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CALMER WEATHER

THE SPIN ON GREENHOUSE HURRICANES

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EXECUTIVE SUMMARY

Somehow, the public has been convinced that the future will include an increasing number of hurricanes of greater intensity that will cause substantial damage throughout the world. Worries about hurricanes have been added to concerns regarding heat stress, sea level rise, droughts, pestilence, crop failures, water shortages, wildfires, and all the other components of the greenhouse disaster.

What is most surprising about the claims regarding the increasing hurricane numbers and intensity in the greenhouse world is the general lack of theoretical or empirical evidence that can be found in support of the claim, particularly if one deals with the issue of hurricane numbers. Much of the evidence we have to date argues *against* the link between global warming and increased hurricane activity.

Concerns about warming-induced hurricanes got their start in 1986 when noted M.I.T. scientist Kerry Emanuel published a paper showing that a fall in sea-surface temperatures could prevent intense hurricanes, and that a warmer sea-surface could theoretically increase the upper limit of a storm's intensity. This publication set the stage for several more important Emanuel papers that would ultimately have a large impact on the greenhouse link to increased hurricane activity and the formation of "hypercanes" — particularly intense hurricanes. Emanuel's research never predicted increased hurricane activity, but instead provided a theoretical discussion of the upper limit of hurricane intensity, given a very large increase in sea surface temperatures. Nonetheless, it was enough to encourage fear mongering about warming-induced hurricanes.

Shortly thereafter several articles appeared in the professional literature that cast serious doubts to the notion that hurricane activity was on the rise. This research showed that Atlantic hurricane activity over the period 1970 to 1987 was less than half of the activity observed for the period 1947 to 1969. Additional research suggested that a warmer world would actually produce fewer storms.

Throughout the 1990s, articles have appeared in major journals supporting and challenging the prediction of increased hurricane activity in the greenhouse world. Researchers found great year-to-year variability in the hurricane data, but no significant evidence to link hemispheric temperatures to variations in hurricane activity. Scientists examining long term hurricane trends found a clear downward trend over the past 50 years. The Intergovernmental Panel on Climate Change, often represented as the scientific consensus, concluded in 1995 that: "Although some models now represent tropical storms with some realism for present day climate, the state of the science does not allow assessment of future changes." Scientific research into hurricanes has not produced ringing endorsements for the popular claim that global warming is causing or will cause more hurricane activity.

One of the most interesting ironies in the claims that recent hurricane activity is linked to warming is that the warming itself may not have occurred — there is strong evidence from satellite measurements that the planet has actually cooled over the past few decades. Blaming hurricanes on recent warming is flawed on all fronts – not only is there little to no linkage between global warming and hurricane activity, but there seems to have been no warming in recent decades either.

A highly popular view has developed that the buildup of greenhouse gases will cause the sea-surface and atmospheric temperatures to rise, and that this will result in an increase in the number and intensity of damaging hurricanes around the world. But, as with so many other elements in the greenhouse debate, the theoretical and empirical evidence is not very supportive of this claim. Indeed, there is plenty of evidence to argue that the greenhouse effect will suppress hurricane activity. In the end, there is little reason to expect an increase in hurricane activity throughout the upcoming century.

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INTRODUCTION

The cover of the January 22, 1996 *Newsweek* showed a man walking through the whiteout of a snowstorm and curiously proclaimed "The Hot Zone: Blizzards, Floods & Hurricanes: Blame Global Warming." To really emphasize the point, "Hot" and "Global Warming" appeared in bright red letters blaring through the white background of blowing snow. To this day, news reports of hurricanes (also called typhoons or tropical cyclones) anywhere around the world are often accompanied by statements mentioning global warming, the greenhouse effect, and the anthropogenic influence on climate.

Somehow, the public has been convinced that the future will include an increasing number of hurricanes of greater intensity that will cause substantial damage throughout the world. We have convinced ourselves that worries about hurricanes should be added to concerns we have regarding heat stress, sea level rise, droughts, pestilence, crop failures, water shortages, wildfires, and all the other components of the greenhouse disaster. This prediction is especially scary given the fact that hurricanes are among the most devastating natural disasters that impact much of the world. Accordingly, suggestions for an increase in hurricane activity should be taken very seriously, and those suggestions deserve critical analysis by scientists and policymakers alike.

We have convinced ourselves that worries about hurricanes should be added to concerns regarding heat stress, sea level rise, droughts, pestilence, and all the other components of the greenhouse disaster.

What is most surprising about the claims regarding the increasing hurricane numbers and intensity in the greenhouse world is the general lack of theoretical or empirical evidence that can be found in support of the claim, particularly if one deals with the issue of hurricane numbers. Much of the evidence we have to date argues *against* the link between global warming and increased hurricane activity. International scientific bodies have divorced themselves from the popularized prediction, and within the most recent months, research is showing that our future may have *fewer* hurricanes of less intensity potentially doing less damage than ever before.

Like so many other elements of the greenhouse debate, the theoretical and empirical evidence does not seem to matter at all to some individuals interested in spreading the gloom and doom of global warming. I spent nearly one hour with the *Newsweek* authors explaining to them all that will follow

in this chapter, but despite this discussion, the magazine published a cover story in which hurricanes are "blamed" on global warming. This was not a matter of confusion regarding a complex scientific issue — I fully believe that *Newsweek* chose to ignore the facts and present the scariest possible story regarding our future and global warming.

BUILDING THE LINK

If the observational and theoretical evidence argues against a linkage between greenhouse gases, global warming, and the intensification of hurricane activity, one may fairly question how the linkage became such a permanent pillar in the global warming apocalypse. A rather amazing set of circumstances may be behind any fear we now have for a future of hurricane destruction.

Research is showing that our future may have fewer *hurricanes of less intensity potentially doing less damage than ever before.*

In 1986, noted M.I.T. hurricane scientist Kerry Emanuel published a highly technical and complex paper in the prestigious *Journal of the Atmospheric Sciences* dealing with the air-sea interactions and hurricane activity.[1] Within that article, Emanuel showed that if the sea-surface temperature falls below approximately 26°C, intense hurricanes would become a physical impossibility. The cooler sea-surface temperatures would strengthen the inversion that exists in the trade winds of the subtropical to tropical latitudes, thereby limiting the growth of convective clouds in the hurricane system. Emanuel further showed that the intensity of a hurricane has a well-defined upper limit that is governed, in part, by the degree of thermodynamic disequilibrium between the atmosphere and the underlying ocean. In simple terms, a warmer sea-surface could theoretically increase the upper limit of a storm's intensity. Only a few storms actually approach this theoretical upper limit, but those storms turn out to be the most destructive and dangerous. Whether he realized it at the time, Emanuel had set a foundation for one of the more interesting misconceptions in the greenhouse debate.

