

It is the best of Climates; It will be the worst of Climates?

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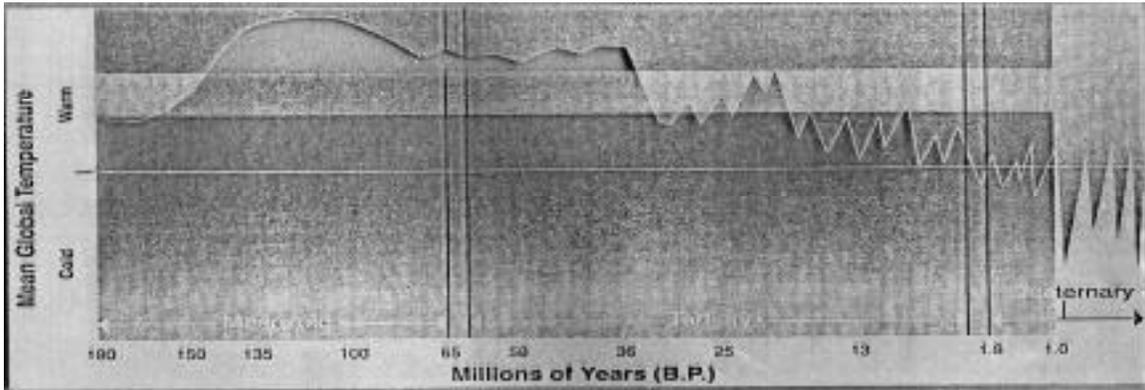
Doomsayers forecast that global warming will bring death, destruction and a downturn in stock prices. Although forecasting the market is impossible, the other catastrophic events are not only implausible but counter intuitive. The evidence for global warming's being relatively benign is overwhelming. Historical data show that climate has always fluctuated but that warmer climates were better for plants and animals, including humans; statistics demonstrate that warm weather and hot climates reduce mortality and morbidity; anecdotal but convincing evidence of human behavior indicates that most people prefer warm weather to cold; simple logic proves that our economy is largely immune to climate. Even such weather sensitive sectors as agriculture would probably benefit from global warming. It is quite likely that any climate change will cut deaths and promote economic wellbeing. Even though climate change may bring those benefits, there will inevitably be costs, but the evidence shows that the positive aspects are likely to outweigh the negative.

History of Climate

Over the four and a half billion years that this earth has existed, the climate has varied from torrid to icy temperatures; the latter condition has been dubbed the "snowball earth" (Ward and Brownlee 2000). Exactly how and when life emerged on the globe is uncertain. We know, however, that life can tolerate extraordinarily hot temperatures, even over the boiling point of water, while extreme cold can kill, with some forms of life surviving by shutting down and becoming dormant. A number of the great extinctions reported by paleontologists appear to have occurred during the "snowball earth" periods.

Five hundred million years ago, carbon dioxide levels may have been up to twenty times current levels, bringing an end to one of those "snowball periods" (Ward and Brownlee 2000). The result appears to have been the Cambrian explosion in life forms so magnificently described by Steven J. Gould in *Wonderful Life* (1986). Later, during the age of the dinosaurs, the world was considerably warmer than today. The end of that era is attributable to a massive comet or meteorite that struck near Mexico, producing first fire, then a pall of particles, clouds, and smoke that shut out sunlight. The result? A frigid world so inhospitable that about 60 percent of the existing species, including the mighty dinosaurs, disappeared (Ward and Brownlee 2000, 157).

Chart 1
Temperatures over the Last 180 Million Years

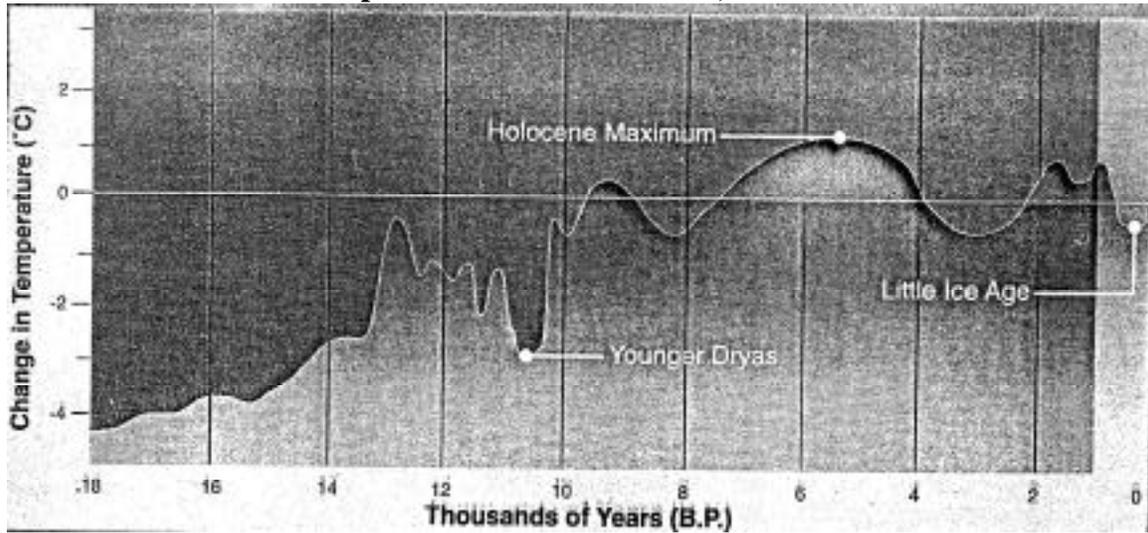


Source: Prepared by J.A. Eddy, OIES, and R.S. Bradley, University of Massachusetts, *Earthquest*, Spring 1991, 5, No. 1.

