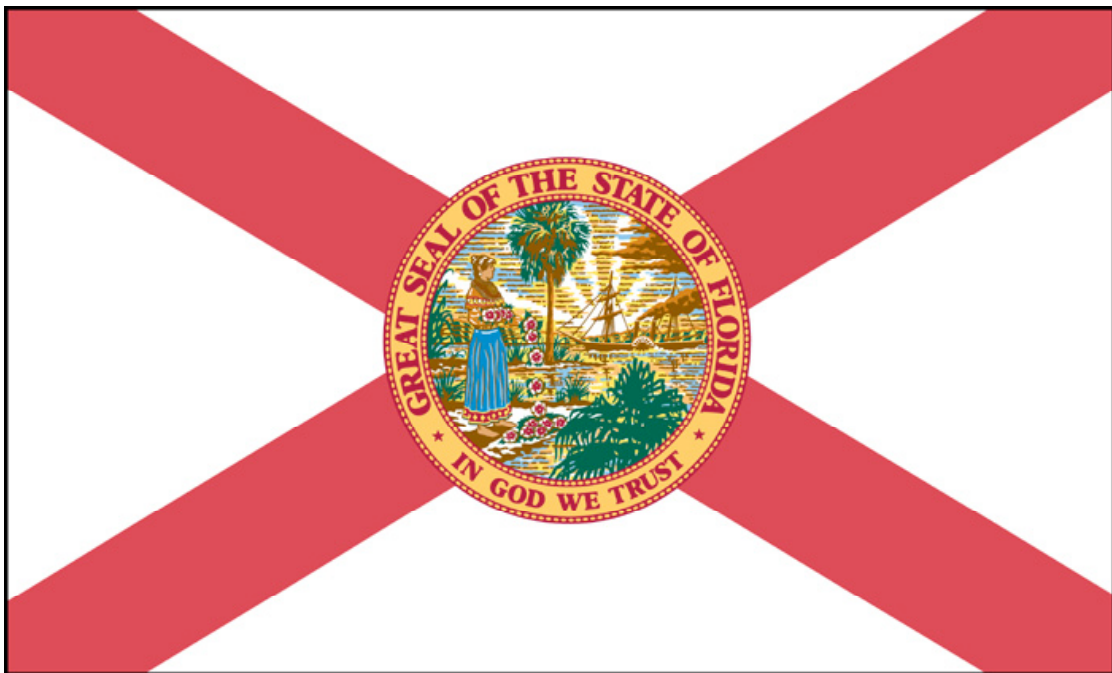


Climate Change in Florida

Is There a Human Footprint in Florida's Climate History?

by

The Center for Science and Public Policy



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I. Introduction

Florida's governor Charlie Crist opened his 2007 legislative session by announcing Florida's Climate Change Summit to be held July 12-13 in Miami. Governor Crist remarked, "I am persuaded that global climate change is one of the most important issues that we will face this century. With almost 1,200 miles of coastline and the majority of our citizens living near that coastline, Florida is more vulnerable to rising ocean levels and violent weather patterns than any other state."

In this report, we review the history of the observed climate and climate trends in Florida and look for evidence that global climate changes caused by anthropogenic emissions of carbon dioxide are adversely impacting the denizens of Florida.

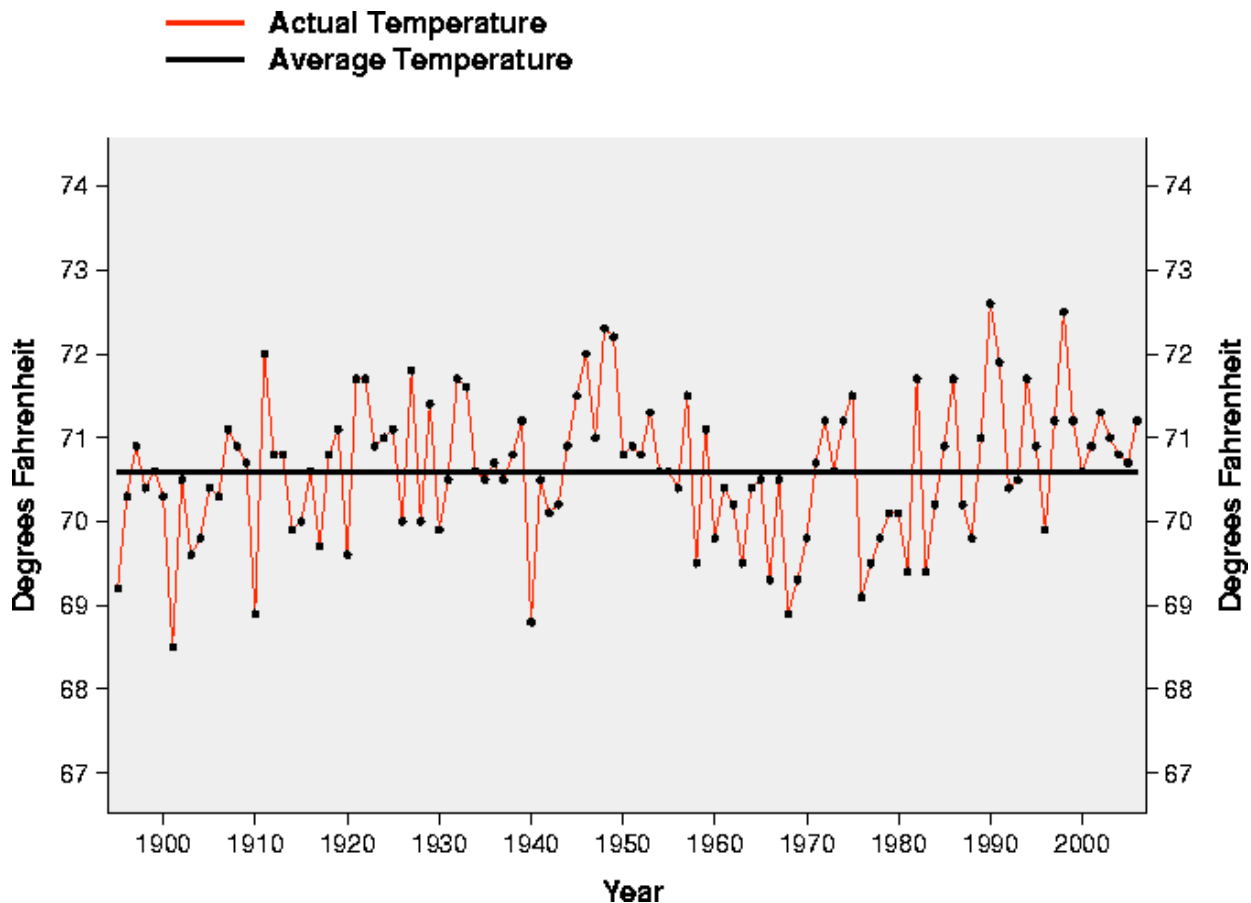
This is a useful exercise since levels of greenhouse gases in the atmosphere are already three-quarters of the way towards an effective doubling of carbon dioxide concentrations, the benchmark typically used in making global warming predictions. If global warming predictions are true, then the consequences of global warming should already be evident in the climate data.

