



FEELING THE HEAT IN FLORIDA

Global Warming on the Local Level

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ABOUT THE FLORIDA CLIMATE ALLIANCE

The Florida Climate Alliance (FCA) was formed in 1999 to educate people about global warming and advocate for common-sense solutions, and has over 40 Florida and national member organizations. Based in Orlando, FCA is a project of the Natural Resources Defense Council.

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EXECUTIVE SUMMARY

The accelerated warming of the global climate may seem like a remote concern to most Floridians. In fact, global warming presents the state with serious challenges—challenges that threaten human health, economic prosperity, and treasured natural areas. Over several decades, changes in sea level, average temperature, and weather will affect coastal property and beaches, water resources, agriculture, and ecosystems. In short, global warming has the potential to affect everything that defines Florida today.

This report is a synthesis of current scientific knowledge about the anticipated effects of global warming on Florida. Prepared by leading research scientists at universities across the state, it draws on global, national, and local studies to better understand Florida's specific vulnerabilities. It is intended as a tool for Florida's leaders to make the best possible choices today to preserve Florida's threatened prosperity for tomorrow. The research indicates that global warming will dramatically change the state of Florida.

THE EFFECTS OF GLOBAL WARMING IN FLORIDA

Scientists have already observed changes in Florida that are consistent with the early effects of global warming. These changes include retreating and eroding shorelines, dying coral reefs, salt water intrusion into the freshwater aquifer, increasing numbers of forest fires, and warmer air and sea surface temperatures. In coming years, these effects may become more common, and increasingly severe.

Projected global warming will raise Florida's average temperature by between 4 and 10 degrees Fahrenheit over the next 100 years. The summer heat index increase of 8 to 15 degrees Fahrenheit will be the most dramatic in the nation. Sea levels could rise by 8 inches to over 2 feet by the year 2100. Rainfall is anticipated to become more intense but also more sporadic, causing worse droughts and storms.

Coastal Florida

Florida's valuable coastal property and key tourist resources will be damaged by the most obvious result of global warming: rising sea levels. In low-lying areas, anticipated sea level rise could force water to flow horizontally as much as 400 feet or more inland—flooding shoreline homes and hotels and eroding Florida's famous beaches. Attempts to block rising seas through sea-wall projects and erosion control will be expensive and will almost certainly fail to protect undeveloped shoreline.

Freshwater supplies that feed cities, agriculture, and tourist centers may be endangered by salt-water intrusion. Sea level rise, rising temperatures, and alterations in rainfall will also combine to harm the very coastal ecosystems such as the Everglades and coral reefs that make Florida a unique and appealing destination. These changes will alter the \$45 to \$50 billion annual revenue from Florida's tourist economy.

Human Health

Global warming poses a threat to people throughout the state. Global warming can harm human health in several ways: by increasing heat-related illness, by exacer-

bating poor air quality, and possibly by increasing the incidence of infectious disease. Senior citizens tend to be most susceptible to these effects, a troubling finding for Florida where the elderly population is increasing and already constitutes the largest population group and the biggest economic base in the state.

Agriculture, Commercial Forests, and Natural Ecosystems

The impact of global warming on agriculture, commercial forests, and natural ecosystems is difficult to predict, because of relatively large uncertainties in future rainfall and the potential for farmers and land managers to adapt to some new conditions. But most scientists agree that a warmer climate means more intense weather systems—heavier, more concentrated rains along with longer droughts.

It is possible that some commercial crops will benefit in the short run from climate changes, as well as the fertilizing effects of an atmosphere richer in carbon dioxide. These effects will be short-lived, however, and most scenarios indicate that important cash crops like sugarcane, tomatoes, and, in some regions, citrus will face declining yields over the long run.

Commercial forestry will probably remain possible, although changes in water availability and temperature may alter the preferred tree species. Forests may be damaged by wildfires, which are very likely to increase with higher temperatures and more intense drought cycles. Global warming may also increase the threat of invasive species and pests. Natural ecosystems are likely to be damaged more than commercial forests and agriculture, because management to address global warming changes is less likely to be effective in protecting these areas.

Hurricanes

The Florida scientists' analysis also brings some good news. In the past, experts believed that global warming would bring more hurricanes to the state. The best current assessment is that a warmer climate will not increase the number of tropical hurricanes, and will have only a small impact on hurricane intensity by 2100 and no measurable change over the next 20 to 30 years. Global warming effects will be dwarfed by cyclical weather patterns unrelated to global warming, which are predicted to intensify hurricanes for the next 25 to 40 years.



Sea level rise of 16 inches would flood homes within 250 feet or more of the current shoreline and allow storm waves to overrun some barrier islands.

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TURNING BACK THE TIDE

While predictions for Florida's future seem grim, there are ways to avoid devastating harm if action is taken now. Florida needs to develop a plan to address its vulnerability to global warming, as 27 other states have already done. One task is to

identify the greatest threats and, where possible, develop the capacity to adapt to them with minimal disruption and cost. A second task is to reduce emissions of global warming pollutants from power plants, cars, and other major sources. In many cases, common-sense solutions exist—using energy more efficiently and cleaning up power plants—that also save money or improve local air quality. Similar actions are also required at the national level because Florida cannot solve such a broad problem alone. The real danger is that delaying responsible action would make it too late or much more costly to stabilize the climate by the end of the century.

This report provides an overview of findings for coastal impacts, hurricanes, human health, agriculture, commercial forests, and natural ecosystems, and includes a review of global warming science and the climate change scenarios upon which the findings are based. An accompanying background document containing the complete findings will also be published.