When a warmer and sunnier world returned, small mammals evolved into bigger and brainier creatures and, eventually, into humans. As Chart 1 shows, the climate has become increasingly cooler over the last 100 million years. Over the last million years it has oscillated between ice ages and short inter-glacial warm periods. During most of human existence, the earth was suffering through the latest ice age, which brought glaciers down as far as modern Illinois in the Americas and covered much of what is now northern Europe. Anatomically modern man may date back as much as 200,000 years, although some evidence indicates a later arrival. In any case, during most of mankind's history, men and women made their way by hunting and gathering. Only with the end of the Ice Age — see Chart 2 — did Homo Sapiens start to produce food rather than living off of the environment. Apparently it was a warmer climate that either forced humans to start domesticating plants and animals or made it possible for them to do so.

Since the Ice Age the climate has continued to fluctuate, although less sharply. In the last 10,000 years, two warm periods stand out (Moore 1995). Around 4,000 to 7,000 years ago, the earth was about 4.5° Fahrenheit warmer than today, somewhat warmer than is predicted for the globe in the year 2100 (Dahl-Jensen, et al. 1998). For around 300 years, from 900 or 1,000 A.D. to 1200 to 1300, much of the world was warmer. The first period saw the creation of the first civilizations. Writing was invented; trade flourished; and mankind shifted from the Stone Age to the Bronze Age.

Chart 2
Temperatures over the Last 18,000 Years

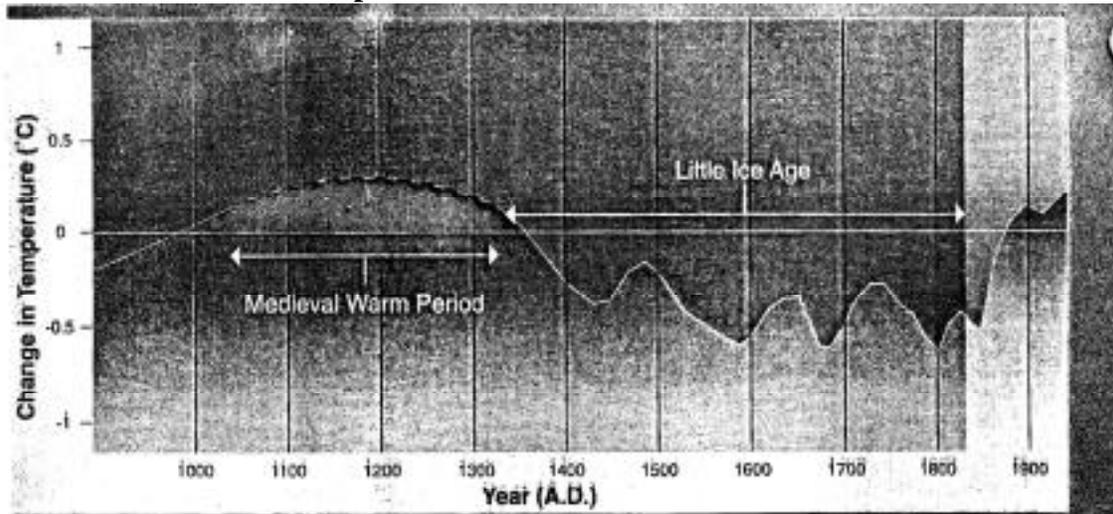


Source: Prepared by J.A. Eddy, OIES, and R.S. Bradley, University of Massachusetts, *Earthquest*, Spring 1991, 5, No. 1.

The later period — the Little Climatic Optimum — which appears to have originated in Asia around 800 to 900 A.D. and spread across the Northern Hemisphere, reached Europe and North America around 1000. (See Chart 3.) In Europe it brought an end to the Dark Ages. The population exploded as the better climate brought more reliable and larger crops. Farmers moved farther north and migrated up the mountains. A building boom of unparalleled magnitude evidenced the increased wellbeing. The good times continued until near the end of the 13th century when the climate cooled sharply (Moore 1995, 1998a).

Not only was this period beneficial for humans in Europe but in North America and Asia as well people and civilizations flourished. In the Americas, the Anasazi Indians built their pueblo dwellings at Mesa Verde and abandoned them only when the climate became drier as the climate cooled. Asia saw the construction of great buildings. On the island of Java, the building boom resulted in the stupa of Borobudur. In the 11th century, the people who lived in what is now Burma (Myanmar) built a huge capital, Pagan, with a large number of temples. During the 12th century, in what is now modern Cambodia, the local population built Angkor Wat.

Chart 3
Temperatures over the Last 1200 Years



Source: Prepared by J.A. Eddy, OIES, and R.S. Bradley, University of Massachusetts, *Earthquest*, Spring 1991, 5, No. 1.

Effect on Health and Mortality

We need not rely solely on history for documentation that a warmer climate brings good things; the modern world provides ample evidence that climate change is likely to produce more benefits than losses. Anecdotal evidence suggests that doctors often recommend a move to a warmer climate for some of their patients. Moreover, good statistical evidence supports the idea that a warm climate is better than a cold one for humans. Mortality statistics show that more people die in the winter than in the summer. In fact, for virtually every major cause of death, from heart disease to cancer, deaths peak in the winter. Only suicides, accidents, and murder are higher in the warm months. Overall about 16 percent more die in the winter months each year than leave this earth in the summer (Moore 1998b).

In an earlier study, I examined the relationship of climate to mortality in the United States (Moore 1998b). Regressing the monthly death rate for Washington, DC, on various measures of weather showed that the average high temperature, the average low temperature, the mean monthly temperature, and the hours of sunlight were all significantly correlated with deaths. The length of the day, however, was less significant than the temperature variables and became insignificant when combined with a temperature measure. Extrapolating from the data, it appears that global warming of 4.5° Fahrenheit would reduce deaths in the United States by 37,000 annually.