As we will show, that evidence is hard to come by. The rate of sea level rise observed along Florida's coastline is little changed for the past century or more, hurricane landfalls show marked interdecadal variability but little to no overall trend, Florida's population is well-adapted to high temperatures and shows no ill-effects resulting from heat waves, and statewide average temperature, precipitation, and moisture conditions fluctuate from year-to-year but indicate no long-term tendencies.

II. Observed Climate Change in Florida

A. Temperature

For over a century, there has been no statistically significant long-term trend in statewide average temperatures for the state of Florida. Current temperatures are similar to those experienced in the 1920s, 1930s and 1940s.

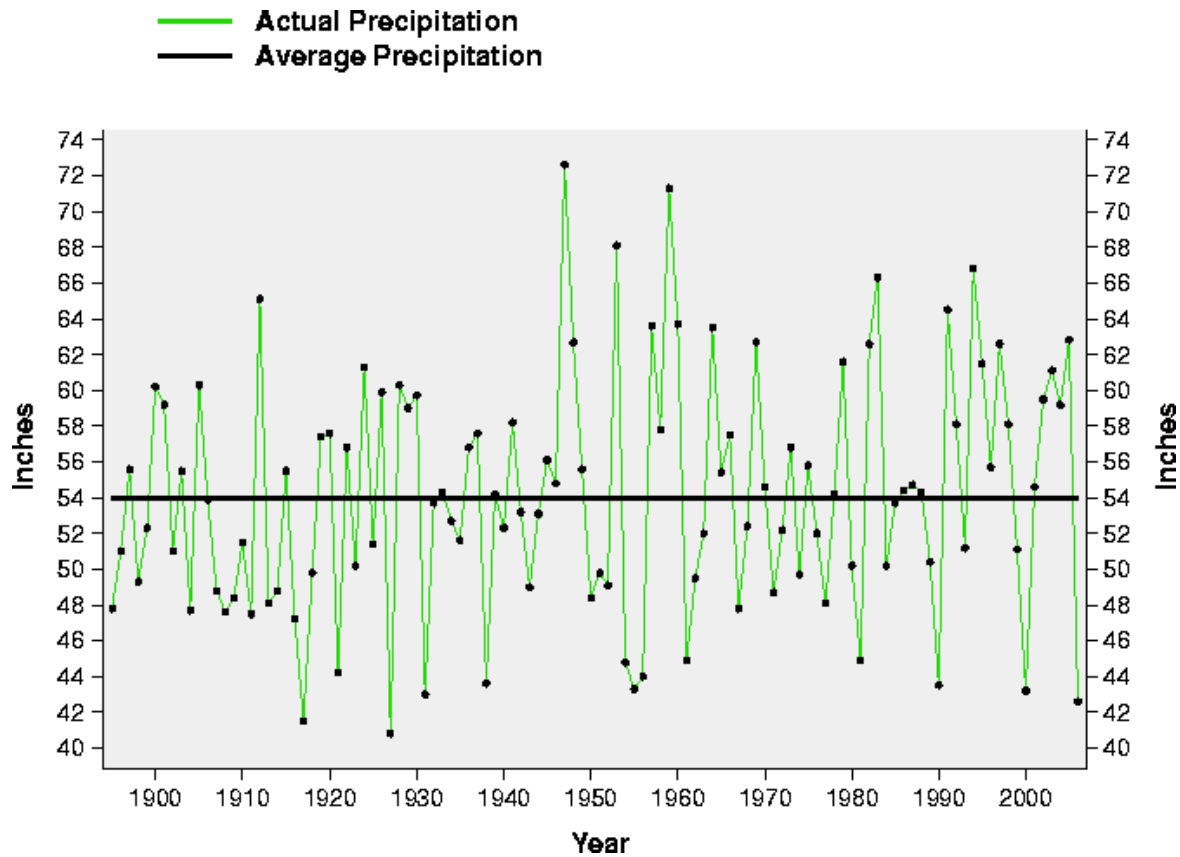


Florida's long-term statewide annual average temperature history as compiled and maintained by the National Climate Data Center (<http://climvis.ncdc.noaa.gov/cgi-bin/cag3/hr-display3.pl>)

According to records compiled and maintained by the National Climatic Data Center (www.ncdc.noaa.gov/oa/climate/research/cag3/fl.html), statewide annual average temperatures show no statistically significant long-term trend since record keeping began in 1895. Instead, the temperature history of the state of Florida has been characterized by variability on yearly and decadal timescales. Recent temperatures are characteristic of those observed during the 1920s, 1930s, and 1940s and are not at all unusual when viewed in the context of the past century or so. When examined on a seasonal level, winter and spring temperatures show little long-term change, while summer and fall temperatures have warmed by about half a degree F over the past 112 years.

B. Precipitation

Since 1895, there has been no statistically significant long-term trend in statewide total precipitation in Florida.



Florida's long-term statewide annual precipitation history as compiled and maintained by the National Climate Data Center (<http://climvis.ncdc.noaa.gov/cgi-bin/cag3/hr-display3.pl>)

Records compiled and maintained by the National Climatic Data Center (www.ncdc.noaa.gov/oa/climate/research/cag3/fl.html), show that the Florida statewide annual total precipitation is variable from year-to-year but shows no statistically significant long-term trend during the past 112 years. While 2006 was a dry year, it follows a succession of relatively wet years.

Such variability is by no means unusual, as similar year-to-year swings have been observed many times during the past century. Conditions in recent years appear not at all unusual.

C. Drought

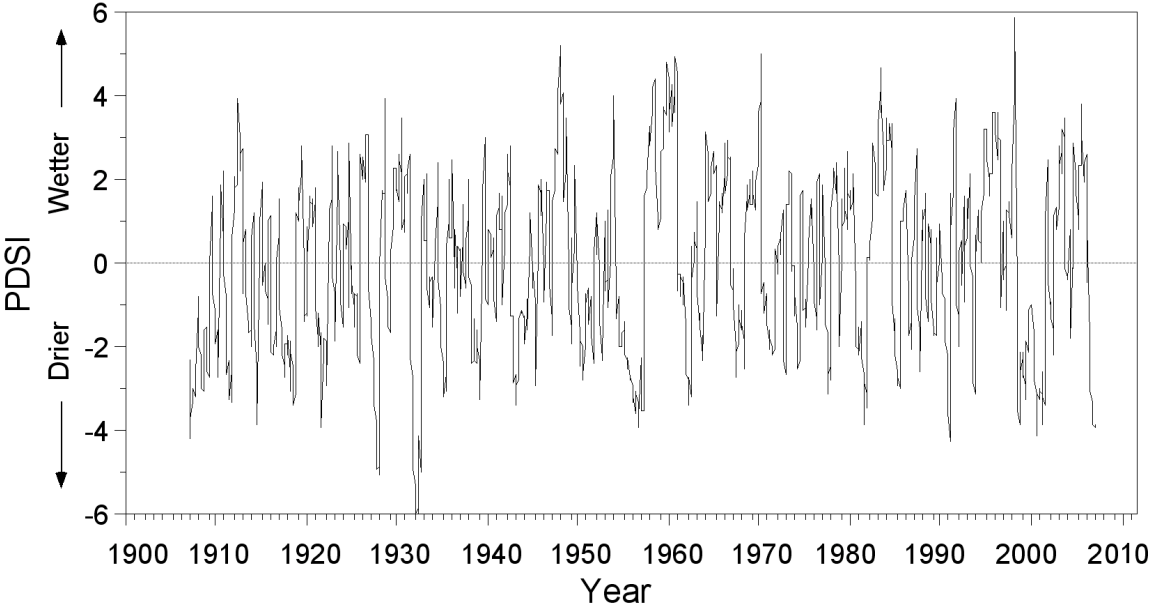
During the past century, there has been no long-term trend in statewide incidence of drought in Florida. According to records compiled by the National Climatic Data Center, statewide monthly average Palmer Drought Severity Index values—a standard measure of

