* than compensated. And in light of these findings, plus the fact that they do "not depend on models" but "only on the observed atmospheric increase and estimates of fossil fuel emissions," Tans concluded that "suggestions that the carbon cycle is becoming less effective in removing $CO_2$ from the atmosphere (e.g., LeQuere *et al*., 2007; Canadell *et al*., 2007) can perhaps be true locally, but they do not apply globally, not over the 50-year atmospheric record, and not in recent years." In fact, he goes on to say that "to the contrary" and "despite global fossil fuel emissions increasing from 6.57 GtC in 1999 to 8.23 in 2006, the five-year smoothed global atmospheric growth rate has not increased during that time, which requires more effective uptake [of $CO_2$] either by the ocean or by the terrestrial biosphere, or both, to satisfy atmospheric observations." And the results portrayed in the figure we have adapted from Tans' paper clearly indicate that this "more effective uptake" of $CO_2$-carbon has occurred primarily over land.

The story reported on a continent by continent basis is much the same as it is for the globe as a whole. Consequently, and in order to curtail the size of this burgeoning treatise, in what follows we provide only references, grouped by continent, of studies where real-world data have documented the greening of the earth phenomena.

For **Africa**, Prince *et al*. (1998), Eklundh and Olsson (2003), Anyamba and Tucker (2005), Olsson *et al*. (2005), Seaquist *et al*. (2006), Ciais *et al*. (2009) and Lewis *et al*. (2009b). For **Asia**, Fang *et al*. (2003), Piao *et al*. (2005a), Brogaard *et al*. (2005), Piao *et al*. (2005b), Lapenis *et al*. (2005), Piao *et al*. (2006a), Schimel *et al*. (2001), Kharuk *et al*. (2006), Piao *et al*. (2006b), Tan *et al*. (2007), Piao *et al*. (2007), Zhou *et al*. (2007), Zhu *et al*. (2007), Mu *et al*. (2008), Mao *et al*. (2009), Zhuang *et al*. (2010) and Forbes *et al*. (2010). For **Australia**, Harrington and Sanderson (1994), Russell-Smith *et al*. (2004) and Banfai and Bowman (2006). For **Europe**, Osborne *et al*. (2000), Lopatin *et al*. (2006), Martinez-Vilalta *et al*. (2008), Alcaraz-Segura *et al*. (2008) and Hallinger *et al*. (2010). For **North America**, Hicke *et al*. (2002), Westfall and Amateis (2003), Lim *et al*. (2004), Peterson and Neofotis (2004), Xiao and Moody (2004), Soule and Knapp (2006), Tape *et al*. (2006), Wang *et al*. (2006), Voelker *et al*. (2006), Piao *et al*. (2006c), Hudson and Henry (2009), Springsteen *et al*. (2010), Pan *et al*. (2010) and Cole *et al*. (2010). And for **South America**, Beerling and Mayle (2006) and Silva *et al*. (2009).

Given the above findings, our assessment of the future of earth's natural and agro-ecosystems is indeed bright. Crop yields will increase by a goodly amount over the course of this century, and tree and shrub growth will surge even more, as the air's $CO_2$ content continues to promote a great *greening of the earth*.

## 9. Frequent Coral Bleaching

***The claim:*** *Rising ocean temperatures driven by $CO_2$-induced global warming is killing the world's corals.*

*Bleaching* is the name of the phenomenon given to the process whereby the corals inhabiting earth's seas expel the algal symbionts or *zooxanthellae* living within their tissues (upon which they depend for their sustenance) when subjected to various environmental stresses, one of the most discussed of which is *excessive warmth*. And as a result of this discussion, primarily among climate alarmists, global warming has long been claimed by them to be one of the primary reasons for mandating reductions in anthropogenic $CO_2$ emissions, in order to prevent our driving numerous species of corals to extinction. But is this contention based on sound science?

***With respect to corals adapting to greater warmth***, Adjeroud *et al*. (2005) documented -- in a study of 13 islands in four of the five archipelagoes of French Polynesia -- the effects of natural perturbations on various coral assemblages over the period 1992-2002, during which time the reefs were subjected to three major coral bleaching events (1994, 1998, 2002). Finding that the impacts of the bleaching events were variable among the different study locations, and that "an interannual survey of reef communities at Tiahura, Moorea, showed that the mortality of coral colonies following a bleaching event was decreasing with successive events, even if the latter have the same intensity (Adjeroud *et al*., 2002)," they concluded that the "spatial and temporal variability of the impacts observed at several scales during the present and previous surveys may reflect an acclimation and/or adaptation of local populations," such that "coral colonies and/or their endosymbiotic zooxanthellae may be phenotypically (acclimation) and possibly genotypically (adaptation) resistant to bleaching events," citing the work of Rowan *et al*. (1997), Hoegh-Guldberg (1999), Kinzie *et al*. (2001) and Coles and Brown (2003) in support of this conclusion.

Other researchers have confirmed the phenomenon of thermal adaptation in coral reefs. Guzman and Cortes (2007), for example, studied reefs of the eastern Pacific Ocean that "suffered unprecedented mass mortality at a regional scale as a consequence of the anomalous sea warming during the 1982-1983 El Niño." In a survey of three representative reefs they conducted in 1987 at Cocos Island, for example, they found that remaining live coral cover was only 3% of what it had been prior to the occurrence of the great El Niño four years earlier (Guzman and Cortes, 1992); and based on this finding and the similar observations of other scientists at other reefs, they predicted that "the recovery of the reefs' framework would take centuries, and recovery of live coral cover, decades."

In 2002, however, nearly 20 years after the disastrous coral-killing warming, they returned to see just how prescient they might have been after their initial assessment of the El Niño's horrendous damage, quantifying the live coral cover and species composition of five reefs, including the three they assessed in 1987. And in doing so, they found that overall mean live coral cover had increased nearly *five-fold*, from 3% in 1987 to 14.9% in 2002, at the three sites studied during both periods, while the mean live coral cover of all five sites studied in 2002 was 22.7%. In addition, they found that most new recruits and adults belonged to the main reef building species of the past, suggesting that a disturbance as outstanding as the 1982-1983 El Niño "was not sufficient to change the role or composition of the dominant species."

The most interesting aspect of their study, however, was the fact that a *second* major El Niño had occurred between the two assessment periods; and Guzman and Cortes report that the 1997-1998 warming event around Cocos Island was more intense than all previous El Niño events, noting that temperature anomalies above 2°C lasted 4 months in 1997-1998 compared to 1 month in 1982-83. Nevertheless, they found that "the coral communities suffered a lower and more selective mortality in 1997-1998, as was also observed in other areas of the eastern Pacific (Glynn *et al*., 2001; Cortes and Jimenez, 2003; Zapata and Vargas-Angel, 2003)," which is indicative of some form of *thermal adaptation* in the wake of the 1982-83 El Niño.

One year later, Maynard *et al*. (2008) described how they analyzed the bleaching severity of three genera of corals (*Acropora*, *Pocillopora* and *Porites*) via underwater video surveys of five sites in the central section of Australia's Great Barrier Reef in late February and March of 1998 and 2002, while contemporary sea surface temperatures were acquired from satellite-based Advanced Very High Resolution Radiometer data that were calibrated to local ship- and drift buoy-obtained measurements, and surface irradiance data were obtained "using an approach modified from that of Pinker and Laszlo (1991)."

With respect to temperature, the four researchers report that "the amount of accumulated thermal stress (as degree heating days) in 2002 was more than double that in 1998 at four of the five sites," and that "average surface irradiance during the 2002 thermal anomaly was 15.6-18.9% higher than during the 1998 anomaly." Nevertheless, they found that "in 2002, bleaching severity was 30-100% lower than predicted from the relationship between severity and thermal stress in 1998, despite higher solar irradiances during the 2002 thermal event." In addition, they found that the "coral genera most susceptible to thermal stress (*Pocillopora* and *Acropora*) showed the greatest increase in tolerance."