In addition to those regressions, I looked at death rates across the country in various large counties. After holding constant race and age, climate emerged as a significant variable. Smoking rates, air pollution, elevation, and latitude were unrelated to deaths. In short, the statistical evidence implied that a temperature increase of 4.5°F would cut deaths nationwide by about 41,000. Together with the Washington evidence, the numbers suggest that a warming of 3° Celsius, which is more than the Intergovernmental Panel on Climate Change (IPCC) is currently predicting, would cut mortality by about 40,000, the number that die each year on the highways.

British study

The Global Atmospheric Division of the British Department of Environment commissioned the University of East Anglia to study the economic impacts of the exceptional temperatures of 1995. The researchers showed that warmer weather reduced deaths (Bentham 1997): a one degree Celsius increase in average temperature cut mortality by about 7,000 per year. They reported that even a 3°C boost in average temperatures would reduce deaths, more in the winter than the summer, resulting in three percent fewer deaths, or a saving in human lives for England and Wales of about 17,500.

According to the authors, the balmy weather in the UK, again paralleling the US (discussed below), evidently led to “a decrease in winter depression” and possibly to an increase in violent crime, although with increased levels of sociability. They were, however, unable to document those hypothesized changes.

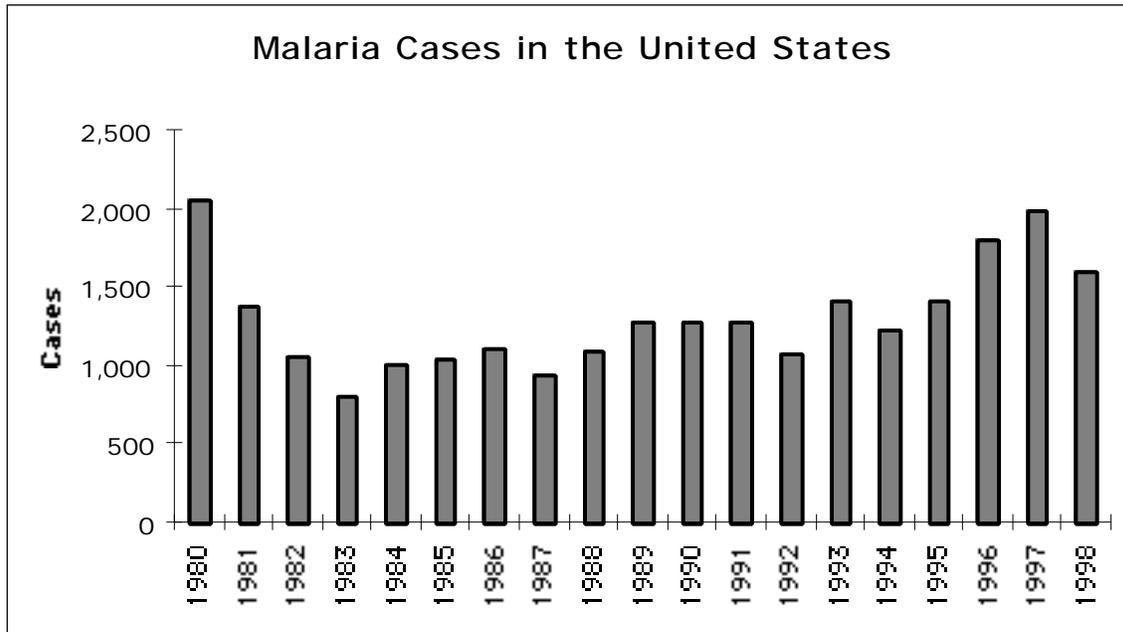
Warm climate diseases

Some have argued that a warmer climate would bring various tropical or warm climate diseases to the United States (e.g. Epstein 2000). Epidemiologists dismiss such fears. *Science* magazine reported: “predictions that global warming will spark epidemics have little basis, say infectious-disease specialists, who argue that public health measures will inevitably outweigh effects of climate” (Taubes 1997).

Malaria and cholera were both major health problems in the United States in the nineteenth century. Few now realize that, before the Second World War, malaria was widespread in the United States. The government recorded over 120,000 cases in 1934; as late as 1940, the number of new sufferers totaled 78,000 (Centers for Disease Control and the *Statistical Abstract of the United States*). After World War II, malaria cases reported in the U.S. plunged from 63,000 in 1945 to a little over 2,000 in 1950 to only 522 in 1955. By 1960, DDT had almost totally eliminated the disease; only 72 cases were recorded in the whole country. In 1969 and 1970, the Centers for Disease Control

reported a resurgence to around 3,000 cases annually, brought in by service personnel returning from Vietnam. Subsequently, immigrants from tropical areas have spawned small upticks in new cases. As Chart 4 shows, new malaria cases have fluctuated in recent years, owing mainly to travelers' bringing back the disease from abroad.

Chart 4



Source: CDC Summary of Notifiable Diseases, United States (various years)

While mosquitoes transmit malaria, cholera comes from ingesting food or water containing the bacterium. Eating tainted shellfish, raw or undercooked fish, raw vegetables, or unpeeled fruits can lead to infection. Drinking unpurified water can also be dangerous.

In 1817, the British first identified this dreaded disease in Calcutta, whence it spread throughout India, Nepal, and Afghanistan. Ships infested with rats carried it into Asia, Arabia, and to the ports of Africa. It reached Moscow, its first port of call in Europe, in 1830, creating panic as locals fled the city. From there it traveled to Poland, Germany and England. In the decade after it first appeared in Europe, it killed tens of thousands in Paris, London, and Stockholm. It reached North America in 1832, appearing first in New York and Philadelphia, then spreading along the coast to New Orleans. In that same year, the disease killed over 2200 people in Quebec. Apparently cholera is not a tropical disease; it can kill and sicken in any climate, although in high latitudes it may do so only in the summer.