This 1986 publication set the stage for several more important Emanuel papers that would ultimately have a large impact on the greenhouse link to increased hurricane activity. The following year, Emanuel published another article in the *Nature* on the dependence of hurricane activity on climate.[2] He showed that a numerical model perturbed by an increase in greenhouse gases would increase the disequilibrium between the ocean surface and the overlying atmosphere, and the theoretical upper limit of storm intensity would increase. This is not to say that the world would see more hurricanes or even more intense hurricanes, but the upper limit of intensity could increase. For a 3°C increase in sea surface temperatures, the potential destructive power, as measured by the square of the wind speed, of storms

[1] K. A. Emanuel, "An air-sea interaction theory for tropical cyclones. Part I: Steady-state maintenance," *Journal of the Atmospheric Sciences,* Vol. 43 (1986), pp. 585-604.

[2] K. A. Emanuel, "The dependence of hurricane intensity on climate," *Nature,* Vol. 326 (1987), pp. 483-485.

approaching this theoretical limit could increase by 40 to 50 percent. Emanuel acknowledged from the outset that there are many reasons to be skeptical about his conclusions regarding this limit of storm intensity, particularly as this value is determined for future climatic conditions. Yet these qualifications are rarely heard in contemporary discussions.

Several more papers in 1988 firmly set the stage for the inclusion of hurricanes into all future gloomy greenhouse predictions. A third paper by Emanuel in the *Journal of the Atmospheric Sciences* further developed the linkage between the upper limit of storm intensity and the warming occurring in the atmosphere.[3] Very importantly, this third paper introduced the rather snappy term "hypercane" into the vocabulary of the atmospheric scientists. Not many people understood that Emanuel was talking about the upper limit of storm intensity, and he suggested with a warming of the sea-surface of 6°C to 10°C (and with conditions in the lower stratosphere held constant), a supersized ultra-powerful hypercane becomes a theoretical possibility. No computer model ever predicted a greenhouse-induced temperature rise of 6°C for the tropical and subtropical sea surfaces that spawn hurricanes, but nonetheless, Emanuel had produced some interesting and valuable information about the physics of hurricane development and maintenance. These ideas were presented to a more popular audience in a paper he prepared for the *American Scientist*, and not surprisingly, more people learned about the hypercane.[4] By the summer of 1988, a world-class scientist at a first-rate institution had published articles in the finest journals that provided a linkage between atmospheric concentrations of greenhouse gases, global warming, and the development of these extraordinary hypercanes.

By the summer of 1988, a world-class scientist at a first-rate institution had published articles in the finest journals that provided a linkage between atmospheric concentrations of greenhouse gases, global warming, and the development of hypercanes.

Other scientists also published articles in 1988 that were in agreement with the work of Emanuel.[5] In addition, Hobgood and Cerveny used a numerical hurricane model to simulate conditions during the height of an ice age, and they found a significant reduction in the intensity of the storms that developed in the model.[6] If hurricanes weaken in ice age conditions, it is logical to assume they may strengthen during a time of increased planetary temperature.

The summer of 1988 also happened to be the time when the greenhouse effect and global warming made headlines day after day. That summer was an absolute climate calamity in many parts of the world, including North America. The summer of 1988 saw a severe drought in the southeastern United States, the drying up of the Mississippi River, record breaking heatwaves, and wildfires in the American West (including the Yellowstone

[3] K. A. Emanuel, "The maximum intensity of hurricanes," *Journal of the Atmospheric Sciences*, Vol. 45 (1988), pp. 1143-1156.
[4] K. A. Emanuel, "Toward a general theory of hurricanes," *American Scientist*, Vol. 76 (1988), pp. 370-379.
[5] see for instance R. T. Merrill, "Environmental influences on hurricane intensification," *Journal of the Atmospheric Sciences*, Vol. 45 (1988), pp. 1678-1687.
[6] J. S. Hobgood and R.S. Cerveny, "Ice-age hurricanes and tropical storms," *Nature*, Vol. 333 (1988), pp. 243-245.

fires). All of these events followed climatoligist James Hansen's famous June 23 statement to Congress that scientists are "99 percent certain" that the anthropogenic greenhouse effect was having an impact on the global climate system.[7] The linkage between the greenhouse effect and hurricanes got a boost the following September when nature provided us with the storm of the century.

North Americans had suffered through a summer like no other, and the greenhouse effect was the culprit many of us blamed for our climate problems. Just as things were quieting down, a tropical storm named Gilbert appeared in September south of the Virgin Islands. Unlike other storms of the that hurricane season, Gilbert grew at an alarming rate. Its center pressure dropped to 885 millibars which was the lowest pressure ever recorded for a hurricane in the Western Hemisphere. Winds in Gilbert were sustained at 280 km/hr (175 mph) as it smashed into the area around Cancun in the Yucatan of Mexico. Gilbert then headed north and arrived in southern Texas on September 16; prayers for rain to end the drought were more than answered as Gilbert died in the interior of the United States.

Suddenly, the image of hurricanes, or even hypercanes, was embossed into our vision of the greenhouse world. While the greenhouse effect was so much a part of the public mindset, this enormous hurricane came along to confirm our worst fears about the future. Emanuel's work was brought into the discussion as proof that solid theoretical and empirical arguments existed in the finest journals linking global warming to super-size hurricanes. Fear-mongering became easy for anyone selling the greenhouse scare — the proof was before our eyes as we saw the incredible images of destruction associated with Hurricane Gilbert. If the events of 1988 were not sufficiently convincing, Hurricane Hugo struck the southeast coast of the United States in the following year, ending all skepticism. People came to believe that hurricanes were increasing in intensity, magnitude, areal extent, duration, and ability to devastate our coastlines.

If the events of 1988 were not sufficiently convincing, Hurricane Hugo struck the southeast coast of the United States in the following year to end all skepticism.