FLORIDA'S PROJECTED GLOBAL WARMING

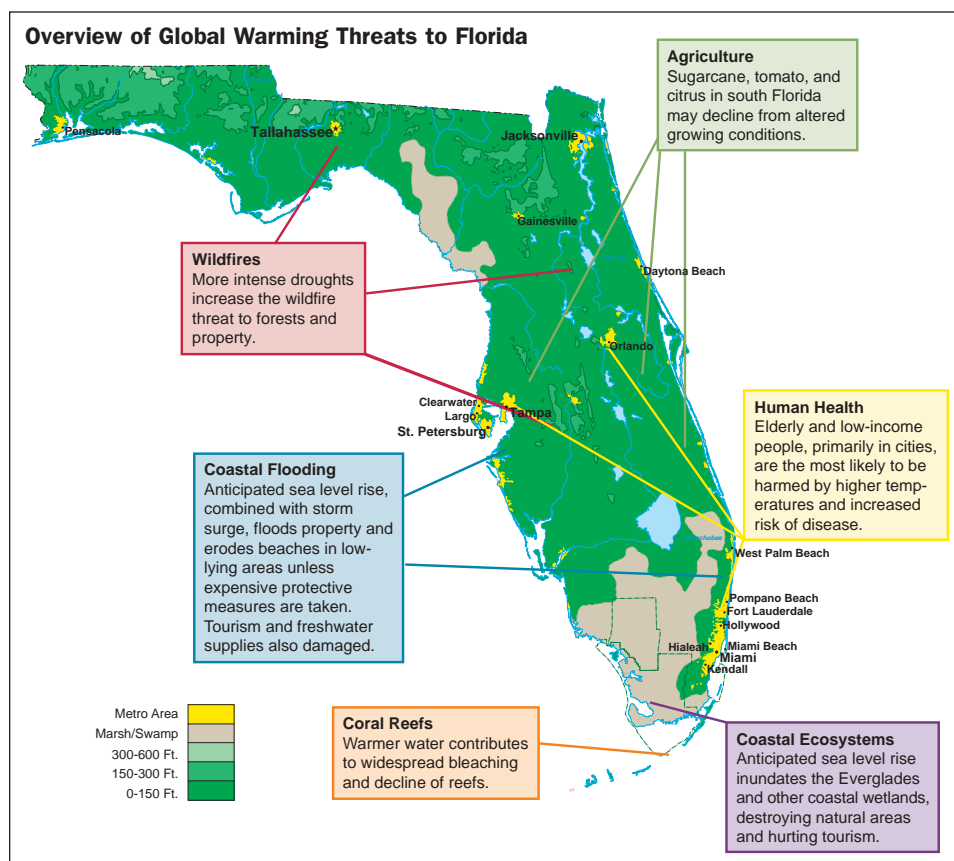


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Global warming will harm Florida's economy and citizens when changes in temperature, sea level rise, and precipitation damage property and resources, or require costly changes in the way people live and work. Therefore, estimates of harm are based on projected scenarios of these three primary variables, which have been developed by complex computer models. This report is based on several such scenarios, which conservatively capture the full range of uncertainties in long-term projections. The following changes are projected for Florida.¹



Temperature Florida may experience increases in average temperature of between 4 and 10 degrees Fahrenheit over the next 100 years. This change will also be associated with warmer summer highs and cooler winters. The summer heat index, which reflects both temperature and humidity, will increase by 8 to 15 degrees Fahrenheit by the year 2100.

Sea Level Rise Sea level is expected to rise roughly 8 to 16 inches without taking into account ongoing land subsidence (which varies by location). Taking subsidence into account, actual sea level rise of 16 inches is likely and as much as 30 inches may be possible in significant areas of Florida.

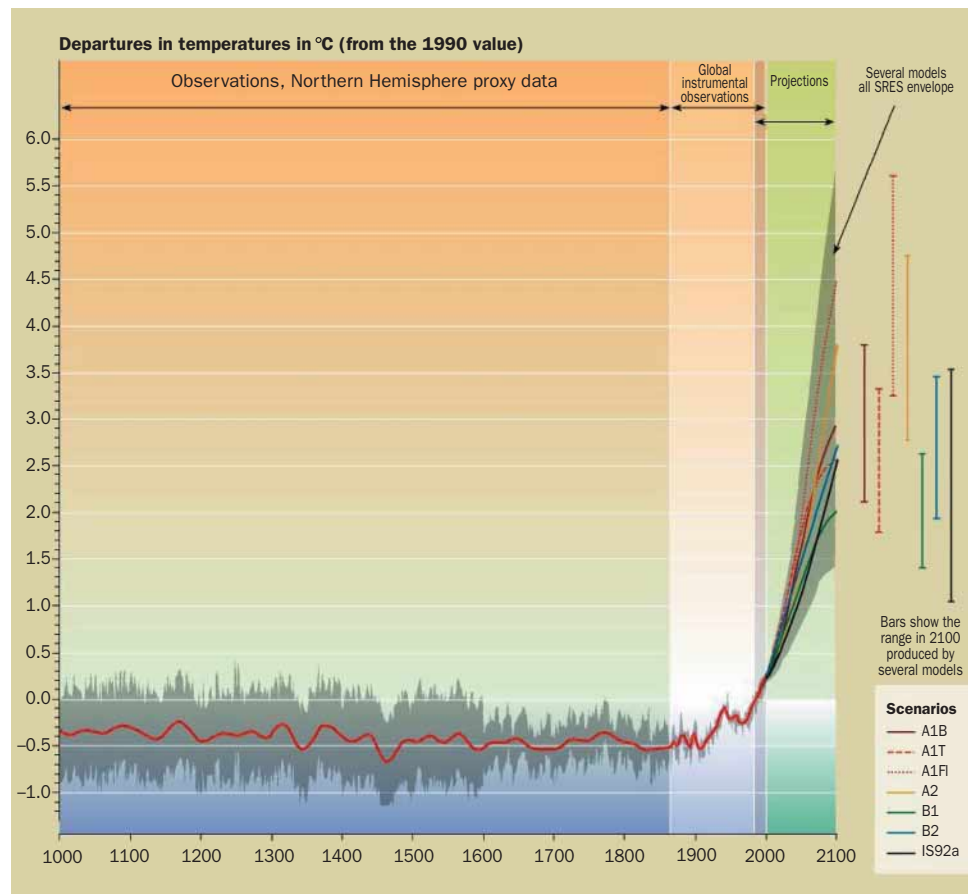
Precipitation The scenarios considered in this report generally agree that rainfall will be more intense when it occurs. Correspondingly, there will likely be longer or more intense periods of drought. The total annual rainfall predicted for specific regions within Florida differs considerably across the scenarios, however, with annual rainfall possibly decreasing over the next century in one scenario and increasing significantly (as much as 20 percent) in another. This large range of uncertainty presents a challenge when evaluating highly water-dependent sectors such as agriculture, forestry, and natural ecosystems.

