Health Effects of Summer Heat in Florida

Florida HEALTH

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Executive Summary

Because of subtropical conditions, Florida experiences warm annual temperatures that can reach levels harmful to human health. The health effects of temperature are often compounded by the effects of humidity. Over the past century, Florida has experienced much variability in inter-annual and inter-decadal temperatures, though a general warming trend has been seen over the past 30 years. Future scenarios indicate that the majority of Florida may be at high heat risk with monthly-mean daily maximum temperatures between 95-100°F. These changes in temperature may disproportionately impact certain parts of the state, with areas in the Panhandle experiencing greater change in heat risk. While there may be geographic variation in severity, extreme heat can affect human and natural systems statewide. Local and state planning efforts should consider this hazard, so communities can mitigate the risk and adapt to future conditions.

There are important public health implications from daily and extreme heat. Besides the potential increase in heat-related illness, a spectrum of symptoms which result from the direct and indirect effects of heat, including heat exhaustion and heat stroke, heat may also impact cardiovascular health, mental health and behavioral disorders, respiratory health, and other health systems including endocrine and renal function. To examine the relationship between heat and these conditions, rates of heat-related illness, certain cardiovascular diseases (myocardial infarction and ischemic stroke), mental health (organic psychotic conditions) and behavioral disorders (substance-related disorders), and respiratory disease (asthma) emergency department (ED) visits among Florida residents were calculated using Agency for Health Care Administration (AHCA) data from 2005-2012. Climate data were obtained from the National Climatic Data Center (NCDC), Florida State University Center for Ocean-Atmospheric Prediction Studies, and the Florida Automated Weather Network (FAWN) from 2005-2012. Data included hourly temperatures and heat index values (both in degrees Fahrenheit), which were summarized into daily maximum temperature and heat index. These daily maximum values were used to assess the effects of daily heat on human health.

After analyzing these data, daily heat exposure, measured by both temperature and heat index, has the strongest relationship with heat-related illness statewide. As both measures of exposure increased, rates of heat-related illness increased significantly. Inconsistent relationships between daily heat exposure and the other diseases of interest were noted in Florida. The heat cardiovascular disease association is positive but stronger for heat index than temperature. No significant associations were noted for the heat mental health relationships considered. Asthma had an inconsistent relationship with heat statewide. As temperature increased, the rate of asthma-related ED visits increased; but as heat index increased, the rate of ED visits decreased. In general, there was a positive association with daily heat exposure for most health conditions of interest using either daily maximum temperature or daily maximum heat index, though these associations were only significant for certain conditions.

Tallahassee Democrat. (1965, September 20). Photograph of Drew Mitchell cooling off with a garden hose in Tallahassee, Florida. State Archives of Florida, Florida Memory, floridamemory.com/items/show/270889.

Historic Patterns

The warm subtropical climate of Florida is punctuated by periods in which temperatures rise to dangerous levels. Because of the close proximity of large bodies of water, Florida typically experiences fewer days in which the temperature reaches 100°F or greater than most other states (Winsberg, O'Brien, Zierden, & Griffin, 2003). While the marine influence decreases temperature, increased humidity decreases the body's ability to dissipate the heat. Humidity levels are typically the greatest in the coastal areas of the state. Most hot periods occur between late May and August, although southern areas may occasionally experience very hot conditions as early as April or as late as October. The hottest daytime temperatures occur in the northern and interior portions of the state, away from the moderating influence of the Gulf of Mexico and Atlantic Ocean (Figure 1). On most summer days, sea breezes advance inland from the coast and take the edge off the heat (Winsberg et al., 2003). Nighttime temperatures are typically the warmest near the coast, especially across the southern two-thirds of the state (Figure 2).

Summer (June, July, and August) temperatures across Florida have displayed much inter-annual and inter-decadal variability over the last century. Relatively cooler conditions were observed in the 1960s and 1970s, followed by a warming trend that continued into the 2000s (Figure 3). This trend is reflected in the increased occurrence of exceptionally high temperatures (100°F and greater) at various inland locations. Tallahassee, for example, crossed this threshold 85 times in the 29-year period between 1985 and 2013, but only 13 times in the 35-year period between 1948 and 1984. Orlando reached it six times between 1985 and 2013 but only two times between 1948 and 1984.