In discussing their findings, Maynard *et al*. wrote that they were "consistent with previous studies documenting an increase in thermal tolerance between bleaching events (1982-1983 vs. 1997-1998) in the Galapagos Islands (Podesta and Glynn, 2001), the Gulf of Chiriqi, the Gulf of Panama (Glynn *et al*., 2001), and on Costa Rican reefs (Jimenez *et al*., 2001)," and they report that "Dunne and Brown (2001) found similar results to [theirs] in the Andaman Sea, in that bleaching severity was far reduced in 1998 compared to 1995 despite sea-temperature and light conditions being more conducive to widespread bleaching in 1998."

As for the significance of these and other observations, the Australian scientists stated that "the range in bleaching tolerances among corals inhabiting different thermal realms suggests that at least some coral symbioses have the ability to adapt to much higher temperatures than they currently experience in the central Great Barrier Reef," citing in this regard, the work of Coles and Brown (2003) and Riegl (1999, 2002). In addition, they note that "even within reefs there is a significant variability in bleaching susceptibility for many species (Edmunds, 1994; Marshall and Baird, 2000), suggesting some potential for a shift in thermal tolerance based on selective mortality (Glynn *et al*., 2001; Jimenez *et al*., 2001) and local population growth alone." Above and beyond that, they said their results suggest "a capacity for acclimatization or adaptation."

In concluding their paper, Maynard *et al*. wrote "there is emerging evidence of high genetic structure within coral species (Ayre and Hughes, 2004)," which suggests, in their words, that "the capacity for adaptation could be greater than is currently recognized." Indeed, as stated by Skelly *et al*. (2007), "on the basis of the present knowledge of genetic variation in performance traits and species' capacity for evolutionary response, it can be concluded that evolutionary change will often occur concomitantly with changes in climate as well as other environmental changes." Consequently, it can be appreciated that if global warming were to start up again (it has been in abeyance for about the last decade), it need not spell *the end* for earth's highly adaptable corals.

But how is it done? How do corals adjust to rising temperatures?

One adaptive mechanism that corals have developed to survive the thermal stress of high water temperature is to replace the zooxanthellae expelled by the coral host during a stress-induced bleaching episode by one or more varieties of zooxanthellae that are more heat tolerant. Another mechanism is to produce heat shock proteins that help repair heat-damaged constituents of their bodies (Black *et al*., 1995; Hayes and King, 1995; Fang *et al*., 1997). Sharp *et al*. (1997), for example, demonstrated that sub-tidal specimens of *Goniopora djiboutiensis* typically have much lower constitutive levels of a 70-kD heat shock protein than do their intertidal con-specifics; and they have shown that corals transplanted from sub-tidal to intertidal locations (where temperature extremes are greater and more common) typically increase their expression of this heat shock protein.

Similar results have been reported by Roberts *et al*. (1997) in field work with *Mytilus californianus*. In addition, Gates and Edmunds (1999) observed an increase in the 70-kD heat shock protein after six hours of exposure of *Montastraea franksi* to a 2-3°C increase in temperature, which was followed by another heat shock protein increase at the 48-hour point of exposure to elevated water temperature. And in their case, they wrote that the first of these protein increases "provides strong evidence that changes in protein turnover during the initial exposure to elevated temperature provides this coral with the biological flexibility to acclimatize to the elevation in sea water temperature," and that the second increase "indicates another shift in protein turnover perhaps associated with an attempt to acclimatize to the more chronic level of temperature stress."

So how resilient are earth's corals to rising water temperatures? No one knows for sure; but they've been around a very long time, during which earth's climatic conditions have changed dramatically, from cold to warm and back again, over multiple glacial and interglacial cycles. And in this regard, we see no reason why history cannot be expected to successfully repeat itself, even as the current interglacial experiences its "last hurrah."

***With respect to corals finding salvation via symbiont shuffling***, we note that although once considered to be members of the single species *Symbiodinium microadriacticum*, the tiny zooxanthellae that reside within membrane-bound vacuoles in the cells of host corals are highly diverse, comprising perhaps hundreds of species, of which several are typically found in each species of coral (Trench, 1979; Rowan and Powers, 1991; Rowan *et al*., 1997). Consequently, a particularly ingenious way by which almost any adaptive response to any type of environmental stress may be enhanced in the face of the occurrence of that stress would be for corals to replace the zooxanthellae they expel during a stress-induced bleaching episode by one or more varieties of zooxanthellae that are more tolerant of the stress that caused the bleaching.

Rowan *et al*. (1997) suggested that this phenomenon occurs in many of the most successful Caribbean corals that act as hosts to dynamic multi-species communities of symbionts, and that "coral communities may adjust to climate change by recombining their existing host and symbiont genetic diversities," thereby reducing the amount of damage that might subsequently be expected from another occurrence of anomalously high temperatures. In fact, Buddemeier and Fautin (1993) suggested that coral bleaching is actually an adaptive strategy for "shuffling" symbiont genotypes to create associations better adapted to new environmental conditions that challenge the *status quo* of reef communities.

Saying essentially the same thing in yet another way, Kinzie (1999) suggested that coral bleaching "might not be simply a breakdown of a stable relationship that serves as a symptom of degenerating environmental conditions," but that it "may be part of a mutualistic relationship on a larger temporal scale, wherein the identity of algal symbionts changes in response to a changing environment." This process of replacing less-stress-tolerant symbionts by more-stress-tolerant symbionts is also supported by the investigations of Rowan and Knowlton (1995) and Gates and Edmunds (1999); and the strategy seems to be working, for as Glynn (1996) observed, "despite recent incidences of severe coral reef bleaching and mortality, no species extinctions have yet been documented."

These observations accord well with the experimental findings of Fagoonee *et al*. (1999), who suggested that coral bleaching events "may be frequent and part of the expected cycle." Gates and Edmunds (1999) additionally reported that "several of the prerequisites required to support this hypothesis have now been met," and after describing them in some detail, they concluded "there is no doubt that the existence of multiple *Symbiodinium* clades, each potentially exhibiting a different physiological optima, provide corals with the opportunity to attain an expanded range of physiological flexibility which will ultimately be reflected in their response to environmental challenge." In fact, this phenomenon may provide the explanation for the paradox posed by Pandolfi (1999), i.e., that "a large percentage of living coral reefs have been degraded, yet there are no known extinctions of any modern coral reef species." Surely, this result is exactly what would be expected if periods of stress lead to the acquisition of more-stress-resistant zooxanthellae by coral hosts.

In spite of this early raft of compelling evidence for the phenomenon, Hoegh-Guldberg (1999) challenged the symbiont shuffling hypothesis on the basis that the stress-induced replacement of less-stress-tolerant varieties of zooxanthellae by more-stress-tolerant varieties "has never been observed." Although true at the time it was written, a subsequent series of studies produced the long-sought proof that transformed the hypothesis into fact.

Baker (2001) conducted an experiment in which he transplanted corals of different combinations of host and algal symbiont from shallow (2-4 m) to deep (20-23 m) depths and vice versa. After eight weeks nearly half of the corals transplanted from deep to shallow depths had experienced partial or severe bleaching, whereas none of the corals transplanted from shallow to deep depths bleached. After one year, however, and despite even more bleaching at shallow depths, upward transplants showed no mortality, but nearly 20 percent of *downward* transplants had died. Why?

The symbiont shuffling hypothesis explains it this way. The corals that were transplanted upwards were presumed to have adjusted their algal symbiont distributions, via bleaching, to favor more tolerant species, whereas the corals transplanted downward were assumed to not have done so, since they did not bleach. Baker suggested that these findings "support the view that coral bleaching can promote rapid response to environmental change by facilitating compensatory change in algal symbiont communities." Without bleaching, as he continued, "suboptimal host-symbiont combinations persist, leading eventually to significant host mortality." Consequently, Baker proposed that coral bleaching may "ultimately help reef corals to survive." And it may also explain why reefs, though depicted by climate alarmists as environmentally fragile, have survived the large environmental changes experienced throughout geologic time.

One year later Adjeroud *et al*. (2002) provided additional evidence for the veracity of the symbiont shuffling hypothesis as a result of their assessment of the interannual variability of coral cover on the outer slope of the Tiahura sector of Moorea Island, French Polynesia, between 1991 and 1997, which focused on the impacts of bleaching events caused by thermal stress when sea surface temperatures rose above 29.2°C. Soon after the start of their study, they observed a severe decline in coral cover following a bleaching event that began in March 1991, which was followed by another bleaching event in March 1994. However, they report that the latter bleaching event "did not have an important impact on coral cover," even though "the proportion of bleached colonies ... and the order of susceptibility of coral genera were similar in 1991 and 1994 (Gleason, 1993; Hoegh-Guldberg and Salvat, 1995)." In fact, they report that between 1991 and 1992 total coral cover dropped from 51.0% to 24.2%, but that "coral cover did not decrease between 1994 and 1995."