The report’s findings are based on a range of scenarios of future climate change over the next 100 years. This range is consistent with those used in the *U.S. National*

Variations of the Earth’s Surface Temperature: 1000 to 2100

Average surface temperature is shown in centigrade, relative to 1990 (i.e., 1990 temperature is indexed to 0). Observations prior to the mid-19th century are based on proxy data derived from tree rings, corals, ice cores, and other historical records. Observations from the mid-19th century to the present are based on instrumental data. The shaded area represents uncertainty ranges for the estimates. Projected average temperatures are shown from 1990 to 2100 for a range of models used by the IPCC, along with the uncertainty range for all projections.

Source: Intergovernmental Panel on Climate Change (IPCC)



EVIDENCE OF GLOBAL WARMING

Study of the global climate is one of humankind's most complex scientific endeavors. While much is known, there is a great deal that remains uncertain. Experts know that atmospheric levels of heat-trapping gasses have increased, and the Earth is warming faster than we have ever seen. Most believe that pollution is responsible for both these trends.

There are key areas about which there is no doubt. First, certain gases trap heat within the Earth's atmosphere. Second, pollution from cars, power plants, and other sources are increasing the amount of these gases in the atmosphere, leading to their highest concentration in more than 400,000 years.² Third, the additional heat trapped by this global warming pollution will, according to the laws of physics, manifest itself as additional energy driving the Earth's climate system; there is simply nowhere else for it to go.

We also know that the planet is getting warmer. Global average temperatures on the Earth's surface have increased by 1.1 degrees Fahrenheit (0.6 degrees Celsius) during the last century—warming faster than any time in the last 1000 years. As a result, the 1990s was the warmest decade in the last 1000 years.

The critical question is whether these changes are the result of human activities, or natural forces. The scientific consensus based on extensive research is that emissions from cars, power plants, and other activities are substantially to blame.

The 2,500-member Intergovernmental Panel on Climate Change (IPCC) is the international authority on global warming, and is made up of leading scientific researchers from around the world. The group has been studying the question for over 10 years. In a report released earlier this year, the IPCC found that “most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations.”³

President Bush asked the U.S. National Academy of Sciences (NAS) to review the findings of the IPCC, and the NAS reported that the IPCC “accurately reflects the current thinking of the scientific community” and that “greenhouse gases are accumulating in the Earth's atmosphere, causing surface temperature's to rise.”⁴ The key facts that support the IPCC and NAS findings include the following:

- ▶ Atmospheric concentrations of carbon dioxide are now at their highest level in 400,000 years and are more than 30 percent higher than pre-industrial levels.
- ▶ Widespread retreat of non-polar glaciers during the twentieth century has been observed on five continents.
- ▶ Changes in underwater ocean temperatures in the last several decades are consistent with the observed surface warming on land and sea.
- ▶ The ranges of plants, insects, birds, and fish have shifted poleward and up in elevation.
- ▶ The best explanation of this observed warming is that human-generated global-warming pollution is a primary cause. It is very unlikely that natural factors alone could cause this sustained temperature anomaly.

Climate scientists will continue to refine our understanding of human and natural influences on our climate. Nevertheless, the vast majority of scientists now believe that human-induced global warming has already occurred and will continue to warm the planet in the future.

Assessment, a comprehensive synthesis of potential global warming effects on the United States prepared by the U.S. Global Change Research Program at the request of Congress.⁵

This conservatively wide range has the advantage of capturing the uncertainties inherent in projections of climate change. In particular, the scenarios reasonably bracket the amount of global warming predicted to occur by the Intergovernmental Panel on Climate Change (IPCC). A disadvantage of a broad range of scenarios, however, is that this report's findings are qualified considerably to accommodate this range, especially when the report attempts to identify more localized results where the variability of climate change indicators are magnified.