Fundamentally cholera is a disease of poverty, crowding, and unsanitary conditions. A warmer climate will not carry this disease to affluent countries; in the Third World, moreover, economic growth can bring freedom from this and many other diseases. Prevention of cholera is simple: filtrate and chlorinate the water supply. Filtering by itself not only reduces the spread of cholera but cuts typhoid significantly. Combining filtration with chlorination eliminates waterborne diseases.

Parasitic diseases, such as AIDS, Lyme disease, yellow fever, malaria, and cholera, can usually be controlled through technology, good sanitary practices, and education of the public. Even without warming, it is certainly possible that Dengue fever or malaria could invade North America. Unfortunately, some of the government's well-meaning environmental policies may make the vector more likely. The preservation of wetlands, although useful in conserving species diversity, also provides prime breeding grounds for the mosquitoes that can carry those diseases. If the United States does in the future suffer from such insect-borne scourges, the infestation may have less to do with global warming than with the restoration of swampy areas.

Hurricanes and Tornadoes

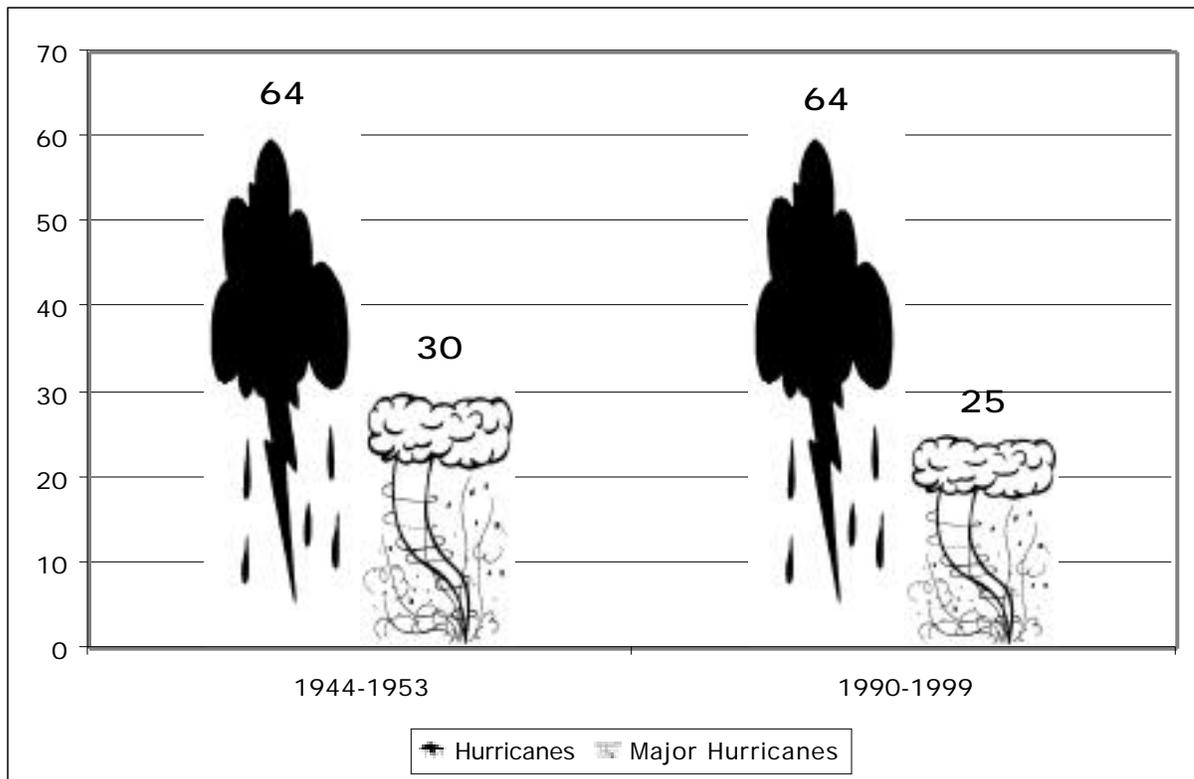
Many Jeremiahs claim that climate change will increase the threat from more frequent or violent storms. Their argument, which has some superficial plausibility, is that a warmer climate means more heat energy will be trapped in the atmosphere leading to bigger and stronger weather systems. On the other hand, warming is most likely to be greatest near the poles and less at the equator. The strength of weather systems is actually a factor of the differential in temperatures between the two regions. Since this differential will diminish, so will the likelihood of more intense cyclones.

Major weather disasters do kill. The evidence, however, fails to support the proposition that weather is becoming more violent. In the Atlantic basin, the number of intense hurricanes, those scaled between 3 to 5 (5 being the most violent), has actually declined during the 1970s and 1980s. The years from 1991 to 1994 enjoyed the fewest hurricanes of any four years over the last half-century (Landsea et al 1996). As Chart 5 shows, National Atmospheric and Oceanic Administration's (NOAA) data illustrate that the average number of hurricanes in the Atlantic basin has not changed over the previous 46 years, while there has been a small decrease (not statistically significant) in the number of intense hurricanes

Preferences for Climate

When people have a chance to choose, where do they prefer to live? Retirees overwhelmingly pick warmer climates: Florida, Arizona, and Hawaii are favorites. Few choose North Dakota, Minnesota, or Duluth.

Chart 5
Number of Hurricanes in the Atlantic Basin
1944-53 and 1990-99



Source: <http://www.aoml.noaa.gov/hrd/tcfaq/tcfaqE.html#E8>.

Although the evidence is anecdotal, it is clear that most welcome warm winters. In 1997/98, the United States enjoyed, courtesy of El Niño, a record breaking year. By all standards it was the warmest yet recorded. During the Little Climatic Optimum of 800 to 1000 years ago, there were probably years that were hotter; but thermometers and the satellites needed to verify the torrid readings were centuries in the future. In 1998, for once, ground-based readings and satellite measurements were able to agree that most places were warm and for most of the year. Most of the globe recorded those higher than normal readings. In the United States, all sections of the country, with the exception of

the West, enjoyed above average temperatures, often records for the year (*Climate Variations Bulletin*, 1998).