In discussing these observations, Adjeroud *et al*. (2002) wrote that a "possible explanation of the low mortality following the bleaching event in 1994 is that most of the colonies in place in 1994 were those that survived the 1991 event or were young recruits derived from those colonies," noting that "one may assume that these coral colonies and/or their endosymbiotic zooxanthellae were phenotypically and possibly genotypically resistant to bleaching events," which is exactly what the symbiont shuffling hypothesis would predict. Hence, they further stated that "this result demonstrates the importance of understanding the ecological history of reefs (i.e., the chronology of disturbances) in interpreting the specific impacts of a particular disturbance."

In the same year, Brown *et al*. (2002) published the results of an even longer 17-year study of coral reef flats at Ko Phuket, Thailand, in which they assessed coral reef changes in response to elevated water temperatures in 1991, 1995, 1997 and 1998. As they described it, "many corals bleached during elevated sea temperatures in May 1991 and 1995, but no bleaching was recorded in 1997." In addition, they report that "in May 1998 very limited bleaching occurred although sea temperatures were higher than previous events in 1991 and 1995 (Dunne and Brown, 2001)." What is more, when bleaching did take place, they say "it led only to partial mortality in coral colonies, with most corals recovering their color within 3-5 months of initial paling," once again providing real-world evidence for what is predicted by the symbiont shuffling hypothesis.

The following year, Riegl (2003) reviewed what is known about the responses of real-world coral reefs to high-temperature-induced bleaching, focusing primarily on the Arabian Gulf, which experienced high-frequency recurrences of temperature-related bleaching in 1996, 1998, and 2002. In response to these high-temperature events, Riegl noted that *Acropora* -- which during the 1996 and 1998 events always bleached first and suffered heaviest mortality -- bleached less than all other corals in 2002 at Sir Abu Nuair (an offshore island of the United Arab Emirates) and actually *recovered* along the coast of Dubai between Jebel Ali and Ras Hasyan. As a result, Riegl wrote that "the unexpected resistance of Sir Abu Nuair *Acropora* to bleaching in 2002 might indicate support for the hypothesis of Baker (2001) and Baker *et al*. (2002) that the symbiont communities on recovering reefs of the future might indeed be more resistant to subsequent bleaching," and that "the Arabian Gulf perhaps provides us with some aspects which might be described as a 'glimpse into the future,' with ... hopes for at least some level of coral/zooxanthellae adaptation."

In a contemporaneous paper, Kumaraguru *et al*. (2003) reported the results of a study wherein they assessed the degree of damage inflicted upon a number of coral reefs within Palk Bay (located on the southeast coast of India just north of the Gulf of Mannar) by a major warming event that produced monthly mean sea surface temperatures of 29.8 to 32.1°C from April through June of 2002, after which they assessed the degree of recovery of the reefs. They determined that "a minimum of at least 50% and a maximum of 60% bleaching were noticed among the six different sites monitored." However, as they continued, "the corals started to recover quickly in August 2002 and as much as 52% recovery could be noticed." By comparison, they noted that "recovery of corals after the 1998 bleaching phenomenon in the Gulf of Mannar was very slow, taking as much as one year to achieve similar recovery," i.e., to achieve what was experienced in one *month* in 2002. Consequently, in words descriptive of the concept of symbiont shuffling, the Indian scientists said that "the process of natural selection is in operation, with the growth of new coral colonies, and any disturbance in the system is only temporary." Consequently, as they concluded in the final sentence of their paper, "the corals will resurge under the sea."

Although these several 2001-2003 findings were very significant, a quartet of papers published in 2004 -- two in *Nature* and two in *Science* -- finally "sealed the deal" with respect to establishing the symbiont shuffling hypothesis as a fact of life, and an ubiquitous one at that.

Writing in *Nature*, Rowan (2004) described how he measured the photosynthetic responses of two zooxanthellae genotypes or clades -- *Symbiodinium C* and *Symbiodinium D* -- to increasing water temperature, finding that the photosynthetic prowess of the former decreased at higher temperatures while that of the latter increased. He then noted that "adaptation to higher temperature in *Symbiodinium D* can explain why *Pocillopora* spp. hosting them resist warm-water bleaching whereas corals hosting *Symbiodinium C* do not," and that "it can also explain why *Pocillopora* spp. living in frequently warm habitats host only *Symbiodinium D*, and, perhaps, why those living in cooler habitats predominantly host *Symbiodinium C*," concluding that these observations "indicate that symbiosis recombination may be one mechanism by which corals adapt, in part, to global warming."

Clinching the concept was the study of Baker *et al*. (2004), who "undertook molecular surveys of *Symbiodinium* in shallow scleractinian corals from five locations in the Indo-Pacific that had been differently affected by the 1997-98 El Niño-Southern Oscillation (ENSO) bleaching event." Along the coasts of Panama, they studied ecologically dominant corals in the genus *Pocillopora* before, during and after ENSO bleaching, finding that "colonies containing *Symbiodinium* in clade D were already common (43%) in 1995 and were unaffected by bleaching in 1997, while colonies containing clade C bleached severely." Even more importantly, they found that "by 2001, colonies containing clade D had become dominant (63%) on these reefs."

After describing similar observations in the Persian (Arabian) Gulf and the western Indian Ocean along the coast of Kenya, Baker *et al*. summarized their results by stating they indicated that "corals containing thermally tolerant *Symbiodinium* in clade D are more abundant on reefs after episodes of severe bleaching and mortality, and that surviving coral symbioses on these reefs more closely resemble those found in high-temperature environments," where clade D predominates. Hence, they concluded their landmark paper by noting that the symbiont changes they observed "are a common feature of severe bleaching and mortality events," and by predicting that "these adaptive shifts will increase the resistance of these recovering reefs to future bleaching."

Meanwhile, over at *Science*, Lewis and Coffroth (2004) described a controlled experiment in which they induced bleaching in a Caribbean octocoral (*Briareum* sp.) and then exposed it to exogenous *Symbiodinium* sp. containing rare variants of the chloroplast 23S ribosomal DNA (rDNA) domain V region (cp23S-genotype), after which they documented the symbionts' repopulation of the coral, whose symbiont density had been reduced to less than 1% of its original level by the bleaching. Also, in a somewhat analogous study, Little *et al*. (2004) described how they investigated the acquisition of symbionts by juvenile *Acropora tenuis* corals growing on tiles they attached to different portions of reef at Nelly Bay, Magnetic Island (an inshore reef in the central section of Australia's Great Barrier Reef).

Lewis and Coffroth wrote that the results of their study showed that "the repopulation of the symbiont community involved residual populations within *Briareum* sp., as well as symbionts from the surrounding water," noting that "recovery of coral-algal symbioses after a bleaching event is not solely dependent on the *Symbiodinium* complement initially acquired early in the host's ontogeny," and writing that "these symbioses also have the flexibility to establish new associations with symbionts from an environmental pool." Similarly, Little *et al*. reported that "initial uptake of zooxanthellae by juvenile corals during natural infection is nonspecific (a potentially adaptive trait)," and that "the association is flexible and characterized by a change in (dominant) zooxanthella strains over time."

Lewis and Coffroth thus concluded that "the ability of octocorals to reestablish symbiont populations from multiple sources provides a mechanism for resilience in the face of environmental change," while Little *et al*. concluded that the "symbiont shuffling" that was observed by both groups "represents a mechanism for rapid acclimatization of the holobiont to environmental change." Consequently, the results of both studies demonstrated the reality of a phenomenon whereby corals may indeed "grasp victory from the jaws of death" in the aftermath of a severe bleaching episode, which is also implied by the *fact* -- cited by Lewis and Coffroth -- that "corals have survived global changes since the first scleractinian coral-algal symbioses appeared during the Triassic, 225 million years ago."

In the years that followed, numerous other studies further elevated the symbiont shuffling hypothesis to a full-fledged *theory*, if not a proven *fact*.