COASTAL FLORIDA AND SEA LEVEL RISE



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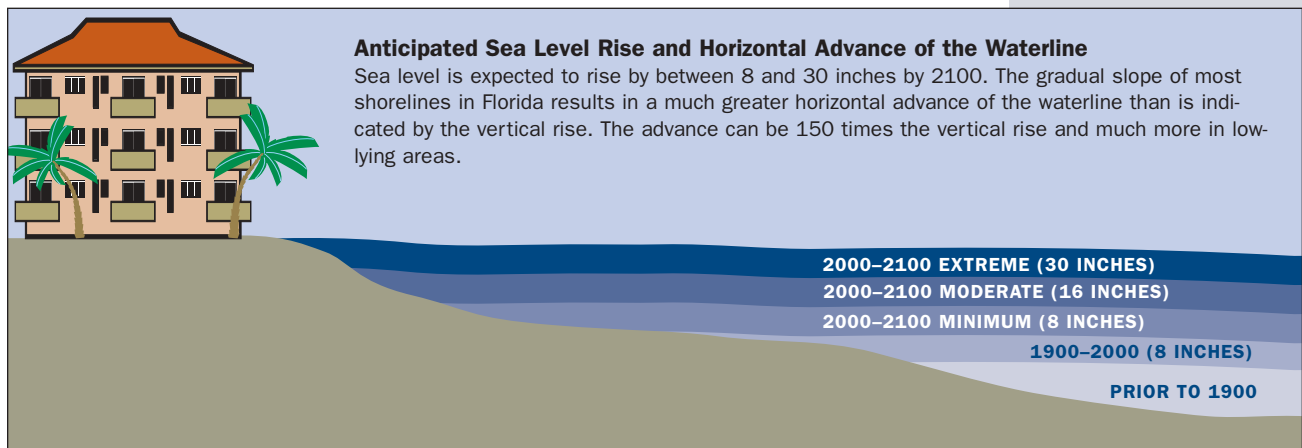
Global warming threatens Florida's coastal cities and treasured locations as well as the tremendous amount of income they generate. Approximately 95 percent of Florida's 16 million residents live and work within 35 miles of coastal areas.⁶ About half of the 67 counties in Florida border the Gulf of Mexico or the Atlantic Ocean.

The Everglades, coral reefs, the Keys, and other nationally unique natural areas define Florida's coastline and have made it a major tourist attraction. The coastline contains almost 800 miles of sand beaches and generates over \$15 billion of revenue for Florida's economy through sales, taxes, and payroll creation.

Global warming will dramatically alter this beautiful and prosperous landscape. Sea level rise will combine with storm surges to increase flooding and damage developed areas. These same forces will also erode beaches, barrier islands, and other coastal ecosystems, and could completely inundate the lower Everglades. Ecosystems already stressed by sea level rise may be further affected by increased temperatures, degraded water quality, or altered water availability.

COASTAL CHANGES

Global warming causes sea levels to rise because warmer water expands and because melting glaciers add water to the oceans. In addition, the local sea level rise will be



greater if the coastline at that point is subsiding. (Subsidence can occur from natural geologic changes and in some cases from human actions. Actual sea level rise is the combination of rising seas and land subsidence.)

The local sea level rise expected in coastal Florida could range from 8 inches to 2.5 feet by 2100. But more important is the fact that horizontal advance of the sea can be much greater than the vertical rise. The horizontal advance can be 150 to 200 times the rise, and even more than this in areas with a gently sloping shoreline as is the case for much of Florida.⁷ As a result, sea level rise over the next century could directly cause flooding of homes, hotels, and property within 200 to 250 feet of the current shoreline. This translates into a 20 to 25 percent increase in the 100-year floodplain, which in turn may increase flood damages by 40 to 60 percent.⁸

The projected horizontal advance of the sea exceeds the typical high tide width of most recreational beaches in Florida. In developed areas, wave-reflective sea walls will make recovery from storm-related beach erosion increasingly difficult. Sea walls and other permanent structures will eventually become the shoreline. Sea level rise also has the indirect effect of increasing the frequency and severity with which storm surges—the temporary increase in local sea level as a result of storm winds—cause flooding.

Sea level rise may reduce the ability of barrier islands and beaches to shield coastal areas from storm surges, exacerbating flood conditions. Barrier islands currently absorb most of the brunt of storm surge, protecting coastal areas behind them. Sea level rise and its associated horizontal advancement may overwhelm some barrier islands along both the Gulf and Atlantic coasts of Florida, allowing storm surges to reach previously protected areas and penetrate farther inland.⁹

Sea level rise over the next century could directly cause flooding of homes, hotels, and property within 200 to 250 feet of the current shoreline.

FRESHWATER SUPPLIES

Rising sea levels cause saltwater to move landward, shifting the boundary between saltwater and freshwater inland and causing intrusion of saltwater into groundwater

COASTAL CHANGES IN FLORIDA'S HISTORY

Florida has experienced in its past a climate-change-related sea level rise—roughly equivalent to that forecast for the coming century—that caused dramatic changes to the south Florida coastline. Those historic events provide an example of how seemingly modest changes in sea level can produce what would today be considered catastrophic.

About 2,500 years ago south Florida experienced a century of rapid sea level rise of 20 to 30 inches.¹⁰ The change repositioned barrier islands and shifted the mangrove coastline of southwest Florida several miles inland.¹¹ It destabilized vast volumes of mud and sand resulting in a 400-year period of erosion and redistribution that reshaped much of the coastline, creating a mud flat 2 to 4 miles in width and extending along the southwest Florida coast for over 80 miles. It began the formation of Cape Sable, and blocked the original discharge paths of the Everglades causing major changes in the appearance of the southern Everglades.

aquifers. Surface and sub-surface freshwater sources, already in short supply for urban areas and agriculture, become contaminated if too much saltwater is introduced. In addition, changes in the availability and distribution of freshwater have serious consequences for the functioning of coastal ecosystems.