Although people differ in their taste for sunny, warm days, most evidently appreciated the absence of winter freezes. Relative to normal, the Northeast, the East North Central, and the Central regions of the United States recorded the warmest weather. The weather spawned by El Niño resulted in a spate of articles describing the pleasure many found with the lack of winter.

People Benefits

At driving ranges, golfers in record numbers improved their game. As the *Sunday Westchester Weekly* (March 22, 1998) put it, “Golfers basked in a spring-like glow almost straight through from November to March, the period that used to be known as winter.” Golf courses enjoyed more business than ever. Spring fever was in the air. Even turtles and snakes were out much earlier than is normal.

The unusual weather did have a downside: Princeton sophomores were bemoaning the absence of snow, which threatened the ritual of a nude midnight foot race through the Yard. Those who make extra money plowing driveways were mourning the lack of white stuff. Towing services, which profit from pulling cars out of ditches, remained underused. Although consumers were saving money on heating bills, gas and oil companies were suffering from reduced demand, lower prices, and less revenue. There can be no sunshine without some sunburn.

Health Benefits

The Minneapolis post office reported that sprained ankles and falls sustained by its mail carriers were down 40 percent from their usual levels (*Star Tribune* of Minneapolis-St. Paul 1998). Only one postal worker suffered from frostbite in 1998, compared with the normal tally of three or four. The absence of harsh weather also meant that service was smoother and more timely while overtime costs were down.

As mentioned above, global warming fear-mongers often predict that a warmer climate will kill people. That is not what happened in 1998. For the first 12 weeks of the year, overall deaths in New York City declined over 8 percent from the levels of 1996 and were down 4.5 percent from the previous year. During the following summer, one of the hottest on record, mortality was 6 percent lower than during the cooler summer of 1996 and, of course, it was lower (about 15 percent) than it had been during the winter.

Psychological Benefits

The absence of winter provided mental and emotional benefits as well. The director of psychiatry at Northern Westchester Hospital, Dr. Maureen Empfield, maintained that the warm sunny weather improved people's moods. As Dr. Empfield put it, "Rarely does anyone come into my office and complain about sunshine" (Revkin 1998). In Minnesota, airlines reported that travel to sunnier climes was down, good news for Twin-Cities residents but bad news for Northwest Airlines.

In the east, low-income elderly residents were delighted with more than just the savings on their heating bills (Revkin 1998). One octogenarian, Helen Nem, was deeply thankful for the warm sunny weather, which staved off despondency. Ms Nem complained that she suffers from depression when winter brings snow; 1998 was a year without gloom.

Ervin Pogue of Bucks County, Pennsylvania, bragged that this had been the best winter of his 77-year life (Shafer 1998). "This winter," he chortled, "I've had a ball." At the zoo, tropical animals, which must normally remain inside all winter, were allowed out, much to the delight of the public and undoubtedly to that of the animals as well. Attendance was up 50 percent at the Philadelphia Zoo in January and February. Even birds benefited: the absence of snow cover meant that they had a plentiful supply of plants for food.

Taxpayer Benefits

The New York Times reported (February 27, 1998) that the warmth had been a blessing for road-plowing budgets, had significantly reduced heart attacks from snow shoveling, and had improved commuter train service by virtually eliminating delays. Public works chiefs were cheering their virtually untouched bank accounts: snow removal budgets and salt for the highways remained unused. During the "winter" of 1998, Greenburgh, New York, spent only \$45,000 of its budgeted \$325,000 for clearing the roads. With deliveries of oil down 20 percent, homeowners enjoyed significant savings on their heating bills.

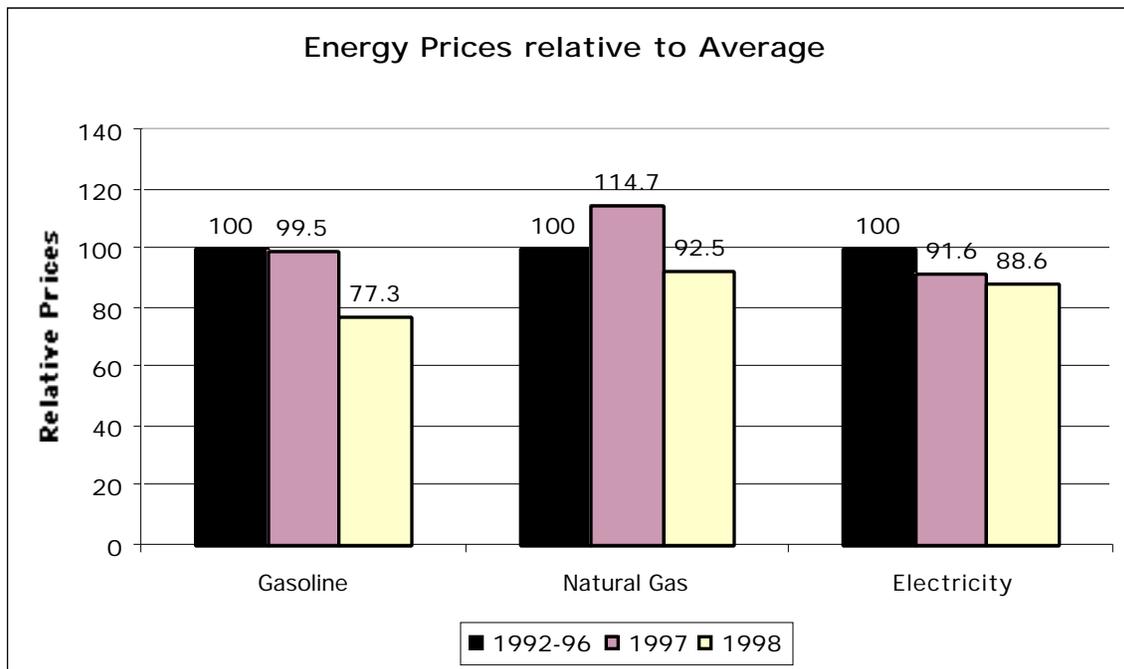
The Philadelphia School District estimated that spending on energy would be down by \$1.5 million. For Pennsylvania as a whole, government officials predicted that expenditures on winter roads would be lower by \$20 million. The New Jersey Department of Transportation boasted that the mild winter saved about a quarter of its winter budget.