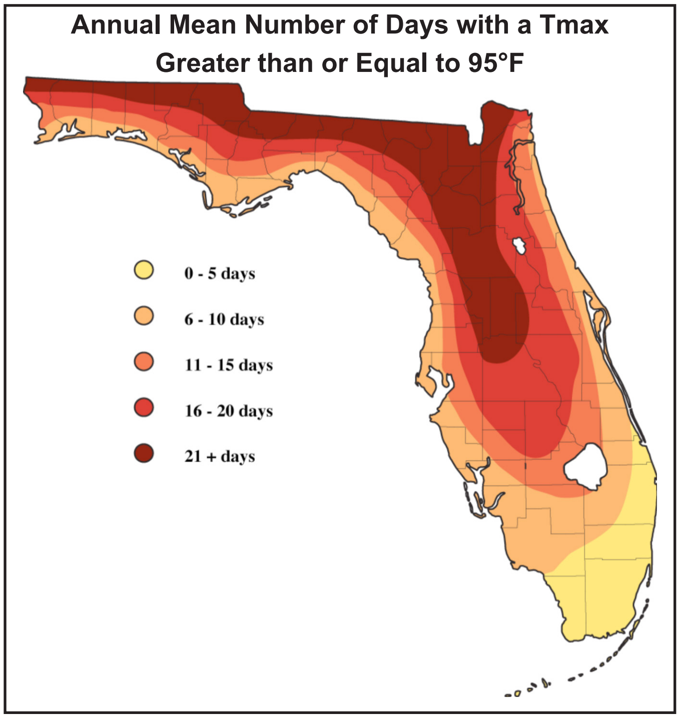


Figure 1. Annual mean number of days with a maximum temperature (Tmax) greater than or equal to 95°F (Source: The Florida State University Center for Ocean-Atmospheric Prediction Studies).

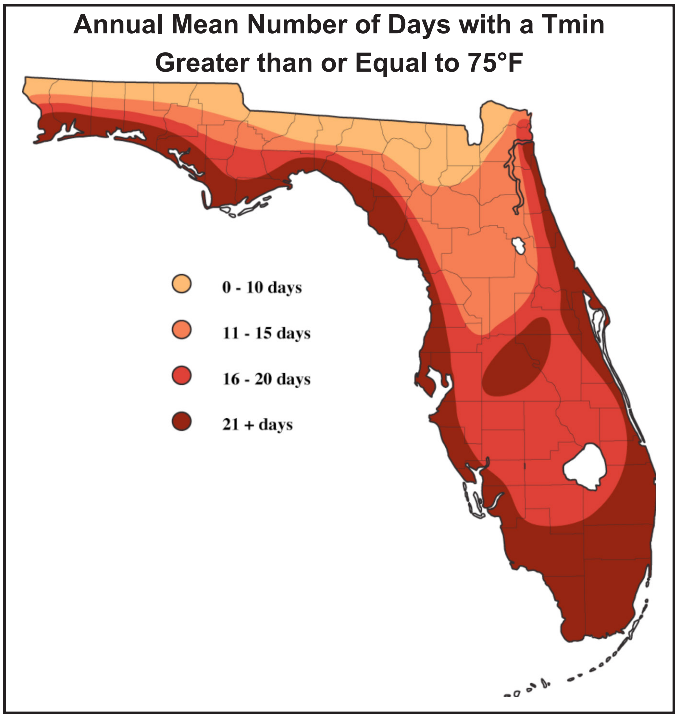


Figure 2. Annual mean number of days with a minimum temperatures (Tmin) greater than or equal to 75°F (Source: The Florida State University Center for Ocean-Atmospheric Prediction Studies).