moisture conditions that takes into account both inputs from precipitation and losses from evaporation—show no long-term trend.

The period of record is dominated by short-term variations, although some longer-term signals are present, such as the extended period of drought in the mid-1950s followed by a wet period in the late-1950s to early 1960s. The ongoing drought in 2007 has followed a multi-year wet period.

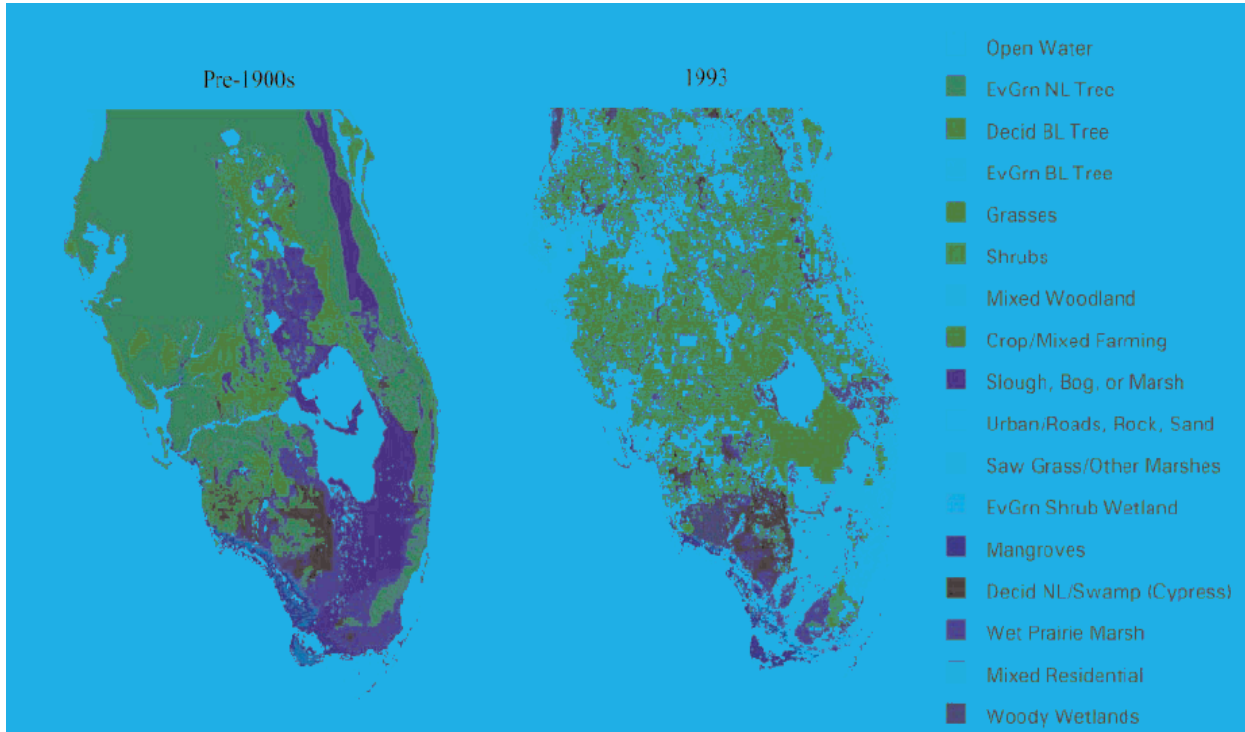
There is no evidence of any recent behavior that is out of the ordinary within the long-term perspective, despite the current dry conditions.

**Florida Statewide Average Palmer Drought Severity Index (PDSI)
Past Century, 1907-2006**



III. Climate and Land Use Change

Florida's landscape has undergone extensive revisions during the past 100 years as the state's growing population has sought to take advantage of Florida's climate for both lifestyle and agriculture.



Land-cover data for pre-1900 period (left) and in 1993 (right) from data from the United States Geological Survey (from Marshall et al., 2004a).

These widespread landscape changes have been shown to have a demonstrable impact of Florida's climate through a series of important modeling and observational studies published within the past several years. Marshall et al. (2004a) describe their efforts and results this way:

During the twentieth century, the natural landscape of the Florida peninsula was transformed extensively by agriculture, urbanization, and the diversion of surface water features. The purpose of this paper is to present a numerical modeling study in which the possible impacts of this transformation on the warm season climate of the region were investigated. For three separate July–August periods (1973, 1989, and 1994), a pair of simulations was performed with the Regional Atmospheric Modeling System. Within each pair, the simulations differed only in the specification of land-cover class. The two different classes were specified using highly detailed datasets that were constructed to represent pre-1900 natural land cover and 1993 land-use patterns, thus capturing the landscape transformation within each pair of simulations.

When the pre-1900 natural cover was replaced with the 1993 land-use dataset, the simulated spatial patterns of the surface sensible and latent heat flux were altered significantly, resulting in changes in the structure and strength of climatologically persistent, surface-forced mesoscale circulations—particularly the afternoon sea breeze fronts. This mechanism was associated with marked changes in the spatial distribution of convective rainfall totals over the peninsula. When averaged over the model domain, this redistribution was reflected as an overall decrease in the 2-month precipitation total.

In addition, the domain average of the diurnal cycle of 2-m temperature was amplified, with a noted increase in the daytime maximum. These results were consistent among all three simulated periods, and largely unchanged when subjected to a number of model sensitivity factors. Furthermore, the model results are in reasonable agreement with an analysis of observational data that indicates decreasing regional precipitation and increasing daytime maximum temperature during the twentieth century.

These results could have important implications for water resource and land-use management issues in south Florida, including efforts to restore and preserve the natural hydroclimate of the Everglades ecosystem. This study also provides more evidence for the need to consider anthropogenic land-cover change when evaluating climate trends. [emphasis added]

In other words, Marshall et al. (2004a) found that changes to Florida's landscape over the past 100 years have led to significant changes in the patterns of summer rainfall as well as temperature. The landscape changes resulted in less summer precipitation and higher summer maximum temperature. The authors deemed these changes to be significant enough to suggest that politicians and planners consider them in their evaluations of future water resource and land-use management issues. And further, these changes had nothing to do with carbon dioxide emissions.