A three-foot sea level rise could be catastrophic for aquifers in the Ft. Lauderdale, Miami and Homestead areas, which are situated on the low coastal ridge and would suffer severe saline intrusion. Although this sea level rise is greater than that in the scenarios examined, these aquifers are vulnerable over the longer-term.

On low-lying coastlines, likely sea level rise will result in a shift in the surface seawater-freshwater boundary of as much as several miles. For south Florida, the relatively low topography means that even a 1-foot rise will cause a significant inland shift in the surface freshwater and shallow groundwater.



Sea level rise will destroy many beaches already facing serious erosion problems.

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COASTAL WETLAND ECOSYSTEMS AND THE EVERGLADES

Anticipated sea level rise will very likely cause vast inundation and destruction of coastal wetlands and allow seawater to encroach 12 to 24 miles into the broad low-lying area of the Everglades. This encroachment threatens much of the lower Everglades because these ecosystems cannot tolerate flooding of this extent. The planned investment of billions of dollars for Everglades restoration is necessary to keep this ecosystem resilient enough to withstand global warming. However, unless the causes of global warming are addressed, significant portions of even the healthiest Everglades ecosystem will be flooded and lost.

Sea-level rise, even at the current rates, has had measurable effects on Florida's low-lying coastal forests. Native palms in the Waccasassa Bay State Preserve on Florida's gulf coast are being killed off by exposure to salt water associated with sea level rise.¹² Pine trees in the Florida Keys have been damaged by saltwater intrusion into the ground water. Although mangroves tolerate salinity well, very rapid sea level rise could prevent landward migration of closed-canopy mangrove forests and destroy them.

CORAL REEFS

As bedrock of the marine ecosystem, Florida's coral reefs are also the foundation for the state's sport and commercial fisheries, as well as a major attraction unto themselves. These reefs will likely become early victims of global warming.

Seawater may encroach 12 to 24 miles into the broad low-lying area of the Everglades, killing much of this unique ecosystem.

Coral reefs can survive only within a narrow range of temperature, salinity, and water quality. The predicted changes over the next 100 years will likely exceed that limited range, and corals and associated tropical marine organisms will probably not survive under the new conditions. Reefs are already dying off from a combination of factors, including warmer water temperatures. Global warming will subject them to further stresses, including deeper water, warmer and colder seasonal extremes of water temperature, and higher nutrient levels and more turbidity.¹³

ECONOMIC CONSEQUENCES

No Florida industry stands to be hit harder by sea level rise than tourism. More than 71 million people visited Florida in 2000, according to the state's tourist development agency, adding about \$51 billion to the state economy. The number one draw for residents and tourists alike, according to the agency, is the beach. Miami Beach alone generates \$2 billion a year in tourism revenues. Tourist spending in the Florida Keys amounts to \$1.8 billion annually. If higher seas ravage beaches, the economy will suffer significant harm.

The loss of coral reefs, coastal estuaries, and associated fisheries will also harm the state's economy. Saltwater fishing, both commercial and sport, are a \$4 billion a year business in Florida. Sport diving involves an estimated 3 million Floridians and

HURRICANES

Earlier climate change research raised the concern that warmer ocean temperatures would lead to more frequent and intense hurricanes. However, the best current assessment is that global warming is unlikely to cause changes in where Atlantic hurricanes occur or their frequency.

As it turns out, the El Niño-Southern Oscillation in the central Pacific and a comparable warming-cooling cycle in the Atlantic will be much more influential on hurricanes and their impact on Florida than global warming. This cycle is believed to cause major Atlantic hurricanes to alternate between active and quiet periods of 25 to 40 years. Thus, despite warming of the Earth's surface over the last few decades, the 1970s to early 1990s was an inactive hurricane period and the period from 1991 to 1994 was the quietest on record. It is likely that the busy hurricane seasons we have experienced since 1995 mark the start of another active period.¹⁴ The Atlantic had a record 49 hurricanes in the six years from 1995 to 2000. This natural active period will have a far greater effect on hurricane activity than global warming.

While global warming may not cause more hurricanes, it will contribute slightly to their destructive abilities by 2100 by increasing maximum wind speed by about 5 percent, and increase the central pressure deficit by 5 to 10 percent.¹⁵ No measurable change is expected, however, in the next 20 to 30 years.

With 14 million people now living in coastal counties, increased hurricane activity could be devastating. Hurricanes will come ashore with damaging storm surges on top of higher sea levels. Hurricanes hitting during droughts will replenish freshwater supplies, but those that hit during wet periods will exacerbate flooding, adding to flood damage in urban areas and destroying some agricultural crops.

another 3 million tourists every year. Dive equipment manufacturing is a \$500 million annual Florida industry.

Many of Florida's great cities by the sea—Miami Beach, Key West, Tampa, St. Petersburg, Pensacola, Marco Island, and others—will face complex challenges from sea level rise in the coming decades, requiring expensive actions to prevent permanent flooding of low lying areas and associated property damage. Developed coastal areas do have options for adaptation: elevating existing areas; building sea walls and flood control structures; and encouraging relocation. Each of these options will be extremely expensive, and it is unlikely that this protection would be extended to the threatened undeveloped areas. In addition to direct costs, protective structures can exacerbate beach erosion by changing water flows. Beach re-nourishment along Florida's Atlantic coast alone could cost between \$50 and \$60 billion (current dollars) over the next 100 years.