Chen *et al*. (2005), for example, studied the seasonal dynamics of *Symbiodinium* algal phylotypes via bimonthly sampling over an 18-month period of *Acropora palifera* coral on a reef flat at Tantzel Bay, Kenting National Park, southern Taiwan, in an attempt to detect real-world symbiont shuffling. Results of their analysis revealed two levels of symbiont shuffling in host corals: (1) between *Symbiodinium* phylotypes C and D, and (2) among different variants within each phylotype. Furthermore, the most significant changes in symbiont composition occurred at times of significant increases in seawater temperature during late spring/early summer, perhaps as a consequence of enhanced stress experienced at that time, leading Chen *et al*. to say their work revealed "the first evidence that the symbiont community within coral colonies is dynamic ... involving changes in *Symbiodinium* phylotypes."

Contemporaneously, Van Oppen *et al*. (2005) sampled zooxanthellae from three common species of scleractinian corals at 17 sites along a latitudinal and cross-shelf gradient in the central and southern sections of the Great Barrier Reef some four to five months after the major bleaching event of 2002, recording the health status of each colony at the time of its collection and identifying its zooxanthella genotypes, of which there were eight distinct clades (A-H) with clade D being the most heat-tolerant. Results of the analysis revealed that "there were no simple correlations between symbiont types and either the level of bleaching of individual colonies or indicators of heat stress at individual sites." However, they said "there was a very high post-bleaching abundance of the heat tolerant symbiont type D in one coral population at the most heat-stressed site."

With respect to the post-bleaching abundance of clade D zooxanthellae at the high heat-stress site, the Australian researchers said they suspected it was due to "a proliferation in the absolute abundance of clade D within existing colonies that were previously dominated by clade C zooxanthellae," and that in the four to five months before sampling them, "mixed C-D colonies that had bleached but survived may have shifted (shuffling) from C-dominance to D-dominance, and/or C-dominated colonies may have suffered higher mortality during the 2002 bleaching event" and subsequently been repopulated by a predominance of clade D genotypes.

Also working within Australia's Great Barrier Reef system, Berkelmans and van Oppen (2006) investigated the thermal acclimatization potential of *Acropora millepora* corals to rising temperatures through transplantation and experimental manipulation, finding that the adult corals "are capable of acquiring increased thermal tolerance and that the increased tolerance is a direct result of a change in the symbiont type dominating their tissues from *Symbiodinium* type C to D." Then, two years later, working with an expanded group of scientists (Jones *et al*., 2008), the same two researchers reported similar findings following the occurrence of a natural bleaching event.

*Prior* to this bleaching event, Jones *et al*. reported that "*A. millepora* at Miall reef associated predominantly with *Symbiodinium* type C2 (93.5%) and to a much lesser extent with *Symbiodinium* clade D (3.5%) or mixtures of C2 and D (3.0%)." *During* the bleaching event, they further reported that "the relative difference in bleaching susceptibility between corals predominated by C2 and D was clearly evident, with the former bleaching white and the latter normally pigmented," while corals harboring a mix of *Symbiodinium* C2 and D were "mostly pale in appearance." Then, three months *after* the bleaching event, they observed "a major shift to thermally tolerant type D and C1 symbiont communities ... in the surviving colonies," the latter of which types had not been detected in any of the corals prior to bleaching; and they reported that "this shift resulted partly from a change of symbionts within coral colonies that survived the bleaching event (42%) and partly from selective mortality of the more bleaching-sensitive C2-predominant colonies (37%)." In addition, they reported that all of the colonies that harbored low levels of D-type symbionts prior to the bleaching event survived and changed from clade C2 to D predominance.

In conclusion, Jones *et al*. wrote that "as a direct result of the shift in symbiont community, the Miall Island *A. millepora* population is likely to have become more thermo-tolerant," as they noted that "a shift from bleaching-sensitive type C2 to clade D increased the thermal tolerance of this species by 1-1.5°C." Therefore, they said their results "strongly support the reinterpreted adaptive bleaching hypothesis of Buddemeier *et al*. (2004), which postulates that a continuum of changing environmental states stimulates the loss of bleaching-sensitive symbionts in favor of symbionts that make the new holobiont more thermally tolerant." In fact, they said their observations "provide the first extensive colony-specific documentation and quantification of temporal symbiont community change in the field in response to temperature stress, suggesting a population-wide acclimatization to increased water temperature," a finding that bodes especially well for earth's corals in a warming climate.

In a much larger geographical study, Lien *et al*. (2007) examined the symbiont diversity in a scleractinian coral, *Oulastrea crispata*, throughout its entire latitudinal distribution range in the West Pacific, i.e., from tropical peninsular Thailand (<10°N) to high-latitudinal outlying coral communities in Japan (>35°N), convincingly demonstrating that "phylotype D is the dominant *Symbiodinium* in scleractinian corals throughout tropical reefs and marginal outlying non-reefal coral communities." In addition, they learned that this particular symbiont clade "favors 'marginal habitats' where other symbionts are poorly suited to the stresses, such as irradiance, temperature fluctuations, sedimentation, etc." And being a major component of the symbiont repertoire of most scleractinian corals in most places, the apparent near-universal presence of *Symbiodinium* phylotype D thus provides, according to Lien *et al*., "a flexible means for corals to routinely cope with environmental heterogeneities and survive the consequences (e.g., recover from coral bleaching)."

At about the same time, Mieog *et al*. (2007) utilized a newly developed real-time *polymerase chain reaction* assay -- which they said "is able to detect *Symbiodinium* clades C and D with >100-fold higher sensitivity compared to conventional techniques" -- to test 82 colonies of four common scleractinian corals (*Acropora millepora*, *Acropora tenuis*, *Stylophora pistillata* and *Turbinaria reniformis*) from eleven different locations on Australia's Great Barrier Reef for evidence of the presence of background *Symbiodinium* clades. Results of this analysis showed that "ninety-three percent of the colonies tested were dominated by clade C and 76% of these had a D background," the latter of which symbionts, in their words, "are amongst the most thermo-tolerant types known to date," being found "on reefs that chronically experience unusually high temperatures or that have recently been impacted by bleaching events, suggesting that temperature stress can favor clade D." Consequently, Mieog *et al*. concluded that the clade D symbiont backgrounds detected in their study can potentially act as *safety-parachutes*, "allowing corals to become more thermo-tolerant through symbiont shuffling as seawater temperatures rise due to global warming." And as a result, they suggested that symbiont shuffling is likely to play a role in the way earth's "corals cope with global warming conditions," leading to new competitive hierarchies and, ultimately, "the coral community assemblages of the future."

In spite of the hope symbiont shuffling provides -- that the world's corals will indeed be able to successfully cope with the possibility of future global warming, be it anthropogenic-induced or natural -- some researchers have claimed that few coral symbioses host more than one type of symbiont, which has led alarmists to argue that symbiont shuffling is not an option for most coral species to survive the coming thermal onslaught of global warming. But is this claim correct? Not according to the results of Apprill and Gates (2007).

Working with samples of the widely distributed massive corals *Porites lobata* and *Porites lutea* -- which they collected from Kaneohe Bay, Hawaii -- Apprill and Gates compared the identity and diversity of *Symbiodinium* symbiont types obtained using cloning and sequencing of *internal transcribed spacer region 2* (ITS2) with that obtained using the more commonly applied downstream analytical techniques of *denaturing gradient gel electrophoresis* (DGGE). The results of their analysis revealed "a total of 11 ITS2 types in *Porites lobata* and 17 in *Porites lutea* with individual colonies hosting from one to six and three to eight ITS2 types for *P. lobata* and *P. lutea*, respectively." In addition, the two authors reported that "of the clones examined, 93% of the *P. lobata* and 83% of the *P. lutea* sequences are not listed in GenBank," noting that they resolved "sixfold to eightfold greater diversity per coral species than previously reported."

In a "perspective" that accompanied Apprill and Gates' important paper, van Oppen (2007) wrote that "the current perception of coral-inhabiting symbiont diversity at nuclear ribosomal DNA is shown [by Apprill and Gates] to be a significant underestimate of the wide diversity that in fact exists." These findings, in her words, "have potentially far-reaching consequences in terms of our understanding of *Symbiodinium* diversity, host-symbiont specificity and the potential of corals to acclimatize to environmental perturbations through changes in the composition of their algal endosymbiont community," which assessment, it is almost unnecessary to say, suggests a *far-greater-than-previously-believed* ability to do just that in response to any further global warming that might occur.