These researchers (Marshall et al., 2004b) also found that land-use changes may be increasing the likelihood and severity of damaging frosts negatively impacting the state's citrus industry. Writing in *Nature* magazine,

South Florida experienced a significant change in land usage during the twentieth century, including the conversion of natural wetlands into agricultural land for the cultivation of winter vegetable, sugar cane and citrus crops. This movement of agriculture from more northerly areas was intended partly to escape the risk of damaging winter freezes.

Here we present evidence from a case study using a coupled atmosphere and land-surface computer-modelling system that suggests that the draining of wetlands may have inadvertently increased the frequency and severity of agriculturally damaging freezes in the south of Florida.... This is ironic, considering that the move was instigated partly to avoid the freezes that occur further to the north. Our results provide another example of the potential for anthropogenic changes in land usage to perturb the climate system.

The significance of these results should be apparent—climate changes that have resulted from landscape changes have an impact on Florida’s current and future water resource needs as well as aspects of Florida’s economy. And these changes are largely independent from any climate changes that may result from other natural or anthropogenic sources. Thus, the picture of Florida’s climate and its multitude of drivers is one that is far more complex than a naïve “fossil fuels emissions up/Florida’s climate down” sort of notion.

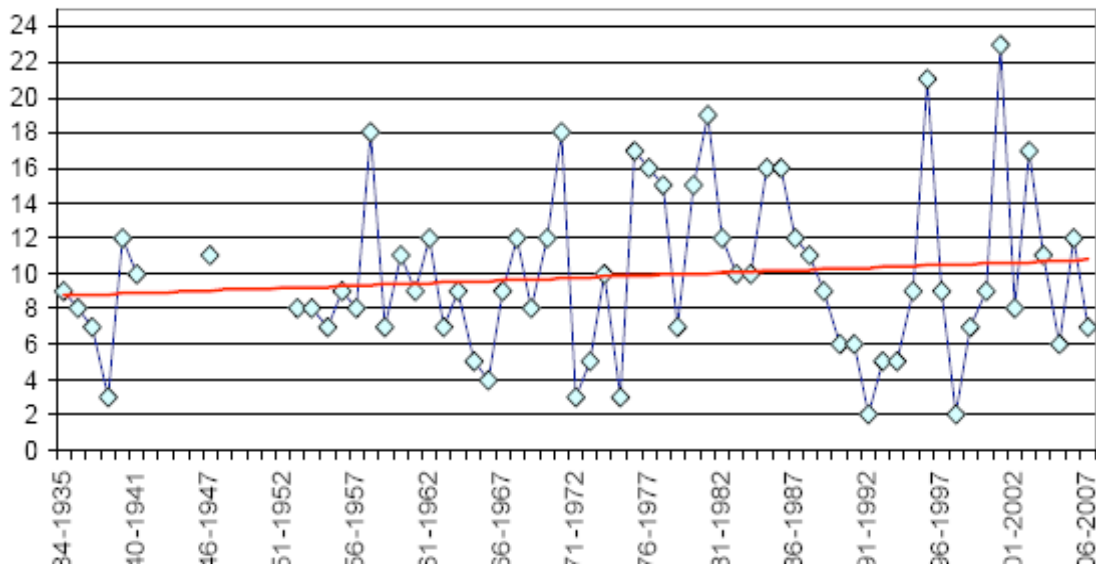
Furthermore, at a May 9-11, 2007 climate change conference held by the Florida Center for Environmental Studies (<http://www.ces.fau.edu/ccf/>) to examine the potential impacts of climate change in Florida. A research team headed by Dr. Hilary Swain, the executive director of the Archbold Biological Station—a long-term, relatively undisturbed natural preserve located on nearly 5,200 acres in south central Florida—gave a presentation entitled “Simplistic predictions, confounding effects, and complex responses; climate tales from Archbold Biological Station” (http://www.ces.fau.edu/ccf/presentations/science/Session_4/02_Swain_CCC.pdf).

Dr. Swain’s team examined the historical observations made at the Archbold Biological Station for the past 70+ years in light of expectations that have been projected to result from anthropogenic climate changes. Dr. Swain laid out the simplistic projections of changes to the state’s climate due to anthropogenic climate change that were drawn from a publication jointly produced in 2001 by the Union of Concerned Scientists and Ecological Society of America titled “Confronting Climate Change in the Gulf Coast Region”—higher summer temperatures, a decrease in winter cold spells, a northward shift in the frost line, earlier breeding for plants and animals, warming of lakes, and increases in drought related fires. She and her colleagues then looked through the varied observations collected at Archbold Research Station for confirmation of these expected/projected changes.

What they found was anything but a clear picture of anthropogenic climate change and/or its impacts. Maximum temperatures during both the summer and the winter showed little long-term change while minimum temperatures in both season were found to be declining. In fact, the number of freeze days per year has actually increased over the past 70 years there.

These trends are consistent with the long-term water temperature measurements from Archbold’s Lake Annie, which show a decline since the mid-to-late 1980s. The historical egg-laying times of the Florida Scrub Jay show no clear long-term trends but instead a strong relationship to El Niño/La Niña cycles. And the history of fire was found to be largely driven by the number of burn permits issued.

Number of freeze days at Archbold



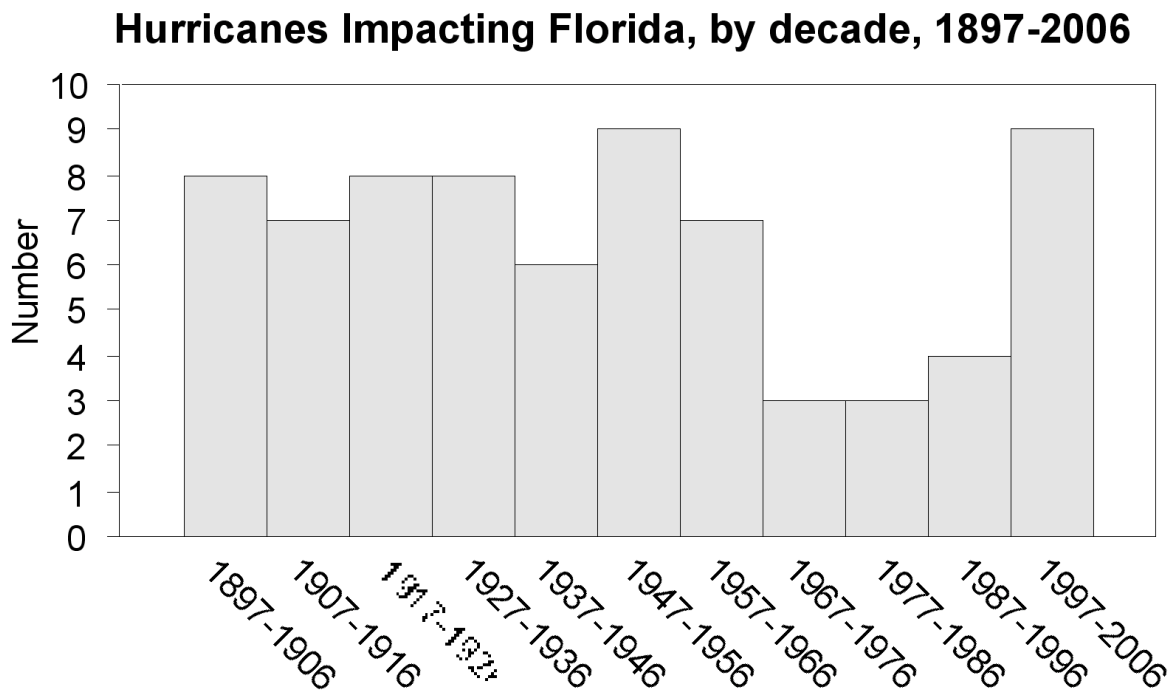
Number of freeze days recorded at the Archbold Research Station in south central Florida since the winter of 1934-35 (from Swain et al., 2007)