Economic Benefits

The good weather was generally good for business. Shoppers in the East and Midwest, lured by the balmy weather, turned out in force. In New York City, sales rose 5 percent in February, largely because of the weather. Construction companies, real estate agents, and transportation firms all benefited from the absence of snow and the sunny skies.

Transport companies as well as consumers enjoyed the lowest gasoline prices since the Second World War. Several factors contributed to their precipitous decline: the collapse of several Asian economies and the consequent fall in the demand for energy; a partial lifting of the embargo on Iraqi production of oil; and, most important, a warmer world which reduced demand for heating oil, natural gas, and electricity. As Chart 6 shows, energy prices fell across the board.

Chart 6



Source: Energy Information Agency, Department of Energy; <http://ftp.eia.doe.gov/pub/>

Minnesota, which enjoyed one of the warmest winters this century, reported that the weather was a boon for its economy (*Star Tribune* of Minneapolis-St. Paul 1998). Residents appreciated a saving in heating bills per household of about \$135 to \$150. Minnegasco, the natural gas company, suffered, of course, from a 15 percent cut in sales. At the same time, however, the utility benefited from a sharp reduction in emergency repairs: in January, there were 21 percent fewer calls; in February, 13 percent fewer.

Northern State Power, a major power company in the upper Midwest, also reported reduced sales of electricity, offset in part by lower expenses. On net, residents of the state gained significantly.

Roofers in the upper Midwest were able to do more business; field workers were less encumbered by heavy clothes and tools were warmer and easier to use. In winter, milk delivery companies face serious difficulties when snow and ice create obstacles for their trucks. In 1998, in contrast, a major Minnesota dairy, Nelson Creamery, reported no delays in deliveries; during the more typical winter of 1997, the company had two truck rollovers; several other vehicles slid into ditches. The firm spent \$1,200 for wrecker services in 1997; zero in 1998.

The good climate produced a bounty on the farm. Although increased production meant lower incomes for farmers, it also meant lower prices for consumers. Contrary to the assertions of global warming activists, who typically forecast crop failures, the warm climate of 1998 led to farm prices that were 13 percent below what they had been in the years 1992 to 1996.

In summary, Stanley A. Changnon, a climatologist, reported, in the *Bulletin of the American Meteorological Society*: the benefits from savings on heat, snow removal, lack of spring flood damages, savings in transportation were almost five times higher than the costs to the economy. In fact, according to Changnon's calculations, winter rains caused about \$4.5 billion in damage; but the savings from lowered heating and other energy use and costs totaled more than \$16 billion. What's more, he also found that the mild winter weather caused far fewer deaths than normal, saving over 650 lives.

Hedonic Wage Study

Even though most of the evidence that people prefer warmth to cold is anecdotal, statistics support that proposition. In a study published in 1998, I examined wage rates for various occupations in cities across the United States. As Adam Smith pointed out over two hundred years ago, employers must pay more to entice workers to unpleasant climates. Depending on the exact model used — various measures of temperature, rainfall, seasonal variation, and population density — the benefits of a warmer world for the population as a whole varied from \$29 billion to \$97 billion annually (Moore 1998b).

U.K. Effects

Warm sunny weather is popular almost everywhere. The years, 1998 and 1995, were two of the United Kingdom's hottest on record. In order to collect data on the effects of global warming, the Global Atmospheric Division of the British Department of

Environment commissioned the University of East Anglia to study the economic impacts of the exceptional temperatures of 1995. Although the researchers failed to put a dollar or pound figure on the results, they concluded that, by and large, it was a good year (Palutikof, Subak, and Agnew 1997).

The university's Climatic Research Unit reported that the twelve months between November 1994 and October 1995 were the warmest in over three hundred years while the summer was 3 degrees Celsius warmer than the average between 1961 and 1990.

In their report, *Economic Impacts of the Hot Summer and Unusually Warm Year of 1995*, the East Anglia researchers detailed the ways in which the warm weather had affected various sectors. Their chapter on the Natural Environment was largely favorable, noting that "Bird populations were in general favoured by the mild winter weather of 1995." Fewer algae blooms than expected meant that water quality was maintained. The evidence showed that a sustained increase in temperature of 1.6 degrees Celsius (as occurred in 1995) "would lead to a substantial increase in [forest] productivity." However, in 1995, the wellbeing of some deciduous trees, especially beech, did decline.

Agriculture

According to the researchers, farmers benefited from the warmer weather: arable crops, like wheat, barley, oilseed rape and sugar beets, did well; but the lack of rainfall hurt the production of potatoes and some vegetables. Irrigation, they pointed out, could mitigate those side effects. Unfortunately livestock farming did suffer, but the report stressed that sprinkling and dousing equipment could offset the effect of any warming on livestock. Freshwater trout farming also lost ground: water oxygenation, the study noted, would eliminate those problems. In total, the British farming sector lost about £182 million (roughly \$275 million at today's exchange rates), virtually all of which stemmed from livestock losses, which could be mitigated if the climate warms.

Other Sector Costs and Benefits

Moreover, savings in energy consumption more than offset those losses to some farmers. Consumers' natural gas bills alone were cut by £220 million (about \$330 million). On net, including an increase in electricity used for cooling, the U.K. economy paid £355 million (nearly \$550 million) less in energy costs.