In a contemporaneous study, Baird *et al*. (2007) also discounted the argument that symbiont shuffling is not an option for most coral species, because, as they indicated, it is the *sub*-clade that must be considered within this context, citing studies that indicate "there are both heat tolerant and heat susceptible sub-clades within both clades C and D *Symbiodinium*." Thus, the more relevant question becomes: How many coral species can host more than one *sub*-clade? The answer, of course, is that most, if not all of them, likely do; for Baird *et al*. indicated that "biogeographical data suggest that when species need to respond to novel environments, they have the flexibility to do so."

So how and when might such sub-clade changes occur? Although most prior research in this area has been on adult colonies switching symbionts in response to warming-induced bleaching episodes, Baird *et al*. suggested that "change is more likely to occur between generations," for initial coral infection typically occurs in larvae or early juveniles, which are much more flexible than adults. In this regard, for example, they noted that "juveniles of *Acropora tenuis* regularly harbor mixed assemblages of symbionts, whereas adults of the species almost invariably host a single clade," and they indicated that larvae of *Fungia scutaria* ingest symbionts from multiple hosts, although they generally harbor but one symbiont as adults.

Because of these facts, the Australian researchers concluded there is no need for an acute disturbance, such as bleaching, to induce clade or sub-clade change. Instead, if it happens that ocean temperatures rise to new heights in the future, they foresee juveniles naturally hosting more heat-tolerant sub-clades and maintaining them into adulthood.

In a further assessment of the size of the symbiont diversity reservoir, especially among juvenile coral species, Pochon *et al*. (2007) collected more than 1,000 soritid specimens over a depth of

40 meters on a single reef at "Gun Beach" on the island of Guam, Micronesia, throughout the course of an entire year, which they then studied by means of molecular techniques to identify unique *internal transcribed spacer-2* (ITS-2) types of *ribosomal* DNA (rDNA), in a project self-described as "the most targeted and exhaustive sampling effort ever undertaken for any group of *Symbiodinium*-bearing hosts."

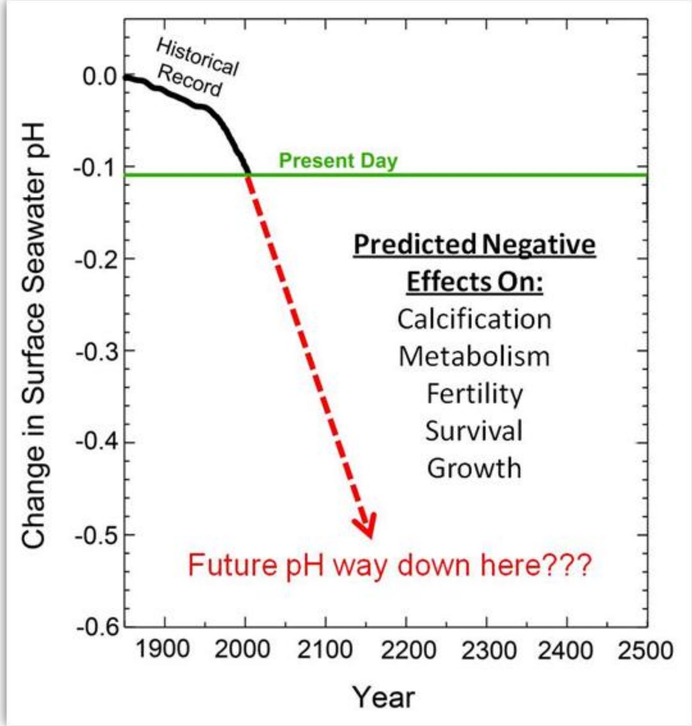
Throughout the course of their analysis, Pochon *et al*. identified 61 unique symbiont types in only three soritid host genera, making the Guam *Symbiodinium* assemblage the most diverse derived to date from a single reef. In addition, they reported that "the majority of mixed genotypes observed during this survey were usually harbored by the smallest hosts." As a result, they speculated that "juvenile foraminifera may be better able to switch or shuffle heterogeneous symbiont communities than adults," so that as juveniles grow, "their symbiont communities become 'optimized' for the prevailing environmental conditions," suggesting that this phenomenon "may be a key element in the continued evolutionary success of these protists in coral reef ecosystems worldwide."

In support of the above statement, we additionally cite the work of Mumby (1999), who analyzed the population dynamics of juvenile corals in Belize, both prior to, and after, a massive coral bleaching event in 1998. Although 70 to 90% of adult coral colonies were severely bleached during the event, only 25% of coral *recruits* exhibited signs of bleaching. What is more, one month after the event, it was concluded that "net bleaching-induced mortality of coral recruits ... was insignificant," demonstrating the ability of juvenile corals to successfully weather such bleaching events.

In light of these several observations, it is logical to believe that earth's corals will be able to successfully cope with the possibility of further increases in water temperatures, be they anthropogenic-induced or natural. Corals have survived such warmth -- *and worse* -- many times in the past, including the Medieval Warm Period, the Roman Warm Period, and the Holocene Optimum, as well as throughout numerous similar periods during a number of prior interglacial periods; and there is no reason to believe they cannot do it again, if the need arises.

## 10. Marine Life Dissolving Away in Acidified Oceans

***The claim:*** *Rising atmospheric $CO_2$ concentrations are lowering seawater pH, resulting in reduced calcification, metabolism, fertility, growth and survival of many marine species.*



Another dire prediction that has raised its ugly head in the climate-alarmist-inspired campaign to force reductions in anthropogenic $CO_2$ emissions is the contention that continued increases in the air's $CO_2$ content will lead to ever more carbon dioxide dissolving in the surface waters of the world's oceans and lowering their pH values, which phenomenon is claimed to make it more difficult for biological calcification to occur in marine organisms. It has been estimated, for example, that the globe's seawater has been *acidified* (actually made *less basic*) by about 0.1 pH unit relative to what it was in pre-industrial times; and model calculations imply there could be an additional drop somewhere in the neighborhood of between 0.3 to 0.7 pH unit by the year 2300. And a pH reduction of this magnitude is viewed by many as a cause for great concern, as it has been postulated to harm calcifying marine life such as corals, not only by reducing their calcification rates, but by negatively impacting their metabolism, fertility, growth and survival.

This *ocean acidification hypothesis* has gained great momentum in recent years, because it offers an independent reason for regulating fossil fuel emissions in addition to that provided by concerns about global warming; for even if the models employed by climate alarmists are proven to be wrong with respect to their predictions of unprecedented temperature increases -- as well as all the catastrophic consequences associated with that warming -- those who desire to regulate $CO_2$ emissions now have a *fall-back position*, which contends that no matter what happens to the planet's climate, the nations of the earth must still reduce their $CO_2$ emissions because of their direct negative impacts on calcifying marine organisms.

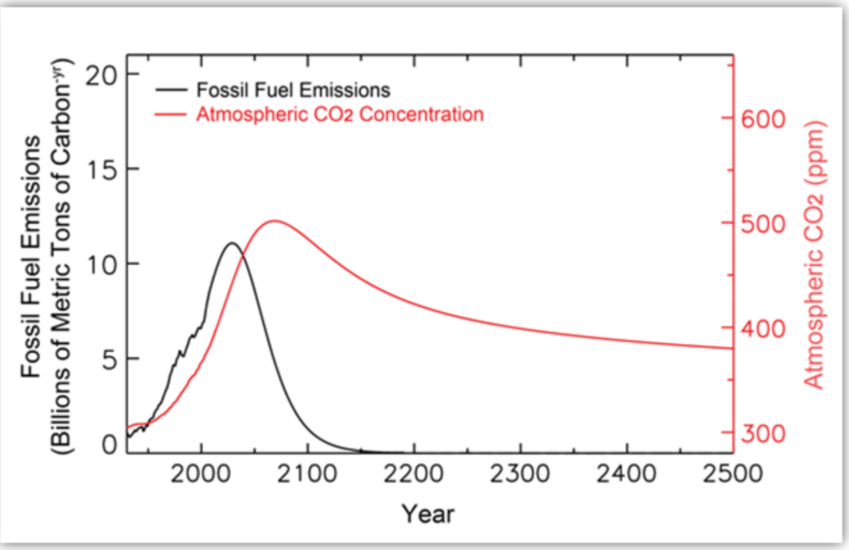
Over time, the rhetoric of these *acidification alarmists* has risen tremendously, as illustrated in a couple of quotes from a short, 21-minute film released in late 2009 by the National Resources Defense Council (NRDC) entitled *Acid Test: The Global Challenge of Ocean Acidification* (Natural Resources Defense Council, 2009). With Sigourney Weaver as its narrator, the film highlights the alarmist views of a handful of scientists, a commercial fisherman and two NRDC employees, as they discuss what they claim is a *megadisaster-in-the-making* for earth's marine life.