Overall, Dr. Swain’s team concluded that there was “no good support for our simplistic predictions” instead they found “plenty of confounding effects, and complex responses” including the existence of naturally occurring 20-30 year climate cycles that dominate any long-term trends in droughts and floods, strong signals from land use changes such as wetland losses and urbanization (even in a relatively isolated setting in central Florida), and socio-economic impacts such as changes in the issuances of burn permits.

IV. Climate Impacts

A. Hurricanes

Despite the increase in Atlantic basin hurricane frequency and intensity during the past decade or so, the number of hurricanes affecting Florida shows no long-term trend.

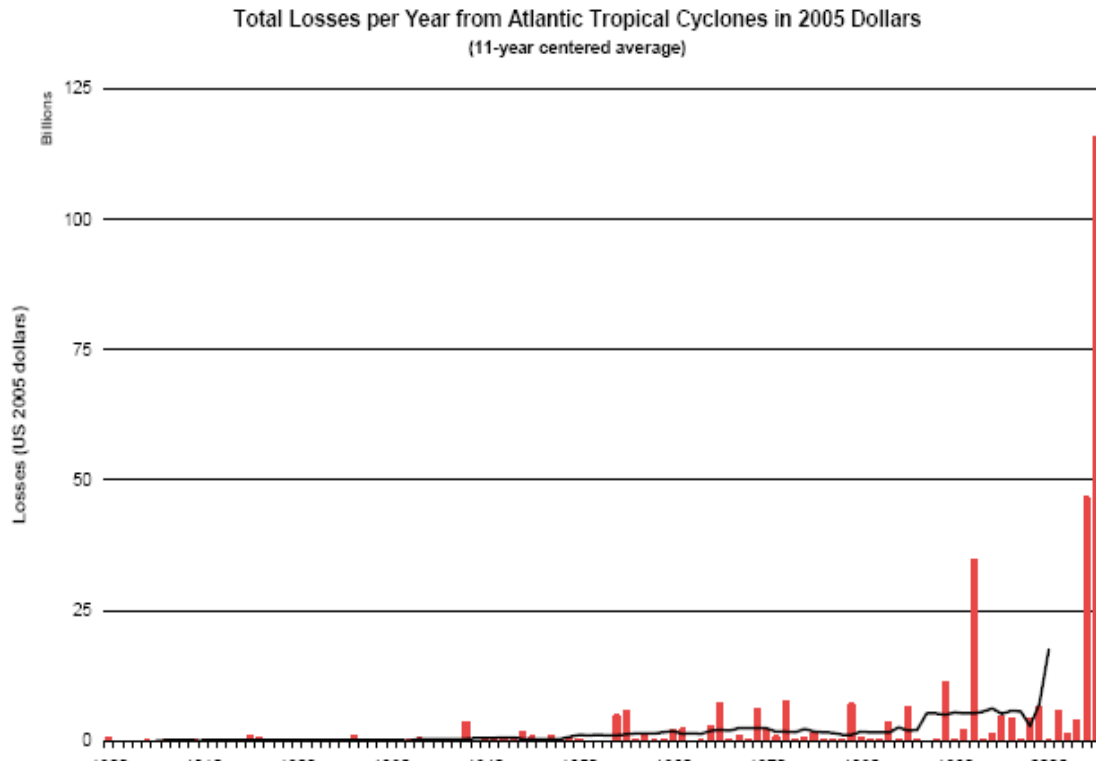


Number of hurricane impacting Florida, by decade, 1897-2006.

Since 1995 there has been an increase in both the frequency and intensity of tropical storms and hurricanes in the Atlantic basin. While some scientists have attempted to link this increase to anthropogenic global warming, others have pointed out that Atlantic hurricanes exhibit long-term cycles, and that this latest upswing is simply a return to conditions that characterized earlier decades in the 20th century.

Along the Florida coast, according to records from the National Hurricane Center (<http://www.aoml.noaa.gov/hrd/tcfaq/E23.html>), the number of total hurricanes exhibits decadal variations, but no real long-term trends. The number of hurricanes impacting Florida during the last 10-year period, 1997-2006, was similar to periods in the first half of the 20th century. However, since it follows a 3 decade-long period of relative quiet, the recent period has seemed exceptionally active. In fact, it has not been in the greater historical perspective.

New research by a team of researchers led by Dr. Roger Pielke Jr. (2007) examines the historical damage amounts from tropical cyclones in the United States from 1900 to 2005. What they found, when they adjusted the reported damage estimates for inflation, was a trend towards increasing amounts for loss, peaking in the years 2004, with the storms that hit Florida, and 2005, which included Katrina as the record holder, causing \$81 billion in damage.