The Climate Research Unit also found that people needed to spend less on clothing, reducing sales in that sector by £383 million (\$575 million) in 1995. The population, however, consumed £134 million more in beer and wine and increased their purchases of fruit and vegetables by £25 million. The increased consumption of beer,

wine, fruits, and vegetables suggests that warming would improve the British diet. In total, the researchers estimated that retail sales in 1995 fell by £87 million (about \$130 million), reflecting a savings for households of the same magnitude.

The British construction industry, like its American counterpart, is subject to delays and interruptions during bad weather. The report claims that “In a warmer climate, the sector should be less affected by weather, since severe winter conditions, which cause the greatest disruption to this section, will become less common.”

The warm winter weather did improve transport during that season, although the hot summer weather led to increased rutting of the road surfaces and higher maintenance costs. On net, the researchers found that the unusually warm conditions in 1995 boosted transport costs by a trivial £16 million. Providing better asphalt would eliminate even that small cost while preserving the savings from reduced traffic delays and fewer potholes.

Likely Effects on the Economy

Most forecasts of global warming’s repercussions have been dire, but an examination of likely effects suggests little basis for that gloomy view. The media and others have attributed almost every possible weather to global warming, from more to less climate variability, both more rainfall and more drought, and more violent winter storms, as well as fewer and weaker cold-weather surges. The IPCC, in contrast, predicts that global warming would bring warmer summers, more precipitation, warmer winters, and warmer temperatures at higher elevations and latitudes.

Two recent studies predict the effects of global warming: Mendelsohn and Neumann (1999) and the National Assessment Synthesis Team (NAST 2000). The latter, which has been released only in draft form, provides no dollar estimates of the impact of climate change on the US economy. The NAST, established at Congress’s request by the Office of Science and Technology Policy in the White House, tries to measure the effects of global warming on eight regions of the country. For their analysis the authors employ two climate models, one from the Canadian Climate Center, the other from the UK Hadley Center for Climate Research and Prediction. Those two state-of-the-art models differ sharply in their estimates of climate changes. One model predicts drought in the Middle West while the other predicts increased rainfall. Both models do, however, forecast increased agricultural output and expanded forests. Urban populations will be subject to greater heat in the summer and less cold in the winter. Coastal regions will see some loss of barrier beaches and low-lying islands. The report concludes by asserting:

There are substantial opportunities to minimize the negative impacts and maximize the benefits of climate change through adaptation.

Robert Mendelsohn, Professor of Environmental Studies at Yale University, and James Neumann, Senior Associate of Industrial Economic Inc., edited *The Impact of Climate Change on the United States Economy*, a work that brought together a group of scholars commissioned to study the effects of climate change on various sectors of the US economy. The authors based their analysis on the estimated impact of a hypothesized doubling of CO₂ which, they concluded, would lead to a 2.5°C (4.5°F) increase in temperature and a 7 percent increase in precipitation. Various scholars authored chapters on agriculture, timber, water resources, sea level rise, energy expenditures, commercial fishing, and outdoor recreation. The research concluded that the economy would suffer losses in water resources, energy, coastal structures and commercial fishing. Those costs would be outweighed by the gains in agriculture and timber. On net, the researchers concluded that there would be small gains from warming.

Robert Mendelsohn followed this with a study, *The Greening of Global Warming*, which brings together a large number of recent studies indicating much smaller impacts of climate change on humans than predicted earlier. Many show small gains; others find small losses. On the basis of those studies, he concluded that the global impact of climate change would lie between a 0.1 percent loss and a 0.1 percent gain of world GDP.

Taken together, these studies — Mendelson's work, my research, and even the NAST report — imply that inhabitants of the advanced industrial countries will scarcely notice a rise in worldwide temperatures. Earlier the president of the American Economic Association, Thomas Schelling, in an address to the members, having come to the same conclusion, told the economists "that in the United States, and probably Japan, Western Europe and other developed countries, the impact on economic output [of global warming] will be negligible and unlikely to be noticed." His reasoning was simple: as modern societies have developed a larger industrial base and become more service oriented, they have grown less dependent on farming, thus boosting their immunity to temperature or rainfall variations.

Sector Analysis

The immunity of the American economy can be shown simply by examining the likely effects of climate change on various sectors of the economy. Climate affects principally agriculture, forestry, and fishing, which together constitute less than two percent of U.S. GDP. Manufacturing, most service industries, and nearly all extractive industries are unaffected by climate shifts. Factories can be built in northern Sweden or

Canada or in Texas, Central America, or Mexico. Banking, insurance, medical services, retailing, education and a wide variety of other services can prosper as well in warm climates (with air-conditioning) as in cold (with central heating). A warmer climate will lower transportation costs: less snow and ice will torment truckers and automobile drivers; fewer winter storms will disrupt air travel — bad weather in the summer is less disruptive and passes quickly; a lower incidence of storms and diminished fog will make shipping less risky. Higher temperatures will leave mining and the extractive industries largely unaffected; oil drilling in the northern seas and mining in the mountains might even benefit.

A few services, such as tourism, may be more susceptible to weather. A warmer climate would be likely to change the nature and location of pleasure trips. Many ski resorts, for example, might face less reliably cold weather and shorter seasons. Warmer conditions might also mean that fewer northerners would feel the need to vacation in Florida or the Caribbean. On the other hand, new tourist opportunities might develop in Alaska, northern Canada, and other locales at higher latitudes or in upper elevations.

In many parts of the world, warmer weather should mean longer growing seasons. Should the world warm, the hotter climate would enhance evaporation from the seas and lead probably to more precipitation worldwide. Moreover, the enrichment of the atmosphere with CO₂ would fertilize plants and make for more vigorous growth. Agricultural economists studying the relationship of higher temperatures and additional CO₂ to crop yields in Canada, Australia, Japan, northern Russia, Finland, and Iceland found not only that a warmer climate would push up yields but also that the added boost from enriched CO₂ fertilization would enhance output by 15 percent (NCPO 1989). The United States Department of Agriculture in a cautious report reviewed the likely influence of global warming and concluded that the overall effect on world food production would be slightly positive and that agricultural prices would be likely to decrease. (Kane 1991).