Bookstores and newsstands were suddenly filled with new issues proclaiming the coming disaster that would be driven, in part, by the increase in hurricane damage. Anyone even remotely skeptical on the issue might look to the most credible professional organizations for a statement regarding the future with respect to hurricane activity. The governing council of the American Meteorological Society and the Board of Trustees of the University Corporation for Atmospheric Research issued a policy statement in 1988 suggesting that greenhouse-induced global warming over the next 50 years will likely lead to "a higher frequency and greater intensity of hurricanes."[8] By the end of the 1980s, the public must have been convinced that the scientific community was reasonably certain of this prediction, and, as we

[7] Testimony before the Senate Committee on Energy and Natural Resources, June 23, 1988.

[8] American Meteorological Society Council and the Board of Trustees of the University Corporation for Atmospheric Research, "The changing atmosphere - challenge and opportunities," *Bulletin of the American Meteorological Society*, Vol. 69 (1988), pp. 1434-1440.

have seen, there were certainly many good reasons to believe in a coming hurricane-driven set of disasters. Anyone could, for whatever reason, construct a powerful case that humans were facing a world of greenhouse-related perils, including the near-certain threat from the coming hurricanes and hypercanes.

THE DEBATE BEGINS

As with so many components in the greenhouse debate, the hurricane story might seem an open and shut case. Emanuel's research provided theoretical reasons to expect an increase in hurricane activity given the buildup of greenhouse gases. He gave us an easy to remember and scary new name (hypercanes), the world seemed to be warming, and Hurricanes Gilbert and Hugo appeared to provide the final proof. However, as with virtually any other area of science, some people began to question this simple interpretation. Some scientists understood that Kerry Emanuel never made a prediction of increased hurricane activity, but rather, he provided a theoretical discussion of the upper limit of hurricane intensity given a very large increase in sea surface temperatures. Within the community of scholars that knew the most about hurricanes and what Emanuel's research really showed, a quiet caution surrounded the loud and public proclamations regarding the prediction of increased hurricane activity.

In 1990, three different articles appeared in the professional literature that made no headlines in the public outlets, but cast serious doubts to the notion that hurricane activity was on the rise.

In 1990, three different articles appeared in the professional literature that made no headlines in the public outlets, but cast serious doubts to the notion that hurricane activity was on the rise. Noted hurricane scientist William Gray published an article in *Science* dealing with landfall of intense hurricanes in the United States and its relation to rainfall in West Africa.[9] Within that article, Gray revealed that Atlantic hurricane activity over the period 1970 to 1987 was less than half of the activity observed for the period 1947 to 1969. The greenhouse gas concentration was going up exponentially, and yet, Gray found that hurricanes were not showing the expected increase in number or intensity. Rather, they were showing a decrease in overall activity.

Another research project was published in 1990 in *Meteorology and Atmospheric Physics* by a band of greenhouse skeptics at Arizona State University.[10] I worked with Sherwood Idso and Randall Cerveny on a research project that ultimately challenged the prediction for increasing hurricane numbers and intensities in the greenhouse world. For this paper we gathered hurricane data for the central Atlantic, east coast of the United States, the Gulf of Mexico, and the Caribbean Sea for the period 1947 to 1987. Data prior to 1947 were considered unreliable and potentially biased

[9] W. M. Gray, "Strong association between West African rainfall and U.S. landfall of intense hurricanes," *Science*, Vol. 249 (1990), pp. 1251-1256.

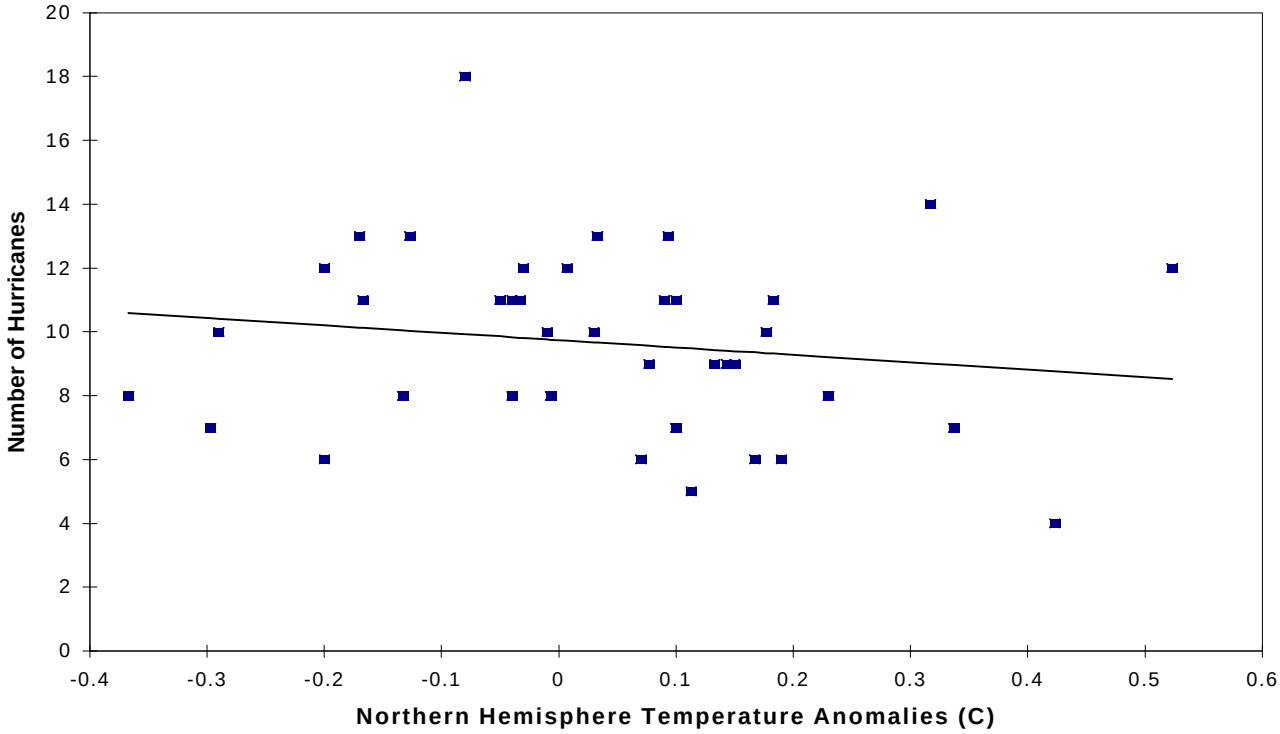
[10] S. B. Idso, R.C. Balling Jr., and R. S. Cerveny, "Carbon dioxide and hurricanes: Implications of Northern Hemispheric warming for Atlantic/Caribbean storms," *Meteorology and Atmospheric Physics*, Vol. 42 (1990), pp. 259-263.