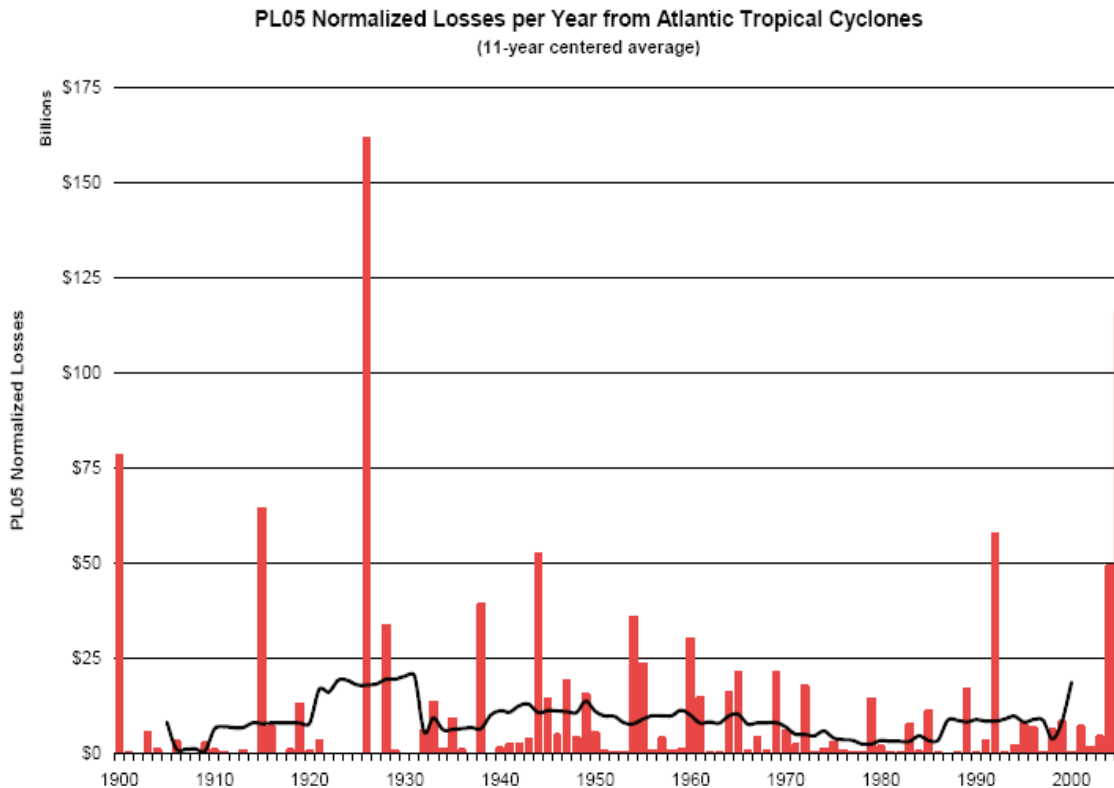


U.S. tropical cyclone damage (in 2005 dollars) when adjusted for inflation, 1900-2005 (from Pielke Jr., et al., 2007)

However, many changes have occurred in hurricane prone areas since 1900 besides inflation. These changes include a coastal population that is growing in size as well as wealth. When adjustments considering all three factors were made, they found no long-term change in damage amounts. In fact, the loss estimates in 2004 and 2005, while high, were not historically high. The new record holder, for what would have been the most damaging storm in history had it hit in 2005, was the Great Miami hurricane of 1926, which they estimated would have caused \$157 billion in damage.

After the Great Miami hurricane and Katrina (which fell to second place), the remaining top-ten storms (in descending order) occurred in 1900 (Galveston 1), 1915 (Galveston 2), 1992 (Andrew), 1983 (New England), 1944 (unnamed), 1928 (Lake Okeechobee 4), 1960 (Donna/Florida), and 1969 (Camille/Mississippi).

There is no obvious bias towards recent years. In fact, the combination of the 1926 and 1928 hurricanes places the damages in 1926-35 nearly 15% higher than 1996-2005, the last decade Pielke Jr. and colleagues studied.



U.S. tropical cyclone damage (in 2005 dollars) when adjusted for inflation, population growth and wealth, 1900-2005 (from Pielke Jr., et al., 2007)

This new result by the Pielke Jr. team, that there has not been any long-term increase in tropical cyclone damage in the United States, is consistent with other science concerning the history of Atlantic hurricanes. One of Pielke Jr.'s co-authors, Dr. Chris Landsea, from the National Hurricane Center, has also found no trends in hurricane frequency or intensity when they strike the U.S. While there has been an increase in the number of strong storms in the past decade, there were also a similar number of major hurricanes in the 1940s and 1950s, long before such activity could be attributed to global warming. The lack of trend in twentieth century hurricane losses is consistent with the lack of trends in hurricane frequency or intensity at landfall.

However, despite the lack of any trends in hurricane landfalls along the U.S. and Florida coast, or damage to U.S. coastlines when population demographics are taken into account, the impact from a single storm can be enormous, as residents of Florida know all too well. The massive build-up of the coastline has vastly raised the potential damage that a storm can inflict. Recently, a collection of some of the world's leading hurricane researchers issued the following statement that reflects the current thinking on hurricanes and their potential impact (http://wind.mit.edu/~emanuel/Hurricane_threat.htm):

As the Atlantic hurricane season gets underway, the possible influence of climate change on hurricane activity is receiving renewed attention. While the debate on this issue is of considerable scientific and societal interest and concern, it should in no event detract from the main hurricane problem facing the United States: the ever-growing concentration of population and wealth in vulnerable coastal

regions. These demographic trends are setting us up for rapidly increasing human and economic losses from hurricane disasters, especially in this era of heightened activity. Scores of scientists and engineers had warned of the threat to New Orleans long before climate change was seriously considered, and a Katrina-like storm or worse was (and is) inevitable even in a stable climate.

Rapidly escalating hurricane damage in recent decades owes much to government policies that serve to subsidize risk. State regulation of insurance is captive to political pressures that hold down premiums in risky coastal areas at the expense of higher premiums in less risky places. Federal flood insurance programs likewise undercharge property owners in vulnerable areas. Federal disaster policies, while providing obvious humanitarian benefits, also serve to promote risky behavior in the long run.

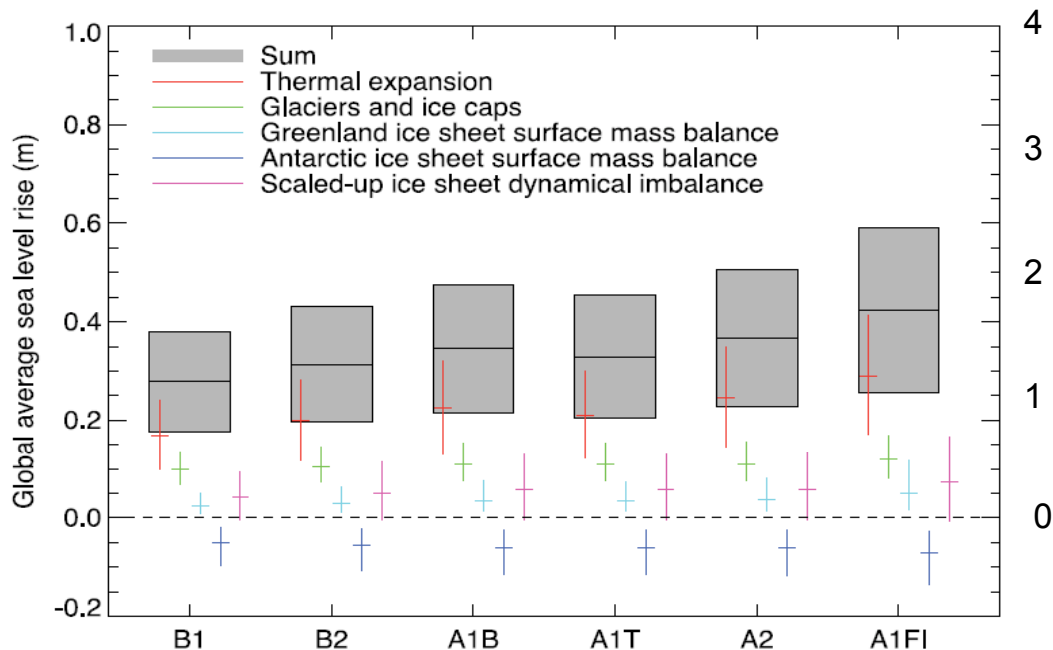
We are optimistic that continued research will eventually resolve much of the current controversy over the effect of climate change on hurricanes. But the more urgent problem of our lemming-like march to the sea requires immediate and sustained attention. We call upon leaders of government and industry to undertake a comprehensive evaluation of building practices, and insurance, land use, and disaster relief policies that currently serve to promote an ever-increasing vulnerability to hurricanes.