The villain of the story is *industrial man*, who has "altered the course of nature" by releasing large quantities of carbon dioxide into the air via the burning of coal, gas and oil. According to Ken Calderia, a professor at Stanford University who appears in the film, "by mid-century, if we continue emitting carbon dioxide the way we have been, entire vast areas of both the Southern Ocean and the Arctic Ocean will be so corrosive that it will cause sea shells to dissolve," leading him to conclude that "we're really in the last decades of coral reefs on this planet for at least the next, let's say million plus years, unless we do something very soon to reduce $CO_2$ emissions ... We're moving from a world of rich biological diversity into essentially a world of weeds."

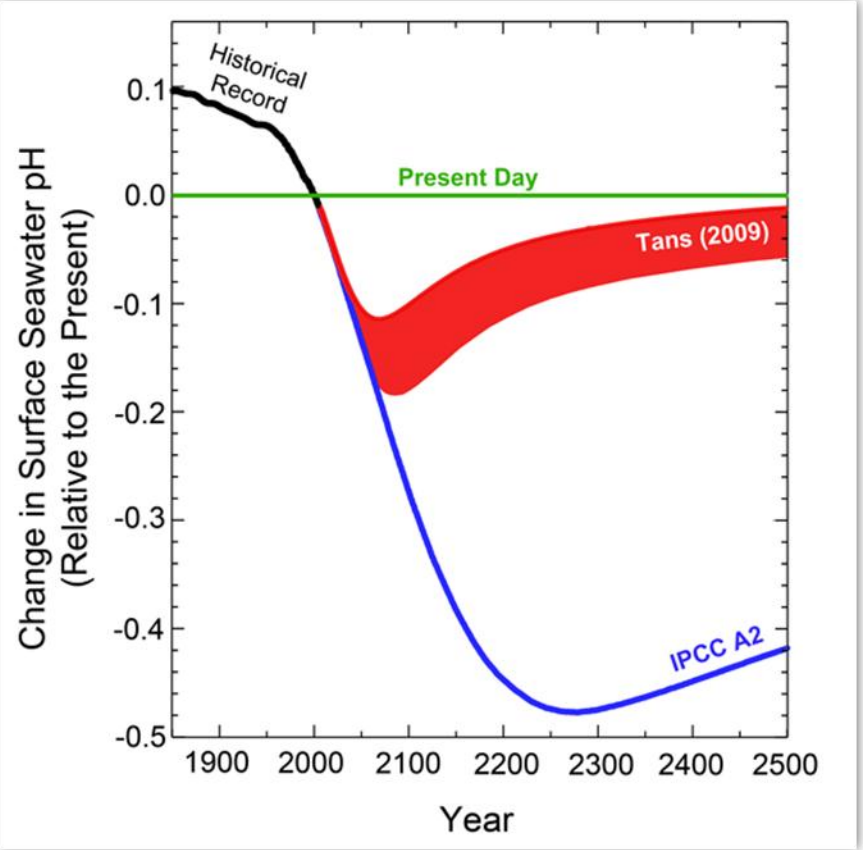
Not to be outdone, Dr. Ove Hoegh-Guldberg of The University of Queensland says:

> "We know that coral reefs are particularly sensitive to ocean acidification. And the reason for that is that corals are unable to form their skeletons as quickly as they used to, and reefs are starting to crumble and disappear. We may lose those ecosystems within 20 or 30 years. ... We've got the last decade in which we can do something about this problem. But it is very, very clear that if we don't start to deal with it right now, with very, very stern cuts to emissions, we are going to condemn oceans to an extremely uncertain future."

The chemistry aspect of the ocean acidification hypothesis is rather straightforward, but it is not as solid as many make it out to be; and a number of respected researchers have published papers demonstrating that the drop in oceanic pH will not be nearly as great as the IPCC and others predict it will be, nor that it will be as harmful as they claim it will be. Consider, for example, the figure below, which shows historical and projected fossil fuel $CO_2$ emissions and atmospheric $CO_2$ concentrations out to the year 2500, as calculated by NOAA's Pieter Tans (2009). As can be seen there, his analysis indicates that the air's $CO_2$ concentration will peak well before 2100, and at only 500 ppm compared to the 800 ppm value predicted in one of the IPCC's scenarios. And it is also worth noting that by the time the year 2500 rolls around, the atmosphere's $CO_2$ concentration actually drops back down to about what it is today.



When these emissions estimates are transformed into reductions of oceanic pH, it can readily be seen in the following figure that Tans' projected pH change at 2100 is far less than that of the IPCC. And Tans' analysis indicates a pH recovery to values near those of today by the year 2500, clearly suggesting that things are *not* the way the world's climate alarmists make them out to be, especially when it comes to anthropogenic $CO_2$ emissions and their effects on the air's $CO_2$ content and oceanic pH values.

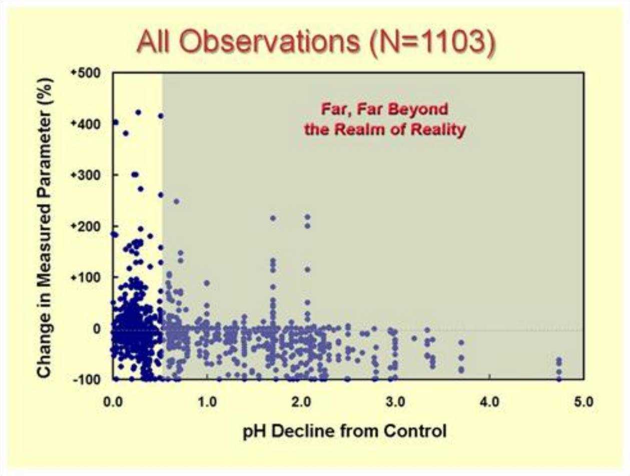


Another reason to not jump on the ocean acidification bandwagon is the fact that, with more $CO_2$ in the air, additional weathering of terrestrial carbonates likely will occur, which would increase delivery of $Ca^{2+}$ to the oceans and partially compensate for the $CO_2$-induced decrease in calcium carbonate saturation state. And as with all phenomena involving *living* organisms, the introduction of life into the acidification picture greatly complicates things, as several interrelated biological phenomena must also be considered; and when they are, it becomes much more difficult to draw such sweeping negative conclusions. In fact, as demonstrated in numerous reviews of the scientific literature, these considerations even suggest that the rising $CO_2$ content of earth's atmosphere may well be a *beneficial* phenomenon with many *positive* consequences (Idso, 2009; Idso and Singer, 2009).

As an example of this fact, the Center for the Study of Carbon Dioxide and Global Change (hereafter, the Center) maintains an online ocean acidification database that may be accessed free of charge at http://www.co2science.org/data/acidification/acidification.php, showcasing over 1100 experimental results on this topic from the peer-reviewed scientific literature (as of Jan 2011). Specifically, their Ocean Acidification Database is an ever-growing archive of the responses of various growth and developmental parameters of marine organisms immersed in seawater at or near today's oceanic pH level, as well as at levels lower than that of today. The measured parameters included in the database pertain to changes in calcification, metabolism, growth, fertility and survival; and the data are arranged by marine organism, accessible by selecting an organism's common or scientific name. In addition, the data have been grouped into similar *types* of organisms, such as bivalves, corals, fish, nematodes phytoplankton, etc.