There is basically no trend of any sort in the number of hurricanes experienced in any of the four regions with respect to variations in temperature.

from hurricane assessment procedures used prior to the end of the Second World War. We carefully collected information on the number of hurricanes observed each year in the study area, the number of days with hurricanes, and the number of storms within various hurricane intensity categories. Rather than assess trends in these hurricane variables over the 41-year period, we compared the hurricane data to estimates of the surface temperature in the Northern Hemisphere. Recognizing that the Northern Hemisphere had shown considerable variation (nearly 1°C) in temperature over the 1947 to 1987 period, we wondered how hurricanes had responded to these observed temperature variations.

Our research found that "there is basically no trend of any sort in the number of hurricanes experienced in any of the four regions with respect to variations in temperature."[11] The number of hurricane days was negatively related to the Northern Hemispheric temperatures; warmer years produced the lowest numbers of hurricane days while the cooler years had more than average numbers of hurricane days. The number of storms within the various intensity classes was also inversely correlated with the hemispheric temperature values (Figure 1). We examined the trends with different intensity

Figure 1. *Number of Atlantic/Caribbean hurricanes verses northern hemispheric near-surface air temperature anomalies (°C) for each year from 1948 to 1987*



(Source: S. B. Idso, R.C. Balling Jr., and R. S. Cerveny, "Carbon dioxide and hurricanes: Implications of Northern Hemispheric warming for Atlantic/Caribbean storms," *Meteorology and Atmospheric Physics*, Vol. 42. 1990, pp. 259-263.)

[11] Ibid., p. 261.

classes and concluded: "For global warming on the order of one-half to one degree Centigrade, then, our analyses suggest that there would be *no change in the frequency of occurrence* of Atlantic/Caribbean hurricanes, but that there would be a significant decrease in the intensities of such storms."

This work had some impact on the scientific debate, but the findings were not publicized in major media outlets; good news about the climate makes fewer headlines.[12] Nonetheless, the scientific literature certainly contained another article with evidence arguing against the popular assertion that hurricanes should be blamed on global warming.

Climate models give no consistent indication whether tropical storms will increase or decrease in frequency or intensity as climate changes.

More research appeared in 1990 that raised doubts on the hurricane issue. Broccoli and Manabe published an article entitled "Can existing climate models be used to study anthropogenic changes in tropical cyclone intensity?"[13] When they allowed certain cloud-related feedbacks to be included in their numerical modeling experiments, they noted a 10 to 15 percent reduction in the number of days with hurricanes for a doubling of carbon dioxide. Their numerical simulation with cloud feedbacks suggested a reduction in hurricane number and/or duration for a world of higher concentrations of greenhouse gases. Broccoli and Manabe noted that their results were a bit unstable and highly dependent upon how they represented cloud processes within the model. Nonetheless, this research further undermined the idea that a warmer world would be a stormier world.

A pillar of the greenhouse scare was not likely to collapse given the evidence presented in these three articles. However, 1990 also brought the world the first scientific assessment from the Intergovernmental Panel on Climate Change.[14] In the "Policymakers Summary" of that widely-distributed and highly-touted document, we are told "climate models give no consistent indication whether tropical storms will increase or decrease in frequency or intensity as climate changes; neither is there any evidence that this has occurred over the past few decades."[15] By the end of 1990, the issue of hurricanes and climate change had truly become a part of the heated debate.

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[12] A few critics pointed to a potentially damaging aspect of the research: the fact that some financial support had been provided by the Cyprus Minerals Company. Funding from many other sources (e.g., National Science Foundation, Environmental Protection Agency, National Oceanic and Atmospheric Administration) would be fine, but funding from a mineral company involved with coal raised the jaundiced eye regarding the results presented in the article.

[13] A. J. Broccoli, and S. Manabe, "Can existing climate models be used to study anthropogenic changes in tropical cyclone intensity?" *Geophysical Research Letters*, Vol. 17 (1990), pp. 1917-1920.

[14] J. T. Houghton, G. J. Jenkins, and J. J. Ephraums eds., *Climate Change: The IPCC Scientific Assessment*, (Cambridge, England: Cambridge University Press, 1990).

[15] Ibid, pp. 25.

EBB AND FLOW IN THE 1990s

Throughout the 1990s, articles have appeared in major journals supporting and challenging the prediction of increased hurricane activity in the greenhouse world. In an article dealing with impacts on tropical forests, O'Brien, Hayden, and Shugart assumed that a doubling of carbon dioxide would increase tropical sea surface temperatures from 1°C to 4°C and double the number of hurricanes, increase their strength by 40 to 60 percent, and extend the hurricane season.[16] Although their interest was clearly on the forests, their acceptance of the estimates of hurricane changes had the effect of adding weight and credibility to the claims. In addition, research by Ryan, Watterson, and Evans the suggested that area conducive to hurricane generation could expand substantially in a warming world, although they fully acknowledged that their results gave an overestimation of the area of cyclogenesis.[17]

In other research, Haarsma, Mitchell, and Senior used an 11-layer global general circulation model coupled with an ocean model and found that a doubling of the concentration of greenhouse gases would increase the frequency of hurricanes by 50 percent, increase the mean intensity of the storms by 20 percent, and increase the number of intense hurricanes developing in the greenhouse world.[18] Conversely, Landsea reported that the intensity of Atlantic hurricanes has been decreasing since the middle of this century.[19] Landsea carefully screened his data to remove known biases, and the decreasing trend remained an identifiable pattern in the intensity estimates (Figure 2, page 9).

Landsea reported that the intensity of Atlantic hurricanes has been decreasing since the middle of this century.

Soon thereafter, eight scientists collaborated on a major review piece entitled "Global climate change and tropical cyclones," that appeared in the *Bulletin of the American Meteorological Society* in 1994 (Lighthill, hereafter).[20] The authors took two basic approaches, but both led to the conclusion that "even though the possibility of some minor effects of global warming on tropical cyclone frequency and intensity cannot be excluded, they must effectively be 'swamped' by large natural variability." This is hardly an endorsement for the idea that any future increases in hurricanes can be expected or blamed on the buildup of greenhouse gases.