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CHAPTER 3

HUMAN HEALTH

Global warming poses potential health threats of several kinds. Higher temperatures can create direct health stresses, increase the prevalence of disease, and potentially increase smog formation. Although these effects cause concern, there is considerable uncertainty in the level of harm that will occur and some specialists believe that increased threats could be handled adequately by the healthcare system.

Given the make-up of Florida's population, the state is particularly vulnerable to health impacts of global warming. In general, the elderly, the young, and other segments of the population with impaired health will be most affected. Low-income populations may also be at risk because they typically have less access to high-quality healthcare.

HEAT STRESS

Projected changes in the heat index for Florida are the most dramatic in the nation: an increase of 8 degrees Fahrenheit to 15 degrees Fahrenheit is likely during the next century.¹⁶ The elderly are particularly vulnerable to severe heat-related illness and death. Seniors over 65 years old today constitute about 18 percent of Florida's population, and that figure is forecast to climb to over 26 percent by 2025.¹⁷ At the same time that Florida's climate is increasingly affected by global warming, the population of the most severely affected age group is growing rapidly.

Many factors combine to put Florida's 2.8 million senior citizens at greater risk of suffering a heat-related illness or death:

- ▶ Impaired ability to disperse heat through the body's physiological mechanisms
- ▶ Greater risk of having underlying diseases
- ▶ Greater risk of taking medications that may contribute to heatstroke
- ▶ Limited mobility
- ▶ Compromised temperature perception.

Others vulnerable to heat stress are persons working or exercising in the heat, such as construction workers, farmers, theme park workers, and even tourists themselves.¹⁸ Low-income households are less likely to have air conditioning and may be at higher risk than the general population.

One study projected that the number of people dying each year from heat stress in Tampa would more than double by the year 2020.¹⁹ However, Florida is well adapted to high temperatures compared to more northern regions, and may be able to adjust

without substantial harm. Additional research is required to draw more certain conclusions about heat-related deaths.

AIR QUALITY

Air quality can be degraded in two ways in the scenarios considered in this report. First, higher temperatures increase the rate of smog formation. Second, increased use of fossil fuels could increase a range of air pollutants.

Ground-level ozone, which is a major component of smog, is formed from nitrogen oxides and volatile organic compounds. With warmer temperatures and sunlight, this reaction proceeds faster and forms more smog. Higher temperatures also cause more evaporation of volatile organic compounds when refueling and operating vehicles, further contributing to smog formation. Chronic respiratory diseases, like asthma or obstructive pulmonary disease, can be made much worse by breathing ozone.²⁰

Smog formation is also influenced by rain and wind patterns, not just temperature. Increased rainfall and stronger winds could decrease smog formation. Predictions of changes in air quality as a result of global warming are very difficult to make, because global warming will affect rainfall and wind patterns in uncertain ways.

Fossil-fuel use is projected to increase under the scenarios considered. In fact, there may even be an increase in energy consumption to power air conditioners as people adapt to warmer temperatures. Without improvements in technology, this would lead to increased amounts of air pollutants, such as sulfur oxides, nitrogen oxides, volatile organic compounds, and particulate matter. However, increased air pollution could be avoided by technological developments and more stringent regulations that would increase energy efficiency and further control air pollutants.

In the absence of controls, carbon monoxide, sulfur oxide, and nitrogen oxides aggravate existing cardiovascular diseases, and may produce lung irritation and reduced lung function. As with heat effects, seniors, the young, and those with existing health problems are particularly at risk. Seniors over the age of 65 are more apt to have underlying conditions exacerbated by air pollution and therefore are at higher risk of suffering the consequences of air pollution.

WATER-BORNE DISEASES

Most of the germs that cause water-borne disease, such as viruses, bacteria, and protozoa, survive longer in warmer water. Bacteria also reproduce more rapidly in warmer water. Increasingly intense rainfall projected for Florida could also increase



Higher temperatures can cause direct health stresses, particularly for senior citizens.

the prevalence of water-borne disease. Outbreaks of two of the most common forms of water-borne diseases, *Cryptosporidium parvum* and *Giardia lamblia*, have been found to occur after heavy rainfall events and cause contamination of drinking water.²¹

For most healthy people, an infection from a water-borne disease will cause diarrhea for a limited time and go away with no treatment needed. In the elderly, infants, pregnant women, and anyone with a weakened immune system, water-borne diseases can be very serious and even fatal. There are some water-borne diseases, such as hepatitis, that can cause serious and long-lasting illness even in previously healthy people.

VECTOR-BORNE DISEASES

Vector-borne diseases are spread by mosquitoes, rodents, ticks, and other insects and animals. Malaria, encephalitis, and dengue fever are three examples of vector-borne diseases, as is the mosquito-transmitted West Nile Virus, which has recently caused several deaths in Florida.

Rising temperatures could expand the range of many vectors, and can play a role in transmission of the disease itself. Each vector and disease will respond differently to temperature and other factors, including efforts at control. Because of high standards of living and better health infrastructure in Florida, vector-borne disease is less of a problem than elsewhere in the world.²² But close monitoring and vigilance will be needed to ensure that diseases such as malaria, encephalitis, dengue fever, and West Nile Virus do not become more widespread problems in Florida.

