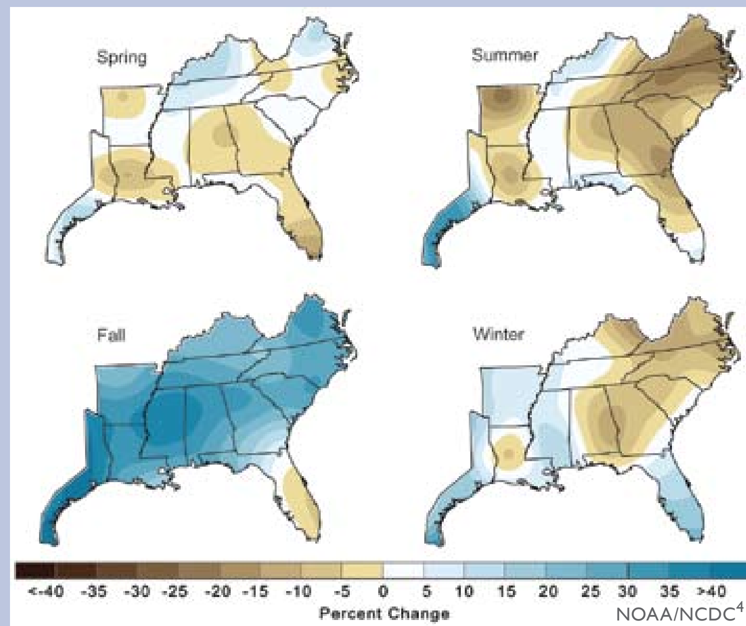
Southeast

The climate of the Southeast is uniquely warm and wet, with mild winters and high humidity, compared with the rest of the continental United States. The average annual temperature of the Southeast did not change significantly over the past century as a whole. Since 1970, however, annual average temperature has risen about 2°F, with the greatest seasonal increase in temperature occurring during the winter months. The number of freezing days in the Southeast has declined by four to seven days per year for most of the region since the mid-1970s. Average autumn precipitation has increased by 30 percent for the region since 1901. The decline in fall precipitation in South Florida contrasts strongly with the regional average. There has been an increase in heavy downpours in many parts of the region[1,2], while the percentage of the region experiencing moderate to severe drought increased over the past three decades. The area of moderate to severe spring and summer drought has increased by 12 percent and 14 percent, respectively, since the mid-1970s. Even in the fall months, when precipitation tended to increase in most of the region, the extent of drought increased by 9 percent.

Observed Changes in Precipitation
1901 to 2007



While average fall precipitation in the Southeast increased by 30 percent since the early 1900s, summer and winter precipitation declined by nearly 10 percent in the eastern part of the region. Southern Florida has experienced a nearly 10 percent drop in precipitation in spring, summer, and fall. The percentage of the Southeast region in drought has increased over recent decades.

Climate models project continued warming in all seasons across the Southeast and an increase in the rate of warming through the end of this century. The projected rates of warming are more than double those experienced in the Southeast since 1975, with the greatest temperature increases projected to occur in the summer months. The number of very hot days is projected to rise at a greater rate than the average temperature. Under a lower emissions scenario†, average temperatures in the region are projected to rise by about 4.5°F by the 2080s, while a higher emissions scenario† yields about 9°F of average warming (with about a 10.5°F increase in summer, and a much higher heat index). Rainfall is projected to decline in South Florida during this century. Except for indications that the amount of rainfall from individual hurricanes will increase[3], climate models provide divergent results for future precipitation for the remainder of the Southeast. Models suggest that Gulf

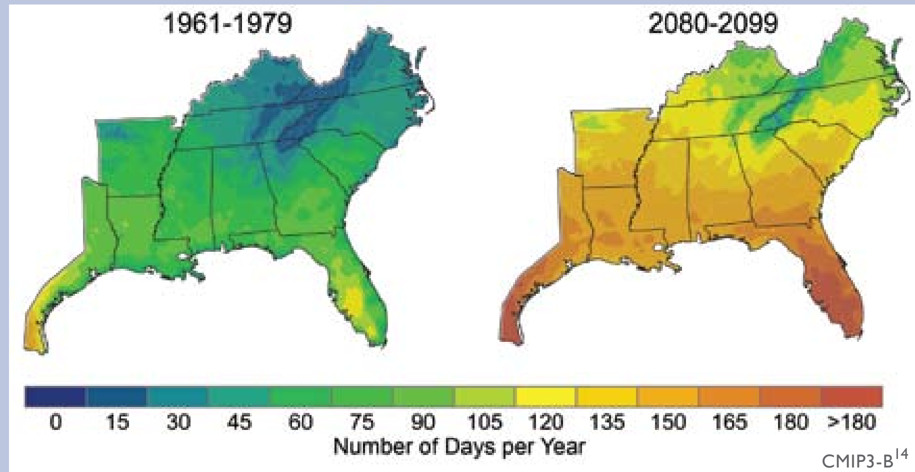
Average Change in Temperature and Precipitation in the Southeast