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[16] S. T. O'Brien, B.P. Hayden, and H.H. Shugart, "Global climatic change, hurricanes, and a tropical forest," *Climatic Change*, Vol. 22 (1992), pp. 175-190.

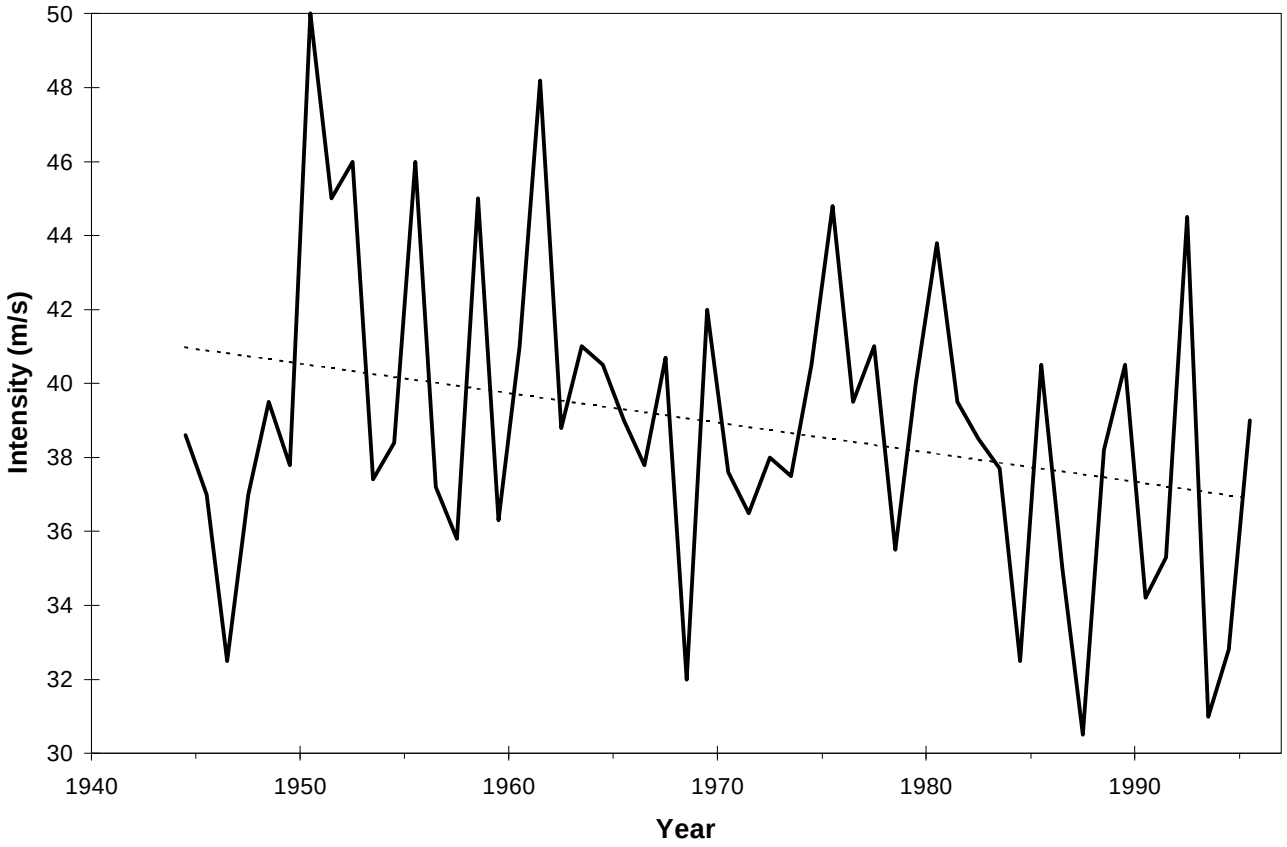
[17] B.F. Ryan, I.G. Watterson, and J.L. Evans, "Tropical cyclone frequencies inferred from Gray's yearly genesis parameter: Validation of GCM tropical climates," *Geophysical Research Letters*, Vol. 19 (1992), pp. 1831-1834.

[18] R. J. Haarsma, J. F. B. Mitchell, and C.A. Senior, "Tropical disturbances in a GCM," *Climate Dynamics*, Vol. 8 (1993), pp. 247-257.

[19] C. W. Landsea, "A climatology of intense (or major) Atlantic hurricanes," *Monthly Weather Review*, Vol. 121 (1993), pp. 1703-1713.

[20] J. Lighthill, G. Holland, W. Gray, C. Landsea, G. Craig, J. Evans, Y. Kurihara, and C. Guard, "Global climate change and tropical cyclones," *Bulletin of the American Meteorological Society*, Vol. 75 (1994), pp. 2147-2157.

Figure 2. *Time series of Atlantic basin mean intensity (m/s). as determined from maximum sustained wind speeds of all hurricanes, in each year from 1944 to 1995*



(Source: C. W. Landsea, N. Nicholls, W.M. Gray, and L. A. Avila, "Downward trends in the frequency of intense Atlantic hurricanes during the past five decades." *Geophysical Research Letters*, Vol. 23. 1996, pp. 1697-1700)

One approach taken in the Lighthill study involved an examination of a widely accepted list of conditions for permitting hurricane formation and development. The list includes some simple conditions such as a sea-surface temperature above 26°C, distance from the equator of at least five degrees of latitude, and fairly high relative humidity levels surrounding the storm. Other entries on the list examined more complex conditions dealing with the vertical temperature structure of the atmosphere, the change in wind velocity with height, and horizontal rotation of the system. Their analyses led to the conclusion that we should not expect any direct effects of changing sea surface conditions on hurricane frequency and intensity. The authors point out that many unknowns and indirect effects could occur, but they found most impacts of rising sea surface temperature to be self-limiting. In other words, global warming should not produce more hurricanes.

This study also examined the empirical records of hurricane activity since 1944 in the Atlantic and since 1970 in the Pacific. The authors noted great year-to-year variability in the hurricane data, but they could not find evidence to link hemispheric temperatures to variations in hurricane activity.