Several factors have contributed to the recent positive trend in temperature. First, urban development across rapidly growing areas, including the southeast coast, Jacksonville, Tampa, and Orlando, has increased the magnitude of the heat island, especially at night (i.e., less nocturnal cooling). The heat island is present in urban areas where heat-absorbing buildings, concrete, and asphalt replace the natural environment (Zierden, 2013). Second, the draining of wetlands in portions of south Florida has dried the surface, which translates into higher daytime temperatures. Third, the exceptionally dry soils during periods of drought in recent years have contributed to warmer daytime temperatures. The warming associated with the increase in greenhouse gases may be playing some role (Konrad & Fuhrmann, 2013), although temperatures across the cooler months of the year at many locations have actually decreased over the last century.

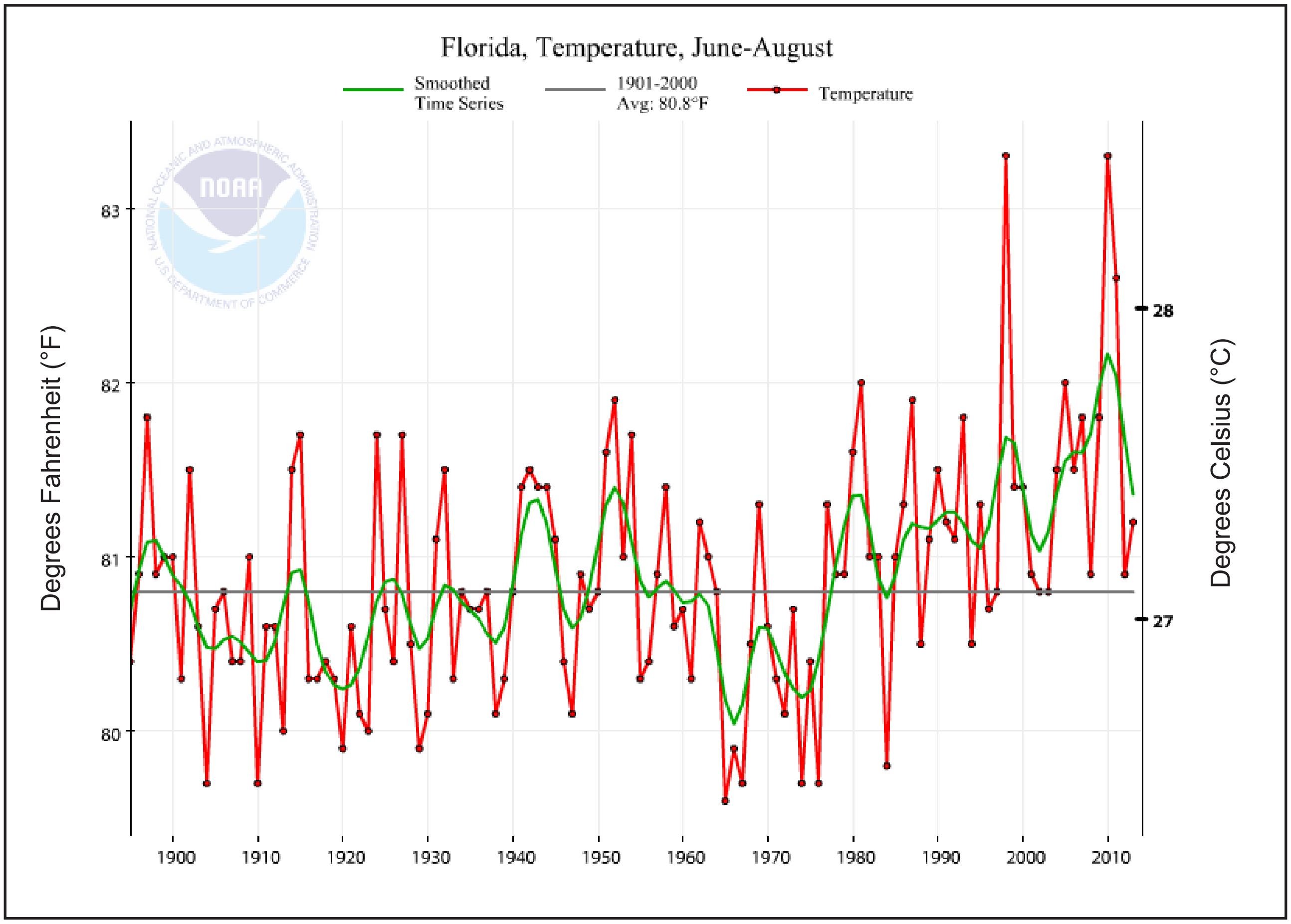
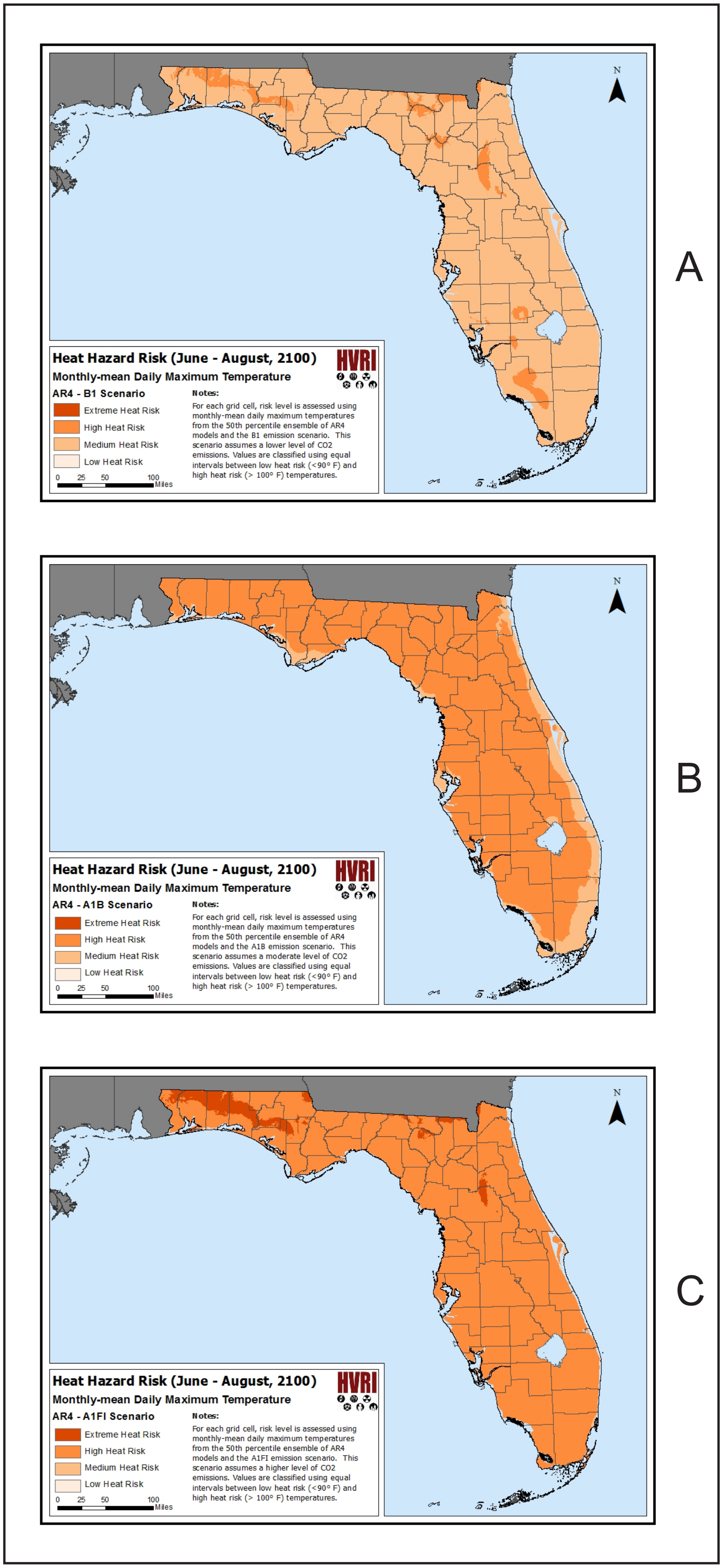


Figure 3. The average summer (June-August) temperature in degrees Fahrenheit and Celsius, Florida 1985-2012 (Source: National Climatic Data Center).