	Temperature Change in °F			Precipitation change in %	
	1901-2007	1970-2007		1901-2007	1970-2007
Annual	0.1	1.5	Annual	6.0	-3.8
Winter	-0.1	2.2	Winter	0.5	-9.5
Spring	0.2	1.1	Spring	0.5	-30.5
Summer	0.3	1.5	Summer	-5.4	7.0
Fall	0.1	1.2	Fall	28.0	7.9

This summary of observed climatic changes in the Southeast for two different periods. Most of the changes over the past century have occurred in the last several decades.

Coast states will tend to have less rainfall in winter and spring, compared with the more northern states in the region (see maps on pages 30 and 31 in the *National Climate Change* section). Because higher temperatures lead to more evaporation of moisture from soils and water loss from plants, the frequency, duration, and intensity of droughts are likely to continue to increase.

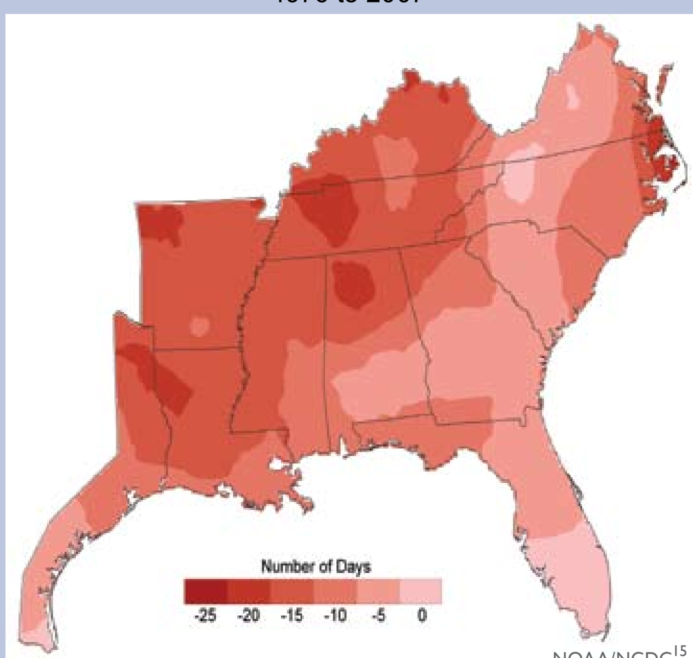
Number of Days per Year with Peak Temperature over 90°F



The number of days per year with peak temperature over 90˚F is expected to rise significantly, especially under a higher emissions scenario† as shown in the map above. By the end of the century, projections indicate that North Florida will have more than 165 days (nearly six months) per year over 90˚F, up from roughly 60 days in the 1960s and 1970s. The increase in very hot days will have consequences for human health, drought, and wildfires.

The destructive potential of Atlantic hurricanes has increased since 1970, correlated with an increase in sea surface temperature. A similar relationship with the frequency of land falling hurricanes has not been established[5-9] (see *National Climate Change* section for a discussion of past trends and future projections). An increase in average summer wave heights along the U.S. Atlantic coastline since 1975 has been attributed to a progressive increase in hurricane power[10,11]. The intensity of hurricanes is likely to increase during this century with higher peak wind speeds, rainfall intensity, and storm surge levels[11,12]. Even with no increase in hurricane intensity, coastal inundation and shoreline retreat would increase as sea-level rise accelerates, which is one of the most certain and most costly consequences of a warming climate[13].

Change in Freezing Days per Year
1976 to 2007



Since the mid-1970s, the number of days per year in which the temperature falls below freezing has declined by four to seven days over much of the Southeast. Some areas, such as western Louisiana, have experienced more than 20 fewer freezing days. Climate models predict continued warming across the region, with the greatest increases in temperature expected in summer, and the number of very hot days increasing at a greater rate than the average temperature.

Projected increases in air and water temperatures will cause heat-related stresses.

The warming projected for the Southeast during the next 50 to 100 years will create heat-related stress for people, agricultural crops, livestock, trees, transportation and other infrastructure, fish, and wildlife. The average temperature change is not as important for all of these sectors and natural systems as the projected increase in maximum and minimum temperatures. Examples of potential impacts include:

- Widespread illness and loss of life due to increased summer heat stress, unless effective adaptation measures are implemented[16].