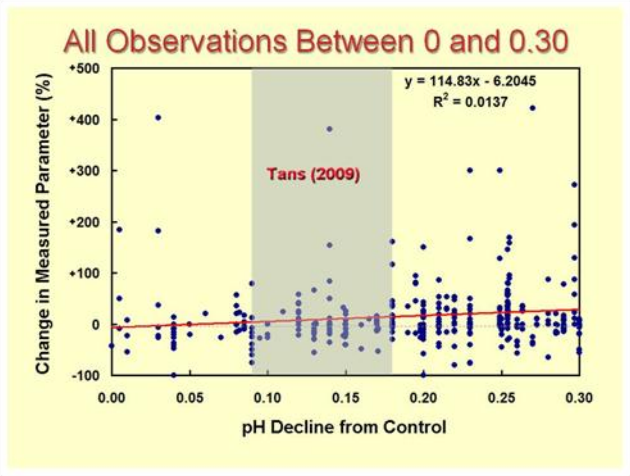
In considering the experimental results that are archived there, the mean response suggests that ocean acidification may indeed harm some organisms. However, it is critical to note that the vast majority of these experiments were performed under highly unrealistic oceanic pH conditions that will never occur, rendering their findings meaningless in terms of what might possibly happen in the real world. And as one examines the results over the more-likely-to-occur pH decline range, a vastly different picture begins to appear.

Returning to the Center's ocean acidification database, consider the figure below, which depicts the percentage changes in all five of the major life characteristics examined in the database (calcification, metabolism, growth, fertility and survival) as functions of the experimentally-orchestrated declines in seawater pH from the present, where each entry in the database is represented by its own individual point.



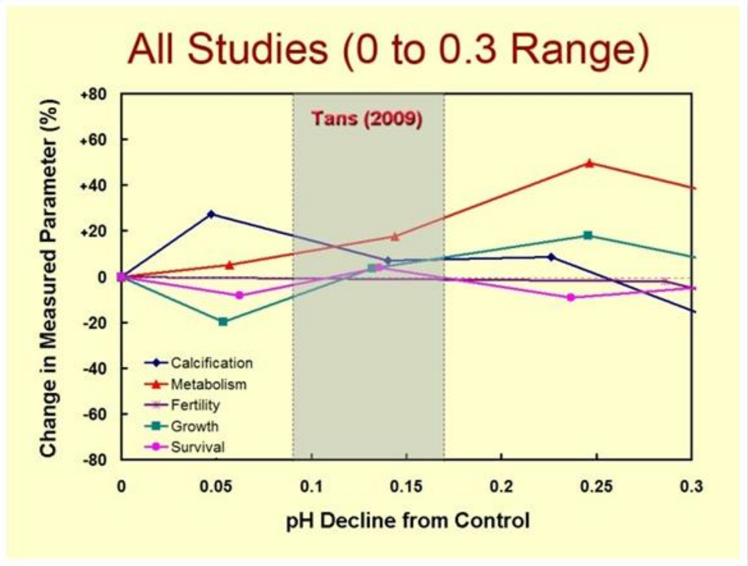
As is clearly evident, the data portray an *extremely* wide range of pH reduction values, the greatest of which corresponds to an increase in the air's $CO_2$ concentration *in excess of 100,000 ppm*, which is *orders of magnitude* greater than what anyone is expecting will ever occur. Thus, highlighted in grey are all data points that pertain to experiments conducted under pH conditions that are considered to be "far, far beyond the realm of reality."

The *low*-end boundary of the unrealistic highlighted region of pH reduction shown in the figure is 0.5, which represents the *high*-end or *maximum value* of most IPCC-based projections of $CO_2$-induced pH reduction, which occurs in the vicinity of AD 2300. Thus, there should be little argument – even from people who think ocean acidification is going to be a problem – in excluding all values beyond a pH decline of 0.5 when considering how acidification of the ocean might realistically affect earth's marine life.



In the next graph to the right, results of all experiments that employed a seawater pH decline that fell somewhere in the *still*-more-likely-to-occur range of 0.0 to 0.3 are plotted, where the latter value is the approximate IPCC-derived pH decline in the vicinity of AD 2100. Then, within this range, highlighted in grey, is the much smaller seawater pH reduction range that comes from the work of Tans (2009), who derived a maximum pH decline that could fall anywhere within an uncertainty range of 0.09 to 0.17 by about AD 2100, after which seawater pH begins its long-term recovery. The Tans prediction range has been emphasized in this manner because his analysis is considered to be more realistic than the analysis of the IPCC. Thus, data within the pH reduction range of 0.0 to 0.17 should be considered as being most characteristic of what might possibly occur in the real world, as time marches on and fossil fuel burning continues as per business as usual. And, interestingly enough – and even incorporating pH reduction data all the way out to 0.30 – the linear trend of all the data is actually *positive*, indicating an overall *beneficial* response of the totality of the five major life characteristics of marine sea life to ocean acidification, which result is vastly different from the tremendously *negative* results routinely predicted by the world's climate alarmists.

The next figure illustrates the *averages* of all responses to seawater acidification for all five of the life characteristics of the various marine organisms (calcification, metabolism, growth, fertility and survival) analyzed over the pH reduction ranges of 0 to 0.09 (from no change to the lower pH edge of the Tans estimate), 0.09 to 0.17 (Tans estimate), and 0.17 to 0.3 (from Tans to the IPCC). The most striking feature of this figure is the great preponderance of data located in positive territory, which suggests that, on the whole, marine organisms likely will not be harmed to any significant degree by the expected decline in oceanic pH. If anything, the results tend to suggest that the world's marine life may actually slightly *benefit* from the pH decline.



Clearly, the results depicted above suggest something very different from the theoretical model-based predictions of the climate alarmists who claim we are in "the last decades of coral reefs on this planet for at least the next ... million plus years, unless we do something very soon to reduce $CO_2$ emissions," or who declare that "reefs are starting to crumble and disappear," that "we may lose those ecosystems within 20 or 30 years," and that "we've got the last decade in which we can do something about this problem." Such scenarios are simply not supported by the vast bulk of pertinent experimental data.

Two other phenomena that suggest the predicted decline in oceanic pH will have little to no lasting negative effects on marine life are the abilities of essentially all forms of life to *adapt* and *evolve*. Of those experiments in the database that report the length of time the organisms were subjected to reduced pH levels, for example, the median value was only *four days*. And many of the experiments were conducted over periods of only a few *hours*, which is *much* too short a time for organisms to adapt or evolve to successfully cope with new environmental conditions. And when one allows for such phenomena -- as oceanic pH declines ever-so-slowly in the real world of nature -- the possibility of marine life experiencing a negative response to ocean acidification becomes even less likely (Idso, 2009).

## Concluding Commentary

*How much land can ten billion people spare for nature?* This provocative question was posed by Waggoner (1995) in the title of an essay designed to illuminate the dynamic tension that exists between the need for land to support the agricultural enterprises that sustain mankind and the need for land to support the natural ecosystems that sustain all other creatures. As noted by Huang *et al*. (2002), human populations "have encroached on almost all of the world's frontiers, leaving little new land that is cultivatable." And in consequence of humanity's ongoing usurpation of this most basic of natural resources, Raven (2002) has stated that "species-area relationships, taken worldwide in relation to habitat destruction, lead to projections of the loss of fully two-thirds of all species on earth by the end of this century," which problem has been noted and discussed by a number of other scientists as well, including Conway and Toenniessen (1999), Wallace (2000), Pretty *et al*. (2003), Foley *et al*. (2005), Green *et al*. (2005), Khush (2005), Hanjra and Qureshi (2010), Lele (2010) and Zhu *et al*. (2010)

If one were to pick the most significant problem currently facing the biosphere, this would probably be it: a single species of life, *Homo sapiens*, is on course to completely annihilate fully two-thirds of the ten million or so other species with which we share the planet within a mere ninety years, *simply by taking their land*. Global warming, by comparison, pales in significance, as its impact is nowhere near as severe, likely being nil or even positive. In addition, its root cause is highly debated; and actions to thwart it are much more difficult, if not impossible, to both define and implement. Furthermore, what many people believe to be the cause of global warming, i.e., anthropogenic $CO_2$ emissions, may actually be a powerful force for *preserving* land for nature.