Geographic Vulnerability

Due to the subtropical climate, Florida has historically been vulnerable to both continuous summer heat and extreme heat events. The positive trend in temperature is likely to continue; projections indicate that, in the future, there will be warmer temperatures and increases in dry days.

Downscaling was used to generate state-specific data for Florida, derived from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4).These downscaled projections were used to create spatial representations of future summer (June to August) heat for the year 2100 under three different scenarios. High heat risk was defined as monthly-mean daily maximum temperatures between 95-100°F. Extreme heat risk was defined as monthly-mean daily maximum temperatures between 100-105°F. Under the lowest scenario (B1), 3% of census tracts in the state, home to over 600,000 residents, are at high risk of summer heat (Figure 4A). Under the middle scenario (A1B), 58% of census tracts in the state, home to almost 11 million residents, are at high risk of summer heat (Figure 4B). Under the highest (A1FI) scenario, nearly all of the state is at high risk (over 18 million people) and approximately 335,000 people in 20 counties are at extreme risk of summer heat (Figure 4C). It is important to note that there may also be a disproportionate increase in future maximum temperatures compared to the current baseline in the Florida Panhandle (Figure 5).

Figure 4. Heat hazard risk (based on monthly-mean daily maximum temperatures) in Florida, June-August, 2100. A) B1 scenario B) A1B scenario C) A1FI scenario (Source: Hazards and Vulnerability Research Institute).

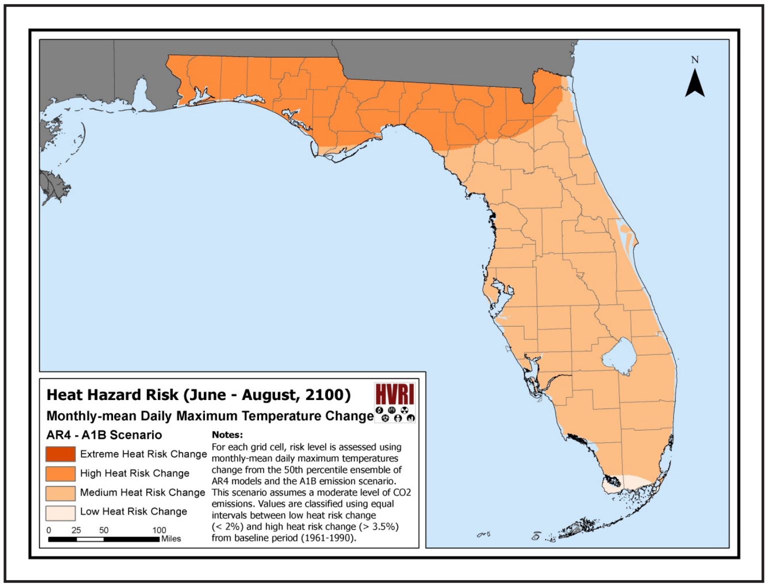


Figure 5. June-August change in monthly-mean daily maximum temperature for the A1B scenario in Florida from 1990 baseline to 2100. (Source: Hazards and Vulnerability Research Institute).

Health Implications

Through internal and external (e.g., behavioral) changes, the human body is able to maintain temperature equilibrium of 37°C ± 0.5 (98.6°F ± 0.9) (Sawaka, Wenger, & Pandolf, 1996). Heat produced internally through normal body operations or absorbed from the external environment can raise body temperature if not dispersed properly (Lugo-Amador, Rothenhaus, & Moyer, 2004). If temperature equilibrium is not maintained, the body quickly deteriorates, leading to illness and death.