In Atlanta and Athens, Georgia, 2007 was the second driest year on record. Among the numerous effects of the rainfall shortage were restrictions on water use in some cities and low water levels in area lakes. In the photo, a dock lies on dry land near Aqualand Marina on Lake Lanier (located northeast of Atlanta) in December 2007.

- Decline in forest growth and agricultural crop production due to the combined effects of thermal stress and declining soil moisture[17].
- Increased buckling of pavement and railways[18,19].
- Decline in dissolved oxygen in stream, lakes, and shallow aquatic habitats leading to fish kills and loss of aquatic species diversity.
- Decline in production of cattle and other rangeland livestock[20]. Significant impacts on beef cattle occur at continuous temperatures in the 90 to 100°F range, increasing in danger as the humidity level increases (see *Agriculture* sector)[20]. Poultry and swine are primarily raised in indoor operations, so warming would increase energy requirements[21].

A reduction in very cold days is likely to reduce the loss of human life due to cold-related stress, while heat stress and related deaths in the summer months are likely to increase. The reduction in cold-related deaths is not expected to offset the increase in heat-related deaths (see *Human Health* sector). Other effects of the projected increases in temperature include more frequent outbreaks of shellfish-borne diseases in coastal waters, altered distribution of native plants and animals, local loss of many threatened and endangered species, displacement of native species by invasive species, and more frequent and intense wildfires.

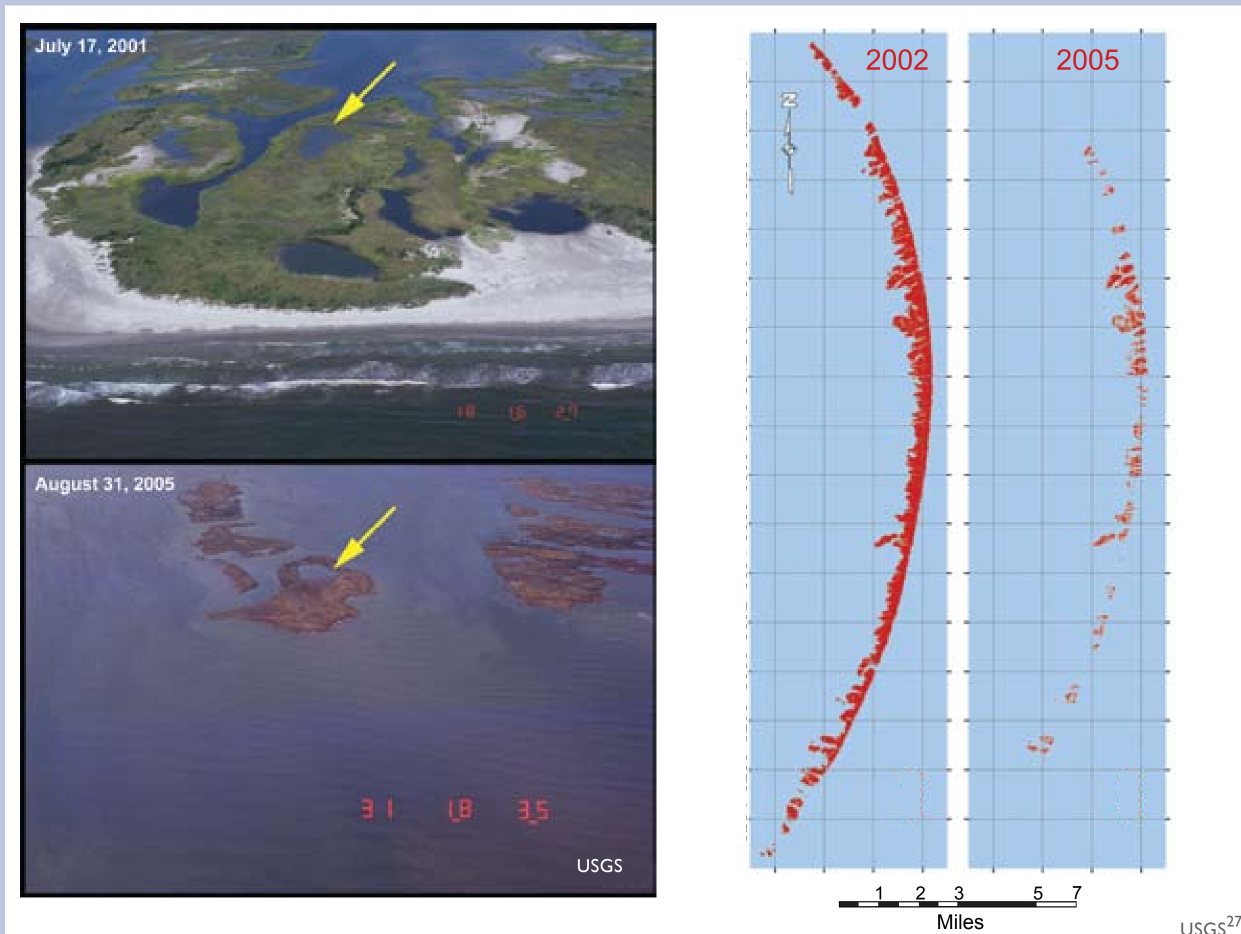
Decreased water availability will impact the economy as well as natural systems.