B. Sea Level Rise

Over the course of the past 50 years Florida's coastline has experienced a relative sea-level rise of the same order of magnitude as the one that is forecast to occur during the next 50 years because of warming temperatures: around six inches.

The relative sea level along the Florida coast has changed due to a combination of the land slightly sinking and the ocean slightly rising (Aubrey and Emery, 1991; Maul and Martin, 1993). Floridians have successfully adapted to this change, as the unprecedented high (and growing) population of coastal Florida attests.

According to the 2007 *Fourth Assessment Report* (AR4) on climate change published by the U.N.'s Intergovernmental Panel on Climate Change (IPCC), the potential sea level rise over the course of the 21st century lies between 7 and 23 inches, depending of the total amount of global warming that occurs. The IPCC links a lower sea level rise with lower future warming. The established warming rate of the earth is 0.18°C per decade, which is near the low end of the IPCC range of projected warming for the 21st century, which is from 0.11 to 0.64°C per decade. Therefore, since we observe that the warming rate is tracking near the low end of the IPCC projections, we should also expect that the rate of sea level rise should track near the low end of the range given by the IPCC—in this case, a future rise much closer to 7 inches than to 23 inches. Thus, the reasonably expected rate of sea level rise in the coming decades is not much different to the rate of sea level rise that Florida coastlines have been experiencing for more than a century—and have adapted to.



Range of sea level rise projections (and their individual components) for the year 2100 made by the IPCC AR4 for its six primary emissions scenarios.

There are a few individuals who argue that sea level rise will accelerate precipitously in the future and inundate large areas of the southern Florida and other low-lying areas around the world. They claim that the IPCC was far too conservative in its projections. However, these alarmist views are not based upon the most reliable scientific information, and in fact, ignore what our best understanding of how a warmer world will impact ice loss/gain on Greenland and Antarctica and global sea level.

It is a fact that all of the extant models of the future of Antarctica indicate that a warmer climate leads to more snowfall there (the majority of which remains for hundreds to thousands of years because it is so cold) which acts to slow the rate of global sea level rise (because the water remains trapped in ice and snow). New data suggest that the increasing rate of ice loss from Greenland observed over the past few years has started to decline (Howat et al., 2007). Scenarios of disastrous rises in sea level are predicated on Antarctica and Greenland losing massive amounts of ice in a very short period of time—an occurrence with virtual zero likelihood.

In fact, an author of the IPCC AR4 chapter dealing with sea level rise projections, Dr. Richard Alley, recently testified before the House Committee on Science and Technology concerning the state of scientific knowledge of accelerating sea level rise and pressure to exaggerate what is known about it. Dr. Alley told the Committee:

This document [the IPCC AR4] works very, very hard to be an assessment of what is known scientifically and what is well-founded in the refereed literature and when we come up to that cliff and look over and say we don't have a foundation right now, we have to tell you that, and *on this particular issue, the trend of acceleration of this flow*

with warming we don't have a good assessed scientific foundation right now. [emphasis added]

Thus the IPCC projections of future sea level rise, which average about 15 inches for the next 100 years, stand as the best projections that can be made based upon our current level of scientific understanding. These projections are far less severe than the alarming projections of many feet of sea level rise that have been made by a few individuals whose views lie outside of the scientific mainstream.

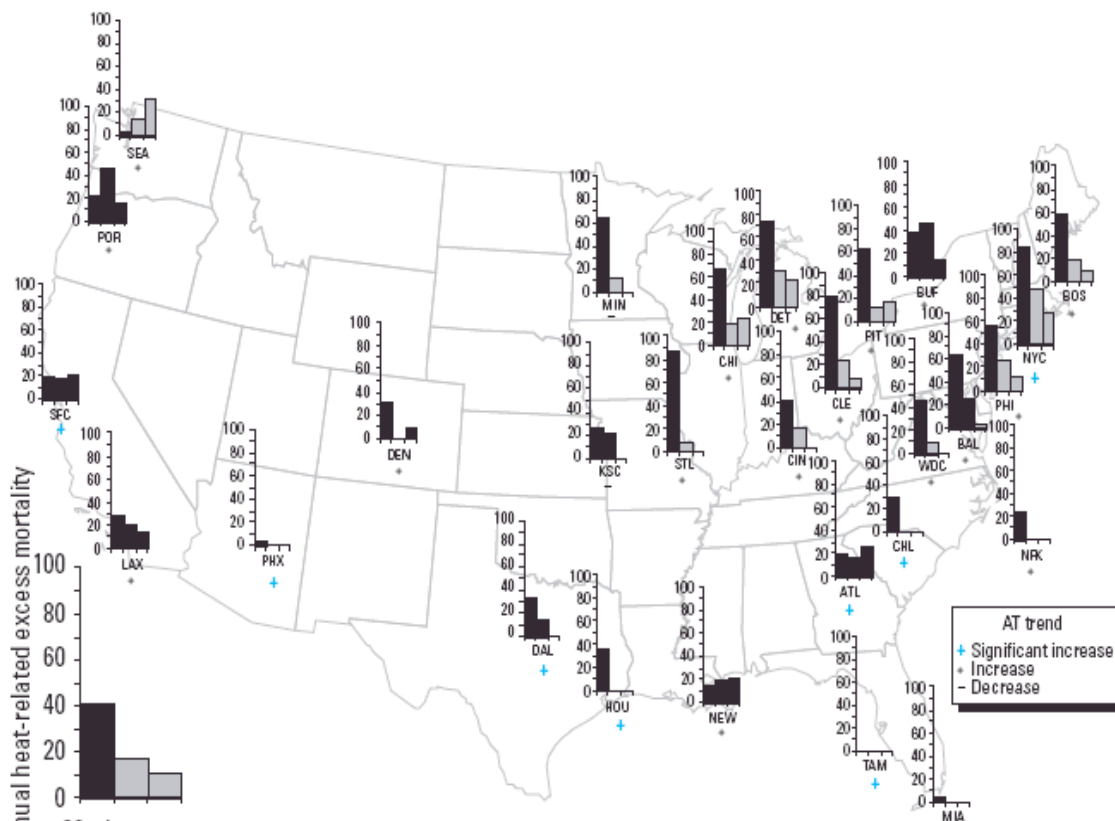
C. Public Health

a. Heat-related Mortality

The state of Florida is a peninsula surrounded on three sides by large bodies of water that helps to keep summer temperatures from reaching dangerously high levels and the population has become well-adapted to the summertime climate there. As a result, there is little indication that heat waves raise mortality across Florida (Davis et al., 2003ab).

Davis et al. (2003ab) focused on heat-related mortality during the summertime and the trends during the past 40 years or so. Davis et al. (2000b) found that in the vast majority of major cities across the United States, the population's sensitivity to extremely high temperatures has been declining over time despite a general rise in summertime temperatures. This desensitization is attributed to better medical practices, increased access to air-conditioning, and improved community response programs. In some cities, by the 1990s, heat-related mortality was virtually non-existent.