Heat-Related Illness: The resulting medical problems are classified by medical practitioners as a continuum of disorders under the heading of heat-related illness (HRI) (Hall, 2011; Lugo-Amador et al., 2004). Timely medical intervention can prevent mild cases of HRI (e.g., heat edema or heat cramps) from becoming severe. Heat exhaustion is often considered a warning of impending heat stroke, and if untreated, heat exhaustion typically turns into heat stroke. Heat stroke, a medical emergency, is the most severe form of HRI and can result in death (Grubenhoff, du Ford, and Roosevelt, 2007). There are two types of heat stroke, classical and exertional. Classical heat stroke occurs in hot environments and usually affects those whose ability to maintain thermal equilibrium is compromised due to medication usage, injury, chronic illness, underdevelopment (i.e., children), or individuals who are not able to employ behavioral modifications, such as the very young or very old (Grubenhoff et al., 2007; Lugo-Amador et al., 2004). Exertional heat stroke occurs in young, healthy individuals under conditions of strenuous activity, typically in hot, humid weather (Lugo-Amador et al., 2004).

Cardiovascular Disease: Maintaining thermal equilibrium in hot environments can be very stressful on the body. As a result, pre-existing conditions may be exacerbated or body system failures may occur. For instance, excess body heat is removed through increased blood flow to the skin. Individuals with heart conditions may not be able to tolerate the increased cardiac output leading to an adverse cardiac event. Even healthy individuals may not be able to tolerate the increase in cardiac activity required to maintain thermal equilibrium. Prior work has demonstrated that mortality related to the circulatory system increases with increasing heat exposure (Basu, 2009). For circulatory morbidity, this relationship is not straightforward (Ye et al., 2012). The majority of the literature has observed a potential increase in circulatory morbidity with increasing heat exposure (Basu, Pearson, Malig, Broadwin, & Green, 2012; Lin et al., 2009; Schwartz, Samet, & Patz, 2004); however, a few studies have observed a decrease in hospital or ED admissions (Green et al., 2010; Michelozzi et al., 2009). For specific circulatory system sub-groups, there is a positive relationship between heat exposure and the following outcomes: ischemic heart disease morbidity and mortality, myocardial infarction morbidity and mortality, and hospital admissions for cardiac dysrhythmia and death due to heart failure (Basu & Ostro, 2008; Basu et al., 2012; Braga, Zanobetti, & Schwartz, 2002; Gasparrini, Armstrong, Kovats, & Wilkinson, 2012; Green et al., 2010; Lin et al., 2009; Medina-Ramon & Schwartz, 2007; Schwartz et al., 2004; Semenza, McCullough, Flanders, McGeehin, & Lumpkin, 1999). However, inconsistent results have been observed when examining the relationship between heat exposure and heart failure and hypertension (Basu et al., 2012; Green et al., 2010; Lin et al., 2009; Semenza et al., 1999). A potentially positive relationship is seen for cerebrovascular mortality and for ischemic stroke morbidity (Basu et al., 2012; Gasparrini et al., 2012b; Green et al., 2010; Semenza et al., 1999). A strong negative association has been observed with hemorrhagic stroke morbidity (Basu et al., 2012; Green et al., 2010).

Mental Health and Behavioral Disorders: People with mental health disorders (e.g., organic disorders, dementia, mood disorders, and stress-related disorders) and certain behavioral disorders, such as substance use or dependence, are at higher risk for morbidity and mortality during extreme heat events (Basu & Samet, 2002; Cusack, de Crespigny, & Athanasos, 2011; Hansen et al., 2008). The nature of the disorder itself may increase an individual's risk; for example, schizophrenia is associated with thermoregulation dysfunction (Shiloh et al., 2001). Also, depending on the condition, an individual may have limited to no ability to adapt to or cope with the heat (Cusack et al., 2011).

Another mechanism by which extreme heat can have adverse effects on people with mental health disorders is that the person may be more vulnerable to the heat due to the effects of their prescription medications. For example, specific antipsychotic and anticholinergic (anti-parkinsonian) medications are associated with heat intolerance because they suppress thermoregulation function and can cause anhydrosis (inability to sweat or perspire) and cutaneous vasoconstriction (narrowing of blood vessels), which reduces the amount of heat the body is able to dissipate (Cusack et al., 2011; Martin-Latry et al., 2007).