Decreased water availability due to increased temperature and longer periods of time between rainfall events, coupled with an increase in societal demand is very likely to affect many sectors of the Southeast's economy. The amount and timing of water available to natural systems also is affected by climate change, as well as by human response strategies such as increasing storage capacity (dams)[22] and increasing acreage of irrigated cropland[23]. The 2007 water shortage in the Atlanta region created serious conflicts between three states, the U.S. Army Corps of Engineers (which operates the dam at Lake Lanier), and the U.S. Fish and Wildlife Service, which is charged with protecting endangered species. As humans seek to adapt to climate change by manipulating water resources, streamflow and biological diversity are likely to be reduced[22]. During droughts, recharge of groundwater will decline as the temperature and spacing between rainfall events increases. Responding by increasing groundwater pumping will further stress or deplete aquifers and place increasing strain on surface water resources. Increasing evaporation and plant water loss rates alter the balance of runoff and groundwater recharge, which is likely to lead to salt water intrusion into shallow aquifers in many parts of the Southeast[22].

Accelerated sea-level rise and increased hurricane intensity will have serious impacts.

An increase in average sea level of 1 to 2 feet and the likelihood of increased hurricane intensity are likely to be among the most costly consequences of climate change for this region. As sea level rises, coastal shorelines will retreat. Wetlands will be inundated and eroded away, and low-lying areas including cities will be inundated more frequently—some permanently—by the advancing sea. As temperature increases and rainfall patterns change, soil moisture and runoff to the coast are likely to be more variable. The salinity of estuaries, coastal wetlands, and tidal rivers is likely to increase in the southeastern coastal zone, thereby restructuring coastal ecosystems and displacing them farther

Land Lost during 2005 Hurricanes

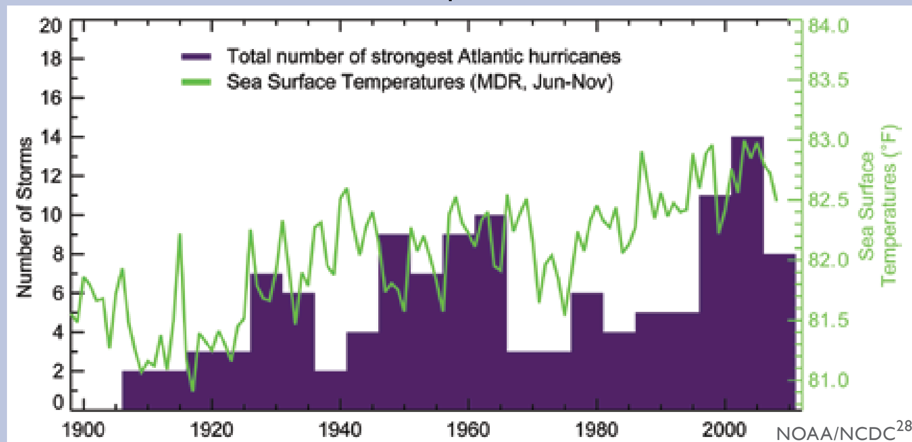


In 2005, 217 square miles of land and wetlands were lost to open water during hurricanes Rita and Katrina. The photos and maps show the Chandeleur Islands, east of New Orleans, before and after the 2005 hurricanes; 85 percent of the islands' above-water land mass was eliminated.

inland. More frequent storm surge flooding and permanent inundation of coastal ecosystems and communities is likely in some low-lying areas, particularly along the central Gulf Coast where the land surface is sinking[24,25]. Rapid acceleration in the rate of increase in sea-level rise could threaten a large portion of the Southeast coastal zone (see *Global Climate Change* section). The likelihood of a catastrophic increase in the rate of sea-level rise is dependent upon ice sheet response to warming, which is the subject of much scientific uncertainty[12]. Such rapid rise in sea level is likely to result in the crossing of thresholds, resulting in the destruction of barrier islands and wetlands[17].