So what parts of the world are likely to be hardest hit by this human land-eating machine? Tilman *et al*. (2001) stated that developed countries are expected to actually *withdraw* large areas of land from farming by the mid-point of this century, leaving developing countries to shoulder essentially all of the increasingly-heavy burden of feeding the still-expanding human population. In addition, they calculate that the loss of these countries' natural ecosystems to cropland and pasture will amount to about half of all potentially suitable remaining land, which "could lead to the loss of about a third of remaining tropical and temperate forests, savannas, and grasslands," along with the many unique species they support.

What can be done to alleviate this bleak situation? In another analysis of the problem, Tilman *et al*. (2002) introduced a few more facts before suggesting some solutions. They noted, for example, that by 2050 the human population of the globe was projected to be 50% larger than it was in 2000, and that global grain demand could well double, due to expected increases in per capita real income and dietary shifts toward a higher proportion of meat. Hence, they but stated the obvious when they concluded that "raising yields on existing farmland is essential for 'saving land for nature'."

So how is it to be done? Tilman *et al*. (2002) suggested a strategy that was built around three essential tasks: (1) increasing crop yield per unit of land area, (2) increasing crop yield per unit of nutrients applied, and (3) increasing crop yield per unit of water used.

With respect to the first of these requirements, Tilman *et al*. noted that in many parts of the world the historical rate of increase in crop yields was declining, as the genetic ceiling for maximal yield potential was being approached. This observation, as they put it, "highlights the need for efforts to steadily increase the yield potential ceiling." With respect to the second requirement, they noted that "without the use of synthetic fertilizers, world food production could not have increased at the rate it did [in the past], and more natural ecosystems would have been converted to agriculture." Hence, they said that the ultimate solution "will require significant increases in nutrient use efficiency, that is, in cereal production per unit of added nitrogen, phosphorus," and so forth. Finally, with respect to the third requirement, Tilman *et al*. noted that "water is regionally scarce," and that "many countries in a band from China through India and Pakistan, and the Middle East to North Africa either currently or will soon fail to have adequate water to maintain per capita food production from irrigated land." Increasing crop water use efficiency, therefore, is also a must.

Although the impending biological crisis and several important elements of its potential solution are thus well defined, Tilman *et al*. (2001) reported that "even the best available technologies, fully deployed, cannot prevent many of the forecasted problems." This was also the conclusion of Idso and Idso (2000), who -- although acknowledging that "expected advances in agricultural technology and expertise will significantly increase the food production potential of many countries and regions" -- noted that these advances "will not increase production fast enough to meet the demands of the even faster-growing human population of the planet."

Fortunately, we have a powerful ally in the ongoing rise in the air's $CO_2$ content that can provide what we can't. Since atmospheric $CO_2$ is the basic "food" of essentially all plants, the more of it there is in the air, the bigger and better they grow. For a nominal doubling of the air's $CO_2$ concentration, for example, the productivity of earth's herbaceous plants rises by 30 to 50% (Kimball, 1983; Idso and Idso, 1994), while the productivity of its woody plants rises by 50 to 75% or more (Saxe *et al*. 1998; Idso and Kimball, 2001). Hence, as the air's $CO_2$ content continues to rise, so too will the *land use efficiency* of the planet rise right along with it. In addition, atmospheric $CO_2$ enrichment typically increases plant *nutrient use efficiency* and plant *water use efficiency*. Thus, with respect to all three of the major needs noted by Tilman *et al*. (2002), increases in the air's $CO_2$ content pay huge dividends, helping to increase agricultural output *without the taking of new lands from nature*.

In light of these observations, it would appear that the extinction of two-thirds of all species of plants and animals on the face of the earth is essentially assured within the current century, if world agricultural output is not dramatically increased. This unfathomable consequence will occur simply because (1) we will need more land to produce what is required to sustain us and (2) in the absence of the full productivity increase required, we will simply take that land from nature to keep ourselves alive. It is also the conclusion of scientists who have studied this problem in depth that the needed increase in agricultural productivity is not possible to achieve, even with anticipated improvements in technology and expertise. With the help of the ongoing rise in the air's $CO_2$ content, however, Idso and Idso (2000) have shown that we should be able -- but just barely -- to meet our expanding food needs without "bringing down the curtain" on the world of nature in the process.

What Idso and Idso (2000) did, in this regard, was to develop and analyze a supply-and-demand scenario for food in the year 2050. Specifically, they identified the plants that at the start of the new century supplied 95% of the world's food needs and projected historical trends in the productivities of these crops 50 years into the future, after which they evaluated the growth-enhancing effects of atmospheric $CO_2$ enrichment on these plants and made similar yield projections based on the increase in atmospheric $CO_2$ concentration likely to have occurred by that future date. This exercise revealed that world population would likely be 51% greater in the year 2050 than it was in 1998, but that world food production would be only 37% greater if its enhanced productivity comes solely as a consequence of anticipated improvements in agricultural technology and expertise. However, they further determined that the consequent shortfall in farm production could be overcome -- but only just barely -- by the additional benefits anticipated to accrue from the *aerial fertilization effect* of the expected rise in the air's $CO_2$ content, assuming no Kyoto-style cutbacks in anthropogenic $CO_2$ emissions.

In light of the above, it is remarkable that many people actually characterize the ongoing rise in the air's $CO_2$ content as the greatest threat ever to be faced by the biosphere, or that the U.S. Environmental Protection Agency has actually classified $CO_2$ as *a dangerous air pollutant*. It is also disturbing to hear some people claim that we must do *now* whatever it takes, at whatever the price, to stop the upward trend in the concentration of this supposedly diabolical trace gas of the atmosphere. Representatives of the nations of the world, for example, meet regularly to consider the issue and talk of the moral imperative we have to do something about it. But as they tilt at this greatest of all environmental issues ever to be created by the mind of man -- for as demonstrated in the pages of this treatise it is by no means clear that it is, or ever will be, a bone fide threat in the real world -- they also weaken our chances of successfully dealing with a host of environmental problems that truly do vex us, such as the food security and extinction threats described above. And there are a great many more threats that are literally crying out for attention.

In the most recent World Energy Outlook Report (2010), produced by the International Energy Agency, for example, the following is reported:

> *"Despite rising energy use across the world, many poor households in developing countries still have no access to modern energy service. The numbers are striking: we estimate that 1.4 billion people – over 20% of the global population – lack access to electricity and that 2.7 billion people – some 40% of the global population – rely on the traditional use of biomass for cooking."*

Furthermore, in an editorial in *Science* entitled "Science and Sustainability," Leshner (2002) wrote that:

> *"One billion people throughout the world have no access to clean water. Two billion people have inadequate sanitation. Almost 1.5 billion people, mostly in cities in the developing world, are breathing air below the standards deemed acceptable by the World Health Organization."*

And things have not changed in the interim.

Where in the world are our priorities? We agonize over a future *hypothetical* scenario -- $CO_2$-induced global warming, which many knowledgeable scientists are convinced will *never occur* -- while billions of people suffer from a host of very *real* energy- and health-related hazards in the here-and-now.

Why would anyone in their right mind give the governments of the world a mandate to totally restructure human society to fight a *hypothetical* problem of vastly *greater* complexity than the very *real* and *clearly-identified* problems we currently face? Why should we not rather confront these genuine energy and health threats with all due haste and with every modern tool we have at our disposal?

Whatever the answers to these disturbing questions might be, it is clear that the current brouhaha over atmospheric $CO_2$ emissions and imagined catastrophic global warming has relegated the very *real* environmental and human concerns of our day to second- and third-class status. This situation is truly regrettable; for unless the more immediate and weighty matters we have mentioned are forthrightly addressed in a timely manner, whatever earth's climate may do in the future will be pretty much a moot point, especially for the millions of species of plants and animals that will have suffered extinction in the interim, as well as the millions of human beings who will have died prematurely as a consequence of environmental problems wholly unrelated to the air's $CO_2$ content *that could have been solved but weren't*.

We humans, as stewards of the earth, have got to get our priorities straight. We must do all that we possibly can, in order to *preserve nature* by helping to *feed humanity* and *raise living standards* the world over; and to do so successfully, we have got to let the air's $CO_2$ content maintain its natural upward course for many decades to come. This is the prudent path we must pursue.

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