Use of substances such as alcohol and drugs (e.g., opioids) contributes to HRI morbidity and mortality through a variety of mechanisms. They can increase cutaneous vasodilation (widening of blood vessels) and perspiration which contributes to dehydration. Alcohol is also a strong diuretic, which can lead to dehydration. Other drugs, like amphetamines, actually elevate the body temperature by causing vasoconstriction and decreasing blood flow in the skin (reducing heat loss) or by increasing muscle activity through agitation (increasing body heat) (Cusack et al., 2011).

Respiratory Disease: Respiratory morbidity and mortality have been shown to increase with increasing heat exposure; however, the mechanisms are not as clear. Poor air quality (e.g., high ozone) often occurs as outdoor temperatures increase, exacerbating pre-existing respiratory system disorders (Kenny, Yardley, Brown, Sigal, & Jay, 2010). Additionally, respiratory alkalosis and adult respiratory distress are both symptoms of HRI (Bouchama & Knochel, 2002; Noakes, 2008). An increase in pneumonia morbidity and mortality, a decrease in asthma morbidity, and an increase in asthma mortality have been noted with increasing heat exposure. There is also a possible increase in chronic bronchitis and emphysema morbidity and mortality with increasing heat exposure (Basu et al., 2012; Braga et al., 2002; Gasparrini et al., 2012b; Green et al., 2010; Lin et al., 2009; Semenza et al., 1999).

Other Diseases: Other diseases or health conditions have been linked to exposure to excess heat. Dehydration is a common symptom of HRI, as the body loses water and electrolytes through sweat. Increasing heat exposure has a strong positive association with dehydration (Basu et al., 2012; Green et al., 2010; Semenza et al., 1999). There is a clear positive association between heat exposure and acute renal failure (Basu et al., 2012; Green et al., 2010; Semenza et al., 1999), which is a common symptom of exertional heat stroke (Lugo-Amador et al., 2004). Additionally, a positive association has been observed for total renal morbidity and mortality (Basu, 2012; Gasparrini, 2012b).

Both type I and type II diabetes are chronic conditions which may impair an individual's ability to properly maintain thermal equilibrium due to inadequate dilatation of blood vessels in the skin leading to poor heat dispersion (Kenny et al., 2010; Yardley, Stapleton, Carter, Sigal, & Kenny, 2013). Individuals with type II diabetes also have decreased sweating response, and the mechanisms for heat dispersion occur at a higher temperature than in individuals without diabetes (Charkoudian, 2003; Kenny et al., 2010).

Methods

The literature surrounding the heat/health relationship can be divided into two general approaches: analysis of extreme heat events (or heat waves) and analysis of daily heat exposure (Basu, 2009; Kovats & Hajat, 2008). Extreme heat events are short periods of intense outdoor heat ranging from a few days to a couple of weeks (Gasparrini & Armstrong, 2011; Smith, Zaitchik, & Gohlke, 2013; Tong, Wang, & Barnett, 2010). During an extreme heat event, a large number of illnesses or deaths can occur over a short period of time. HRI and deaths also occur daily as outdoor heat increases; however, due to the longer time period (e.g., entire summer) the burden may not be as visible. The characteristics of individuals and groups affected during episodic events may be different from the daily occurrences. For instance, on warm days, individuals exerting themselves (e.g., workers or athletes) outside may succumb to HRI, while elderly individuals may not be at risk until the temperatures are unusually high, like during a heat wave. Further, by only examining heat waves, a large portion of the burden of disease may be ignored. At the same time, analysis of daily events may ignore the importance of duration on the risk of HRI and death. To have a complete understanding of the heat/health relationship, considering both types of heat exposure is necessary. Florida's Environmental Public Health Tracking Program, with researchers from the University of Florida, has undertaken an analysis of extreme heat events and health outcomes. The results of this analysis will be provided on Florida's Tracking Portal (Florida Environmental Public Health Tracking, 2015). This report, therefore, focuses on the heat/health relationship in terms of daily heat exposure.