Compared to the present coastal situation, for which vulnerability is quite high, an increase in hurricane intensity will further affect low-lying coastal ecosystems and coastal communities along the Gulf and South Atlantic coastal margin. An increase in intensity is very likely to increase inland and coastal flooding, coastal erosion rates, wind damage to coastal forests, and wetland loss. Strong hurricanes also pose a severe risk to people, personal property, and public infrastructure in the Southeast, and this risk is likely to be exacerbated[24,25]. Hurricanes have their greatest impact at the coastal margin where they make landfall, causing storm surge, severe beach erosion, inland flooding, and wind-related casualties for both cultural and natural resources. Some of these impacts extend farther inland, affecting larger areas. Recent examples of societal vulnerability to severe hurricanes include Katrina and Rita in 2005, which were responsible for the loss of more than 1,800 lives and the net loss of 217 square miles of low-lying coastal marshes and barrier islands in southern Louisiana[17,26].

Hurricanes and Ocean Temperatures in the North Atlantic



Total numbers of strongest (Category 4 and 5) North Atlantic basin hurricanes (purple) in 5-year periods from 1901 to 2008. The number of strongest hurricanes have not been adjusted owing to the fact that storms of this strength are unlikely to be missing in the observational record of the pre-satellite era. The last 5-year period is standardized to a comparable 5-year period assuming the level of activity from 2006 to 2008 persists through 2010. The green line indicates the June-November sea surface temperature in the Main Development Region for hurricanes in the Atlantic.

Flooding damage due to Hurricane Katrina.

Ecological thresholds are likely to be crossed throughout the region, causing the rapid restructuring of ecosystems and the services they provide.

Ecological systems provide numerous important services that have high economic and cultural value in the Southeast. Ecological effects cascade among both living and physical systems, as illustrated in the following examples of ecological disturbances that result in abrupt responses, as opposed to gradual and proportional responses to warming:

- The sudden loss of coastal landforms (such as in a major hurricane) that serve as a storm-surge barrier for natural resources and as a homeland for coastal communities[17,29].
- An increase in sea level can have no apparent effect until an elevation is reached that allows widespread, rapid salt water intrusion into coastal forests and freshwater aquifers[30].
- Lower soil moisture and higher temperatures leading to intense wildfires or pest outbreaks (such as the southern pine beetle) in southeastern forests[31], intense droughts leading to the drying of lakes, ponds, and wetlands, and the local or global extinction of riparian and aquatic species[22].
- A precipitous decline of wetland-dependent coastal fish and shellfish populations due to the rapid loss of coastal marsh[32].

Quality of life will be affected by increasing heat stress, water scarcity, severe weather events, and reduced availability of insurance for at-risk properties.

Over the past century, the southeastern "sunbelt" has attracted people, industry, and investment. The population of Florida more than doubled during the past three decades, and growth rates in most other southeastern states were in the range of 45 to 75 percent. Future population growth and the quality of life for existing residents is likely to be affected by the many challenges associated with climate change, such as reduced insurance availability, and increases in water scarcity, sea-level rise, extreme weather events, and heat stress.

Adaptation: Reducing Exposure to Flooding

Three different types of adaptation to sea-level rise are available for low-lying coastal areas[33]. One is to move buildings and infrastructure further inland to get out of the way of the rising sea. Another is to accommodate rising water through actions such as elevating buildings on stilts. Flood insurance programs even require this in some areas with high probabilities of floods. The third adaptation option is to try to protect existing development by building levees and river flood control structures. This option is being pursued in some highly vulnerable areas of the Gulf and South Atlantic coasts. Flood control structures can be designed to be effective in the face of higher sea level and storm surge. Some hurricane levees and floodwalls were not just replaced after Hurricane Katrina, they were redesigned to withstand higher storm surge and wave action[34].

Recent upgrades underway to raise the height of this earthen levee to the 100-year level in the New Orleans area.

The costs and environmental impacts of building such structures can be significant. Furthermore, building levees can actually increase future risks. This is sometimes referred to as the levee effect or the safe-development paradox. Levees that provide protection from, for example, the storm surge from a category 3 hurricane, increase real and perceived safety and thereby lead to increased development. This increased development means there will be greater damage if and when the storm surge from a category 5 hurricane tops the levee than there would have been if no levee had been constructed[35].

In addition to levees, enhancement of key highways used as hurricane evacuation routes and improved hurricane evacuation planning is a common adaptation underway in all Gulf Coast states[18]. Other protection options that are being practiced along low-lying coasts include the enhancement and protection of natural features such as forested wetlands, saltmarshes, and barrier islands[17].