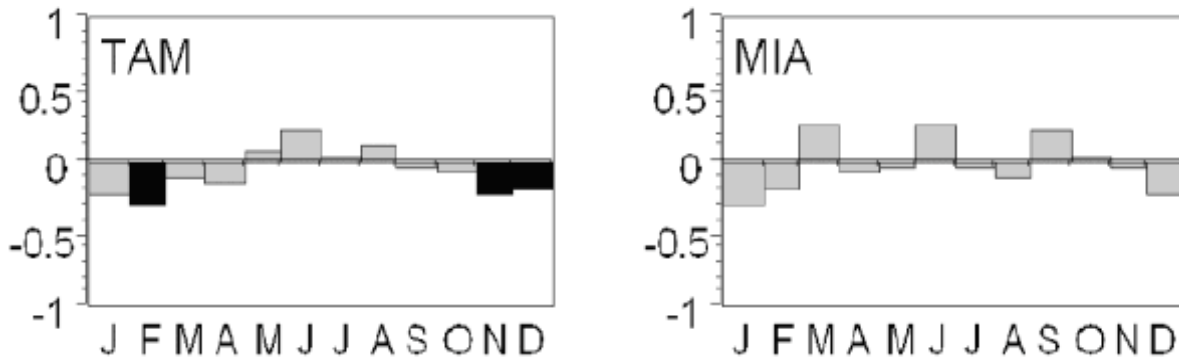
In general, in locations where high summertime temperatures are commonplace the people were found to be well-adapted to, and typically displayed little if any mortality response to heat waves. This is true of the two Florida cities examined, Tampa and Miami. In both of these locations, no significant relationship was found between daily mortality and daily temperatures during the summertime (with the exception of a very small relationship in Miami during the 1960s). This is evidence that Floridians have adapted their way of life to best cope with high summer temperatures. There is no reason to believe that this adaptation will change into the future.



Annual average excess summer mortality due to high temperatures, broken down by decade, for 28 major cities across the United States. For each city each of the three bars represents the average mortality during successive decades (left bar 1964-66 + 1973-1979; middle bar 1980-1989, right bar 1990-1998). Bars of different color indicate a statistically significant difference. No bar at all means that no temperature/mortality relationship could be found during that decade/city combination (taken from Davis et al., 2003b).

In a subsequent study, Davis et al. (2004) focused not just on summertime heat/mortality relationships, but looked across all months of the year. Unlike the lack of response to summer high temperatures, Davis et al. (2004) found that, during the wintertime, cold, dry air masses can, on occasion, drop down into Florida from the north and cause a rise in mortality.

Relationship between monthly average temperature and monthly average mortality for the Florida cities of Tampa (TAM) and Miami (MIA)



Relationship between average monthly temperature and total monthly mortality in Tampa (left) and Miami (right). Positive bar mean high temperatures lead to higher mortality, while negative bars mean lower temperatures lead to high mortality. Only the bars shaded in black represent statistically significant relationships (from Davis et al., 2004).

The figure above (taken from Davis et al., 2004) shows the relationship between monthly averaged temperature and monthly averaged mortality (anomaly) for the Florida cities of Tampa (left) and Miami (right) (in extra deaths per °C for a standardized population). Negative bars indicate a negative relationship between temperature and mortality, that is, the colder it is, the more people die and vice versa for warmer than average conditions. Solid bars mean the relationship is statistically significant. Positive bar indicate positive relationships between temperature and mortality, that is more people die when it is hotter than normal, and few die when it is below normal.

For the most part, Tampa and Miami exhibit more negative bars than positive ones, with the cold season months showing negative relationships and a couple months in summer showing weak positive relationships. Taken together, a warming climate, especially one in which winters warmed a greater degree than summers (in character, matching the pattern of warming that has been observed in the Northern Hemisphere for the past 50 years or so), would result in fewer temperature-related deaths in Florida, or at least in the two major cities examined in the Davis et al. (2004) study.

b. “Tropical” Disease

“Tropical” diseases such as malaria and dengue fever have been erroneously predicted to spread due to global warming. In fact, they are related less to climate than to living conditions. These diseases are best controlled by direct application of sound, known public health policies.

Malaria Distribution in the United States, 1882



Shaded regions indicate locations where malaria was endemic in the late 1800s (from Reiter, 2001).

The two tropical diseases most commonly cited as spreading as a result of global warming, malaria and dengue fever, are not in fact “tropical” at all and thus are not as closely linked to climate as many people suggest. For example, malaria epidemics occurred as far north as Archangel, Russia, in the 1920s, and in the Netherlands. Malaria was common in most of the United States prior to the 1950s (Reiter, 1996). In fact, in the late 1800s, a period when it was demonstrably colder in the United States than it is today, malaria was endemic in most of the United States east of the Rocky Mountains—a region stretching from the Gulf Coast all the way up into Northern Minnesota (gray area in the Figure above).

In 1878, about 100,000 Americans were infected with malaria; about one-quarter of them died. Malaria was eradicated from the United States in the 1950s not because of climate change (it was warmer in the 1950s than the 1880s), but because of technological advances. Air-conditioning, the use of screen doors and windows, and the elimination of urban overpopulation brought about by the development of suburbs and automobile commuting were largely responsible for the decline in malaria (Reiter, 1996).

The effect of technology is also clear from statistics on dengue fever outbreaks, another mosquito-borne disease. In 1995, a dengue pandemic hit the Caribbean and Mexico. More than 2,000 cases were reported in the Mexican border town of Reynosa. But in the town of Hidalgo, Texas, located just across the river, there were only seven reported cases of the disease (Reiter, 1996). This is just not an isolated example, for data collected over the past decade has shown a similarly large disparity between the high number of cases of the disease in northern Mexico and the rare occurrences in the southwestern United States (Reiter, per. comm.). There is

virtually no difference in climate between these two locations, but a world of difference in infrastructure, wealth, and technology.

V. Summary

The observations we have detailed above illustrate that climate variability from year-to-year and decade-to-decade plays a greater role in Florida's climate than any long-term trends. Such short-term variability will continue dominate Florida's climate into the future.

At the century timescale, Florida's climate shows no statically significant trend in statewide average annual temperature, statewide total annual precipitation, or in the frequency and/or severity of droughts. The same is true for tropical cyclones impacting Florida and the United States—there is a great degree of annual and decadal variability, but no long-term trends in frequency, intensity, or damage.

Florida's population is relatively immune from the effects of high temperatures, as its populace is well adapted to the state's summer climate conditions that are mollified by the proximity to the Gulf of Mexico and the Atlantic Ocean.

And global sea levels are indeed rising, but they are rising, and should continue to rise, at a pace that is not dissimilar to the pace of rise experienced and adapted to during the 20th century.

Taken as a whole, there is no evidence that the impacts of emissions resulting from the burning of fossil fuels for energy is negatively impacting the climate of the state of Florida. In fact, evidence remains scant that there are been any impact at all.

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