The draft of the US Global Change Research Program, circulated for public review — the National Assessment Synthesis Team report described above — concluded that most commercial crops in the United States would enjoy increased yields of 15 to 20 percent under a doubling of CO₂ (NAST 2000). This report also found that forests in most parts of the country would gain with increased carbon storage.

In 1994 two scientists, Paul Knapp and Peter Soulé, compared a site in central Oregon that had been extensively surveyed in 1960 with its flora fourteen years later. The region was almost inaccessible; climate had remained constant; human activity, given its remoteness, was negligible. They reported that the site had become much greener, with

large increases in trees, perennial grasses and western juniper. After excluding systematically all other factors, they concluded that the rise in CO₂ had boosted growth (Knapp & Soulé 1996).

There is strong evidence that the world is becoming greener under warmer weather with increased rainfall and higher carbon dioxide levels. Overall increased levels of carbon dioxide make plants grow better under virtually all circumstances: whether they experience higher temperatures or lower rainfall, they do better. Europe's forests, for example, have expanded over recent decades (Kauppi et al. 1992). A study reported in *Nature* found that the photosynthetic activity of vegetation increased from 1981 to 1991 as a result of the longer growing season (Myneni et al. 1997). A greener world is a richer world ecologically. All animals either eat plants or eat animals that eat plants. More vegetation makes the environment more diverse, better able to withstand any change. Of critical importance, a greener world will make it easier to feed the world's population.

Not all effects of a warmer climate are positive. Rising sea levels would impose costs on low-lying regions, including a number of islands and delta areas. For the United States, however, assuming a one meter rise in sea level, at the high end of predictions for the year 2100, economists, such as William Cline, William Nordhaus, and Richard Morgenstern, have estimated the costs of building dikes, levees and from the loss of land at \$7 to \$10.6 billion annually. That represents less than 0.2 percent of GDP. For some small low-lying island nations, the problems would be much more severe.

Professor Gary W. Yohe of Wesleyan University and his colleagues (1999) found those estimates of the costs of sea level changes to be an order of magnitude too high. They concluded that the cost would be about \$1.3 billion, considerably less than earlier estimates.

Morrison and Mendelsohn (1999) estimated that, in the long run, increases in expenditures on air conditioning would exceed savings during the winter. They calculated the net expenditures as about \$4.1 billion annually by 2060. Other studies have predicted much lower costs. A study by the Department of Energy, for example, found net savings of \$12.2 billion (Rosenthal et al. 1995). Morrison and Mendelsohn did find short-run savings; but, after people adjusted and purchased air conditioning, outlays rose.

None of those studies included savings on transportation, which I have estimated at \$300 million (Moore 1998a). Although I calculated gains for leisure activity at \$1 billion, Mendelsohn and Neumann put the figure at \$3.5 billion, more than triple my estimated gain.

In summary, most studies, even those done by proponents of global warming action, find that the costs to the economy would be small. For example, William Cline

and William Nordhaus estimated, separately, the cost of warming of 2.5 degrees Celsius at about one percent of the U.S. GDP. Both ignored, however, the potential benefits from a warmer climate. In fact, Nordhaus calculated the cost at only one-quarter of one percent of GDP, then guessed, on the basis of unmeasured sectors, that the total might be as high as one or two percent.

Parts of the rest of the world, especially poor agricultural regions and those subject to flooding from rising sea levels, would suffer more than the U.S. or Europe. Nevertheless, virtually all published estimates based on careful research put the cost to the world of a doubling of CO₂ at less than or equal to 1.5 percent of world income. The IPCC's Working Group III in its report to policy makers quoted estimates of the total cost from a doubling of CO₂ of “a few percent of world GDP.”

Table 1
Estimates of Costs or Benefits of Climate Change

Researcher	Temperature Increase in Fahrenheit	Gain (+) or Loss (-) % Change in GDP
William Cline (1992)	4.5°	-1.1
Willima Nordhaus (1994)	5.0°	-1.0
S. Frankhauser (1995)	4.5°	-1.3
J. G. Titus (1992)	3.5°	-1.25
R.S.J Tol (1995)	4.5°	-1.5
Mendelsohn & Neumann (1999)	3.5°	+0.2
T. G. Moore (1998a)	4.5°	+1.0

Although many agree that the cost of warming, after adjustment, may be small, some observers have worried that the speed of climate change will be unprecedented, making adaptations difficult and costly. Ice core researchers have shown, however, that climate has shifted in the past as rapidly or more rapidly than is predicted over the next century (Taylor, et al. 1997; Stevens 1997, 1998; McElroy 1994). It is important to note that the IPCC has reduced the forecast temperature increase over the next century, sharply slicing the rate of change of climate. In short there is little to fear from global warming and possibly much to gain; even the need for a “no regrets policy” is arguably nonexistent.

Conclusion

If global warming occurs, it may cost the world at most one or two percent of the world's GDP, most likely much less. Offsetting the drawbacks are the many benefits of

warmer winters: people like warm climates; heating bills are lower; clothing costs are reduced; transportation is less troubled; and death rates are lower. Trying to slow the emissions of greenhouse gases is likely to be costly, significantly exceeding two percent of the world's GDP. Adaptation rather than prevention appears to be the best strategy. Over the twenty-first century, incomes and technology will almost certainly grow. Should serious problems arise from climate change, mankind will then have more resources and the technology to mitigate putative difficulties. Prudence requires watching, waiting, and weighing alternatives. Acting now is dangerous, damaging, and possibly destabilizing to the world. Certainly the potential effects of climate change do not currently call for any action. As Franklin Delano Roosevelt declared, "The only thing we have to fear is fear itself."

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