Not surprisingly, their article stirred-up the debate on the hurricane question. Emanuel questioned the Lighthill evaluation, and suggested that both the basic physics and the empirical records of hurricane activity suggest that warming in the tropical oceans would be accompanied by an increase in the limiting intensity of actual hurricanes.[21] Broccoli and three colleagues also questioned the pessimistic view of the Lighthill study regarding the use of numerical climate models, and they suggested that current and future simulations hold enormous promise in providing answers to the questions surrounding future tropical storms.[22] In that same year, Pielke reported to the insurance industry that recent decades have been unusually quiet in terms of the number of hurricanes making landfall in Florida, and he suggested that a return to normal conditions would substantially increase hurricanes in Florida.[23]

Landsea reconfirmed the view that hurricane frequency and intensity were not increasing over the past five decades.

Lennart Bengtsson of Germany's Max Planck Institut fur Meteorologie was one of the members of the Broccoli team that commented on the Lighthill article. One year later, Bengtsson co-authored a paper in *Tellus* entitled, "Will greenhouse gas-induced warming over the next 50 years lead to a higher frequency and greater intensity of hurricanes?"[24] In this study, high-resolution numerical simulations with a coupled ocean-atmosphere model showed that greenhouse-induced changes would weaken the Hadley circulation that dominates the tropics but strengthen the upper-level westerlies in the vicinity of hurricane development. When compared to present day global distribution and seasonality of hurricanes, they found no changes for a doubling of a greenhouse gases. However, the number of hurricanes in the Northern Hemisphere fell from 56.2 storms per year in the present-day climate simulation to only 42 storms per year for a doubling of carbon dioxide or its equivalent. (The observed value from 1958-1977 is 54.6.) In the Southern Hemisphere, the number of hurricanes dropped from 26.8 in the present-day model run to only 11.6 storms per year. (24.5 is the observed value.) Their results on intensity were less conclusive, but they did find a tendency for reduced wind speeds in model simulations of a doubling of carbon dioxide.

[21] K. A. Emanuel, "Comments on 'Global climate change and tropical cyclones': Part I," *Bulletin of the American Meteorological Society*, Vol. 76 (1995), pp. 2241-2243.

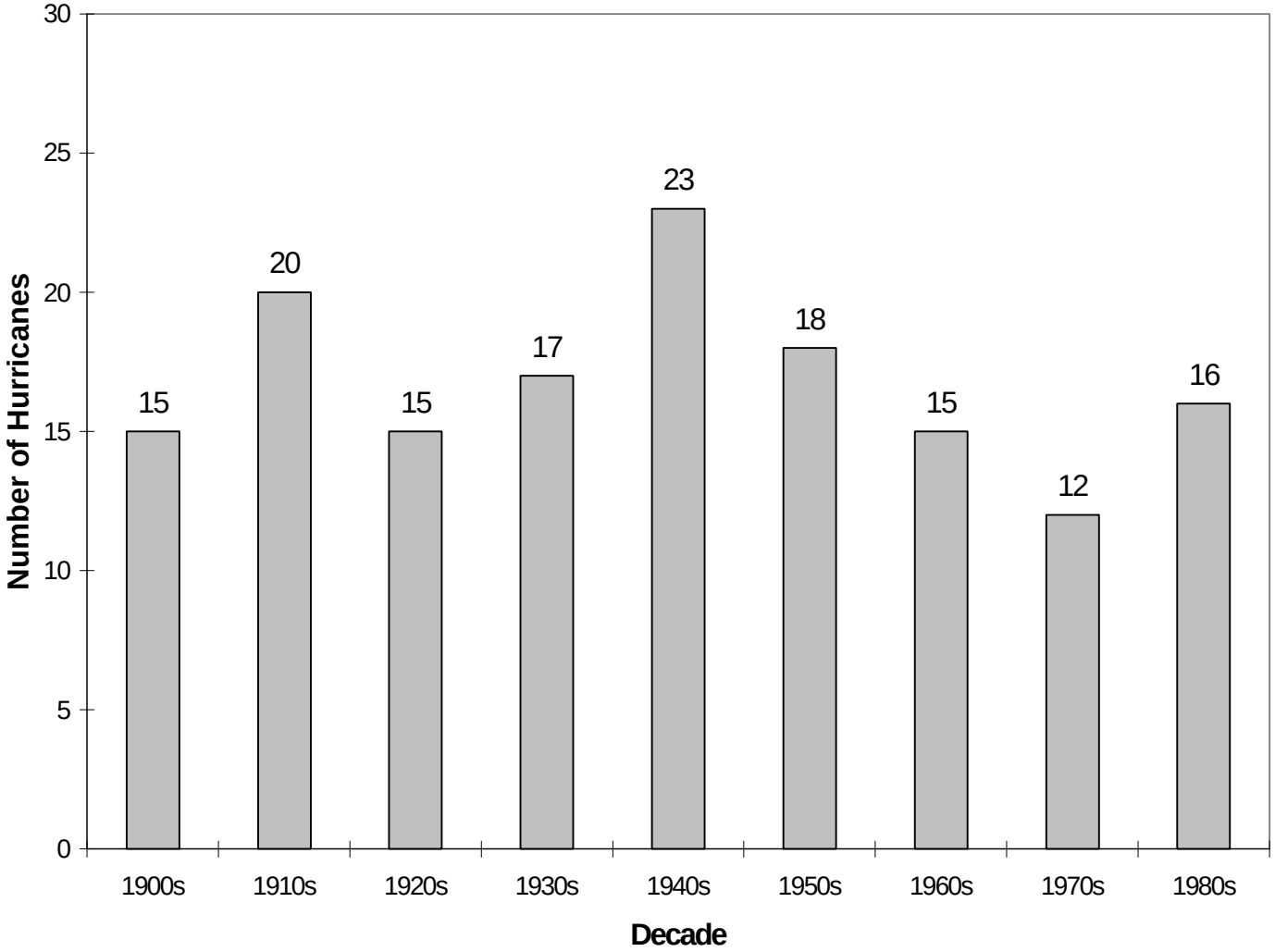
[22] A. J. Broccoli, S. Manabe, J. F. B. Mitchell, and L. Bengtsson, "Comments on 'Global climate change and tropical cyclones': Part II," *Bulletin of the American Meteorological Society,* Vol. 76 (1995), pp. 2243-2245.

[23] R. A. Pielke, Jr., "Preparing for the past: Global warming and response to hurricanes in the U.S.," *Insurance Specialist,* Vol. 1 (1995), pp. 14-15.