AGRICULTURE, COMMERCIAL FORESTS, AND NATURAL ECOSYSTEMS



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Projected global warming will raise temperatures in Florida and do so at a rate perhaps 15 to 40 times as fast as past natural changes. Agriculture, commercial forests, and natural ecosystems are all highly sensitive to changes in weather and climate because they depend on specific temperatures and water availability. They are also vulnerable to severe weather, increased insect populations, and competition from invasive species.

The net impact of this radical shift will be highly localized, making it difficult to draw general conclusions for such a large state. An additional uncertainty arises in the ability of farmers and land managers to adapt to changes that do occur. Although the effects are uncertain, the vast economic importance of these sectors makes their potential vulnerability a significant concern.

AGRICULTURE

Florida is the leading national producer of citrus, sugarcane, and tomatoes, and agriculture adds billions of dollars to Florida's economy. Global warming will certainly lead to changes in where and how Florida's farmers grow crops. In some cases these changes may be beneficial and increase productivity. In others, they may be detrimental or become so over time as economic growing conditions are exceeded for certain crops.

In general, warmer temperatures will increase yields as long as maximum temperature thresholds are not exceeded. All other factors being equal, increased carbon dioxide levels in the air also results in higher crop yields, a process referred to as "carbon dioxide fertilization." At the same time, changes in rainfall patterns and temperature may affect water availability and soil moisture, in some cases limiting crop growth.

The effects on agriculture will vary greatly by location, with the impact roughly varying according to the state's three primary climate zones. Warmer spring and summer temperatures may favor crop production in central and northwest Florida.



Hotter summer temperatures can decrease Florida's crop yields.

Hotter weather would cause problems in southern Florida, however, where summer temperature and limited water availability already limit crop production. Increases in climate variability between hot and cold, wet and dry, could make adaptation by farmers more difficult in the short run.

Effects also depend on the specific crop, since each has its own requirements. Anticipated effects due to global warming are presented for three major crops: citrus, sugarcane, and tomatoes.²³

Citrus

Florida is the nation's number one citrus producing state, and citrus is the state's most important crop, earning more than \$1.6 billion in 1998. Warmer temperatures and carbon dioxide fertilization may increase commercial citrus production by 6 to 15 percent in warmer south Florida and by 20 to 30 percent in cooler central Florida over the next 40 to 50 years. Yields may be up to 70 percent larger in central Florida by 2100 as a result of a significant drop in freeze-related losses. Despite the warming, periodic freezing temperatures will continue to threaten growers in the central and northern parts of the state.

While citrus stands to benefit overall in the early stages of global warming, however, longer-term citrus productivity in

southern Florida may decline. Specific findings include the following:

- ▶ Yields in south Florida will decrease because temperatures will exceed the nominal growing range, soil moisture will be reduced from the heat, the dormant season will be shorter, and there will be greater exposure to disease and insects.
- ▶ Despite the fact that the 1980's were the second warmest decade on record, they also contained three devastating freezes in central Florida that forced much of citrus farming to move south. The freeze threat remains despite global warming and may deter relocation from south Florida.
- ▶ Optimal growing conditions in central Florida are offset by competition for land from urban development, which has claimed much of the land formerly used for citrus groves. Northward expansion is also limited due to lower yields and higher irrigation need.

Sugarcane

Florida is the nation's leading producer of sugarcane, accounting for more than half the nation's sugarcane sales. It is a \$473 million industry, mostly located in Palm Beach County. Global warming could severely impact production and sales, and even threaten the industry's continued presence in Florida.

Sea level rise, if it approaches 18 to 20 inches, may intensify flooding, and decrease sugarcane yields due to rootstock damage caused by increased soil moisture. Frequent

flooding may further intensify nutrient pollution problems already associated with sugarcane production in Florida. Additionally, warmer temperatures could decrease yields by about 20 percent.

In sugar growing areas of Louisiana—inland from the coast and in the mid-to-upper elevation range—warmer and wetter climate would probably increase yields, making economics of production less attractive in Florida.

Tomatoes

Florida is the nation's leader in fresh-market tomato production. Climate changes, however, could decrease Florida tomato yields by as much as 44 percent by shortening the growth cycle. Adverse impacts on Florida tomatoes may indirectly make tomato production in California more profitable. Current production in Florida is almost entirely irrigated and irrigation requirements may increase 6 to 35 percent, making production more expensive.

COMMERCIAL FORESTS

Commercial forestry in Florida adds approximately \$9 billion per year to the state economy, including over \$1.25 billion in wages.²⁴ Commercial forestry is concentrated in the north of the state. Industrial and private land owners account for about 80 percent of the forested land in Florida.²⁵ It is likely that commercial forestry in Florida will remain possible under nearly all climate change scenarios. How much land is actually planted, however, depends on the economics of production. If the costs of fertilization, fire control, and pest losses become too high, commercial forestry will leave the state.

Some of the effects of global warming may initially benefit commercial forests. Elevated levels of carbon dioxide and increasing temperatures are believed to increase tree growth rates initially. The magnitude of this effect in real growing conditions and over the long-term, however, is less certain. Higher levels of carbon dioxide may disrupt forests as a result of the following indirect effects:

- ▶ Changes in forest composition, favoring species with larger growth responses (perhaps including undesirable or exotic species)
- ▶ Changes in the spread and severity of plant diseases
- ▶ Changes in behavior of plant-eating insects and animals leading to increased damage
- ▶ Changes in decomposition (critical for nutrient recycling and long-term forest health)

Shifts in the tree species planted and the associated forest management systems are possible, but difficult to predict given the uncertainty in rainfall predictions and adaptive responses in managed forests. Higher temperatures may limit the growth of pine forests relative to hardwoods, leading to a change in which forest products can be grown profitably in Florida.