[24] L. Bengtsson, M. Botzet, and M. Esch, "Will greenhouse gas-induced warming over the next 50 years lead to a higher frequency and greater intensity of hurricanes?" *Tellus,* Vol. 48A (1996), pp. 57-73.

Another article by Landsea et al. reconfirmed the view that hurricane frequency and intensity were not increasing over the past five decades.[25] This study examined Atlantic hurricanes from 1944, when aircraft reconnaissance began in the Atlantic, to the present. The researchers found that "a long-term (five decade) downward trend continues to be evident primarily in the frequency of intense hurricanes. In addition, the mean maximum intensity (i.e., averaged over all cyclones in a season) has decreased." A plot of the mean intensity (Figure 2, page 9) clearly shows this downward trend during a time of greatest buildup of greenhouse gases. Landsea et al. are fully aware that hurricanes occur in other ocean basins, but the data quality problems from other parts of the world preclude similar analyses from other locations.

Figure 3. *Number of hurricanes making landfall in the conterminous United States*



(Source: T.R. Karl, R. W. Knight, D. R. Easterling, and R. G. Quayle, "Trends in U.S. climate during the twentieth century," Consequences, Vol. 1 (1995), pp. 3-12; and T. R. Karl, R. W. Knight, D. R. Easterling, and R. G. Quayle, "Indices of climate change for the United States," *Bulletin of the American Meteorological Society*, Vol. 77. 1996, pp. 279-292)

[25] C. W. Landsea, N. Nicholls, W.M. Gray, and L. A. Avila, "Downward trends in the frequency of intense Atlantic hurricanes during the past five decades." *Geophysical Research Letters*, Vol. 23 (1996), pp. 1697-1700.

This downward trend in Atlantic basin hurricanes over the past five decades is certainly interesting, but it raises a question about trends prior to the 1940s. Hard evidence is difficult to find for storms that moved through the Atlantic prior to the World War II. However, in 1995 and 1996 Karl et al. examined records of the number and intensity of hurricanes that reached the continental United States over the past century.[26] Their research showed that the number of hurricanes making landfall in the United States has decreased from the 1940s through the 1980s, but their records also showed an increase in storms in the first half of the record (Figure 3, page 11). Over the twentieth century, no overall trend was discernible in the records. Elsner et al. looked at Atlantic hurricanes in the tropics from 1896 to 1990, and they noted a drop in these tropical hurricanes in the 1960s.[27] The trend in tropical hurricanes was clearly downward during the past 50 years of most reliable records.

The number of hurricanes making landfall in the United States has decreased from the 1940s through the 1980s.

The second scientific assessment of the Intergovernmental Panel on Climate Change was published in 1996 and once again, this international body addressed the issue of increasing hurricane activity in the next century.[28] The IPCC has refused to endorse the apocalyptic view that a modest warming will significantly increase hurricane activity. In the Technical Summary, the IPCC group states: "Although some models now represent tropical storms with some realism for present day climate, the state of the science does not allow assessment of future changes."[29] Similarly, Karl et al. reported in *Scientific American* that: "Overall, it seems unlikely that tropical cyclones will increase significantly on a global scale. In some regions, activity may escalate; in others, it will lessen."[30] These summary statements are hardly ringing endorsements for the popular claim that we should blame hurricanes on global warming, but have received far less attention than more apocalyptic projections.

BLAMING WARMING?

One of the most interesting ironies in the claims that recent hurricane activity is linked to warming is that the warming itself may not have occurred — there is strong evidence from satellite measurements that the planet has actually cooled over the past few decades (see Figure 4, page 13). Each day, measurements of microwave emissions from molecular oxygen in the lower

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[26] T.R. Karl, R. W. Knight, D. R. Easterling, and R. G. Quayle, "Trends in U.S. climate during the twentieth century," *Consequences*, Vol. 1 (1995), pp. 3-12; and T. R. Karl, R. W. Knight, D. R. Easterling, and R. G. Quayle, "Indices of climate change for the United States," *Bulletin of the American Meteorological Society*, Vol. 77 (1996), pp. 279-292.

[27] J. B. Elsner, G. S. Lehmiller, and T. B. Kimberlain, "Objective classification of Atlantic hurricanes," *Journal of Climate*, Vol. 9 (1996), pp. 2880-2888.