With increased drought intensity predicted even for scenarios with more precipitation, wildfires pose a significant threat to commercial forests. In the past four years, wildfires have burned over 1.4 million acres in Florida, the most fire-intensive four-

Florida is the nation's leader in fresh-market tomato production. Climate changes, however, could decrease Florida tomato yields by as much as 44 percent by shortening the growth cycle.

year period since records have been kept.²⁶ Catastrophic wildfires in 1998 burned more than 506,000 acres, sent thousands of residents fleeing from their homes, destroyed more than 300 houses—and in some cases, whole neighborhoods—in central and northeast Florida. The resulting economic loss was estimated at \$620 million.²⁷ Global warming may increase the frequency of such destructive wildfires.

NATURAL ECOSYSTEMS

Florida's natural ecosystems are incredibly valuable. For example, Florida's forests are home to more endangered species than all but two other states. Protected areas around the state are a vital resource for Florida's tourist economy. The main threats from global warming include a spread of exotic species, pests and disease, wildfire, changes in precipitation, and the effects of sea level rise discussed previously in Chapter 2.

Florida ecosystems include upland, wetland, freshwater, estuarine, and coastal ecosystems, all closely linked by hydrology. Natural ecosystems face the same changes as agricultural crops and commercial forests, and therefore global warming may increase the range of some ecosystems and push others beyond their limits.

The natural sequence of alternating drought and flooding years and the normal seasonal variability in precipitation are important to the functioning of many Florida ecosystems. Whether Florida precipitation increases or decreases due to global

warming, there are likely to be more extremes between dry and wet periods in the decades ahead. These extremes will increase the threat from wildfire, particularly affecting forest ecosystems.

The greatest risk to wetlands and other ecosystems stems from a possible decrease in precipitation and higher temperatures, especially if it occurs over several consecutive years. The occasional drought is an important positive ecological event in Florida, enhancing the food supply for wading birds and providing germination conditions for cypress trees. But too frequent, too extensive, or too many consecutive years of droughts are harmful. Droughts also greatly increase the competition for water supply for human uses, further reducing freshwater available to natural wetland and coastal ecosystems.

If precipitation increases, it will influence coastal estuaries, where the "excess" freshwater is discharged. The St. Lucie and Caloosahatchee estuaries already receive much greater freshwater flows than they did historically, resulting in ecological shifts to more estuarine and less lagoonal conditions. By contrast, Florida Bay has much less freshwater flow now than previously. Thus, increased precipitation might return Florida Bay to healthier conditions and reduce the frequency of

Increased wildfires will threaten forests, natural areas, and homes.



adverse hyper-saline conditions. Increased precipitation could also result in expansion of wetland habitats, but in most instances that would be constrained by human development.

Global warming may also introduce noxious weeds to more ecosystems. South Florida currently has serious problems with a wide variety of exotic organisms such as Brazilian pepper and melaleuca, which is officially designated a Federal Noxious Weed. Expensive control measures include use of herbicides and mechanical removal, but the plant remains aggressive and difficult to control. It is likely melaleuca and other invasive exotics will spread far north of their current ranges. In turn, they will crowd out many native plants and trees, just as they have done in south Florida.

Changes in climate can also affect plant responses to herbivores and forest pests. Southern Pine Beetle infestation required clear-cutting 500 acres at the Wekiwa Springs State Park and Rock Springs State Preserve near Orlando this year. Sections of the Ocala National Forest have also been particularly hard hit.

The significant difference between ecosystems and commercial forests is that because they are not actively managed, it is unlikely that any planned adaptation measures will be undertaken to reduce the impacts of global warming. Indeed, some of the adaptation possible for crops and trees—such as relocating and switching which species are planted in which locations—would change the very nature of these ecosystems.



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CHAPTER 5

CONCLUSION

Global warming presents Florida with serious challenges—challenges that threaten human health, economic prosperity, and treasured natural areas.

This report, prepared by leading research scientists at universities across the state, is a synthesis of current scientific knowledge about the anticipated effects of global warming on Florida. The research indicates that over several decades, changes in sea level, average temperature, and weather will damage coastal property and beaches, water resources, human health, agriculture, and natural areas.

- ▶ Anticipated sea level rise will make storms more damaging and flood shoreline homes and hotels. Protecting these areas will be extremely costly.
- ▶ Some freshwater supplies may be contaminated with saltwater.
- ▶ Sea level rise and higher temperatures will damage the Everglades, coral reefs, beaches, and other coastal ecosystems, and alter the state's tourist economy.
- ▶ Senior citizens will be particularly at risk from heat stress, degraded air quality, and possibly increased incidence of infectious disease.
- ▶ Important cash crops like sugarcane, tomatoes and, in some regions, citrus may face declining yields over the long run, despite possible short-term benefits.
- ▶ Increased wildfires will threaten forests, natural areas, and homes.

Florida can avoid devastating harm by taking common-sense actions before it is too late. Florida needs a plan to reduce the power-plant and automobile pollution that causes global warming. The state can begin to do this by using energy more efficiently and cleanly. Florida also needs to develop the capacity to adapt to some global warming threats with minimal disruption and cost. Similar actions are also required at the national level because Florida cannot solve such a broad problem alone.

ENDNOTES

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