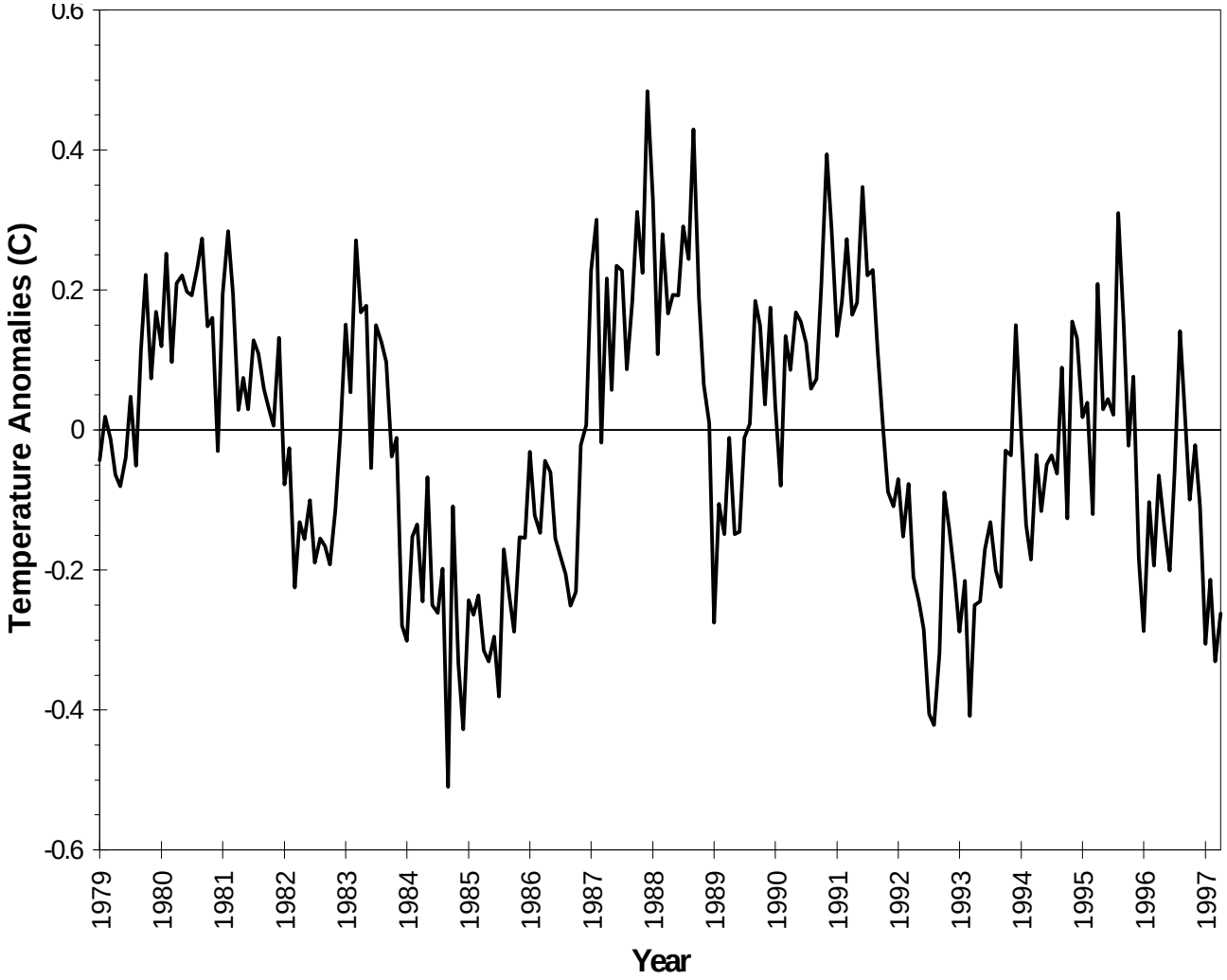
[28] J. T. Houghton, L. G. Meira Filho, B. A. Callander, N. Harris, A. Kattenberg, and K. Maskell, eds. *Climate Change 1995: The Science of Climate Change*, (Cambridge, England: Cambridge University Press, 1996).

[29] Ibid., p. 44.

[30] T. R. Karl, N. Nicholls, and J. Gregory, "The coming climate," *Scientific American* (May 1997) pp. 79-83.

eight kilometers of the atmosphere are made by instruments onboard polar orbiting satellites, and the results provide an excellent measure of lower-tropospheric temperatures.[31] Microwaves are able to penetrate the atmosphere with little attenuation, and the amount of energy received by the satellites is directly proportional to the temperature in the lower atmosphere. The 53.74 GHz channel is highly sensitive to the thermal emission of molecule oxygen in the middle troposphere and has little sensitivity to water vapor, the earth surface properties, or cloud variations. The polar orbits of the satellites assure that the entire earth is covered; remote and oceanic areas of the earth are covered as easily as any other part of the planet.

Figure 4. *Satellite-based monthly planetary temperature anomalies from January 1979 to April 1997*



(Source: R. W. Spencer and J.R. Christy, "Precise monitoring of global temperature trends from satellites," *Science,* Vol. 247 (1990), pp. 1558-1562)

[31] R. W. Spencer and J.R. Christy, "Precise monitoring of global temperature trends from satellites," *Science,* Vol. 247 (1990), pp. 1558-1562.

As seen in Figure 4, the satellites have not observed any warming since the measurement program began in 1979. Over the period January 1979 to April 1997, the satellites have actually observed a statistically significant *cooling* of 0.09°C! Furthermore, the first four months of 1997 have been cold on the global scale with no warming in sight. Blaming hurricanes on recent warming is flawed on all fronts — not only is there little to no linkage between global warming and hurricane activity, but there seems to have been no warming in recent decades either. But as we see on the *Newsweek* cover, these facts simply make little difference in the greenhouse debate.

THE FUTURE

As we have seen in this section, a highly popular view has developed that the buildup of greenhouse gases will cause the sea surface and atmospheric temperatures to rise, and this will result in an increase in the number and intensity of damaging hurricanes around the world. But as with so many other elements in the greenhouse debate, the theoretical and empirical evidence is not very supportive of this claim. Indeed, there is plenty of evidence to argue that the greenhouse effect will suppress hurricane activity.

There is strong evidence from satellite measurements that the planet has actually cooled over the past few decades.

In terms of direct effects, the information we have today does not predict any increase in the number of hurricanes in the future. Similarly, the mean intensity of the hurricanes that develop is not likely to increase. Emanuel's research has survived a decade of debate, and should there be a substantial warming in the tropical sea surface, the upper limit of hurricane intensity probably will rise, and over a long time period, a few very powerful hurricanes may develop.

A compounding factor exists that may make detection of any changes more difficult than ever. It is well known that interannual variations in El Nino and La Nina have a significant impact on hurricane activity.[32] During the El Nino periods with warm water off the Pacific coast of South America, the upper-level winds over the Atlantic increase, hurricane development and maintenance are inhibited, and the number of hurricanes as well as hurricane days are reduced. Alternatively, the cold water phase, called La Nina, tends to be associated with increased hurricane activity in the Atlantic. The overriding problem here is that Meehl and Washington have presented results from climate model simulations showing that an increase in the atmospheric concentration of greenhouse gases could lead to climatic anomalies in the tropical Pacific that are similar to the quasi-periodic (and natural) El Nino events.[33] This finding further complicates the problem of

[32] W. M. Gray, "Atlantic seasonal hurricane frequency. Part 1: El Nino and 30 mb quasi-biennial oscillation influences," *Monthly Weather Review,* Vol. 112 (1984), pp. 1649-1668.

[33] G. A. Meehl and W.M. Washington, "El Nino-like climate change in a model with increased atmospheric CO_2 concentrations," *Nature,* Vol. 382 (1996), pp. 56-60.

untangling natural variations in hurricane activity from the effects of humans increasing the concentration of greenhouse gases in the atmosphere.

questions — the month-to-month information flow in the greenhouse debate gives it a flavor unlike many similar debates in science. But if your insurance company raises your rates in the name of increased hurricane risk, get skeptical, get the facts, and get the truth working for you. It is easy to go along

expect an increase in hurricane activity throughout the upcoming century.

There is plenty of evidence to argue that the greenhouse effect will suppress hurricane activity.

ABOUT THE AUTHOR

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