Hourly weather data for the months of May through October (i.e., expanded warm season) for the years 2005 through 2012 were obtained from two weather station networks: National Weather Service (NWS) first-order weather stations and Florida Agricultural Weather Network (FAWN) automated weather stations. Each ZIP Code in Florida was assigned to the nearest weather station, such that each weather station was attached to a group of ZIP Codes for analysis with health data. Missing weather data was minimized by substituting data from the next nearest station for a given ZIP Code, as needed. Heat index was calculated according to NWS methodology and based on temperature and relative humidity (National Weather Service, 2014). Maximum daily temperature and maximum daily heat index were determined for each day based on the hourly data and were used as the primary exposure variables in our analyses.

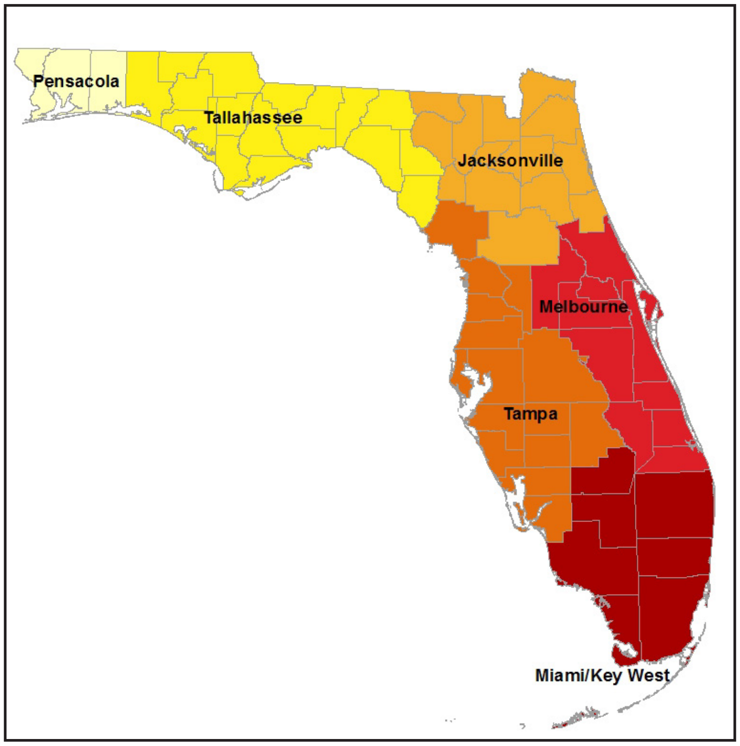


Figure 6. National Weather Service regions in Florida (Source: National Weather Service).

A variety of health data sources are readily available in Florida to study the effects of continuous summer heat on human health outcomes. Using existing data sources is beneficial for several reasons. They provide immediate access to data to understand historical trends and associations between weather and public health, and they collect information statewide on a variety of health outcomes and diseases. However, using these data sources is not without limitations. These data sources were mostly created for surveillance or quality assurance purposes and were not intended for research in general or to specifically study the effects of weather hazards on health. Information on data sources can be found in Appendix 1.

Except for HRI, the health conditions considered in relation to summer heat are chronic in nature including cardiovascular disease, mental health and behavioral disorders, and respiratory disease. However, we are more concerned with the short-term or immediate health effects of heat exposure that result in people with these chronic conditions. For example, the respiratory disease of interest (asthma) is considered chronic, with individuals suffering from the effects of asthma for many years or throughout their lifetimes. We are interested in the acute, more immediate triggers of asthma episodes.

We examined associations between daily maximum temperature or daily maximum heat index and rates of ED visits for specific health conditions among Florida residents from May to October (warm season), 2005 to 2012. We limited our analysis to this warm season period to more accurately assess the effects of outdoor heat, but we have also provided estimates of health outcomes for the entire period of study and included all months to better understand the total burden of disease. The average maximum daily temperature and heat index values for Florida and by each of six NWS regions (Figure 6) are shown in Table 1. Note that for the purposes of this analysis, the Miami and Key West regions have been combined, due to a relatively small population in Monroe County resulting in smaller counts of health outcomes of interest. Average temperature and heat index are higher in the southern parts of the state than in the northern regions; however, the variability in temperature and heat index was greater for the northern part of the state than for the southern regions.

Region	Temperature (°F)		Heat Index (°F)	
	Mean (SD)	Min-Max	Mean (SD)	Min-Max
Pensacola	86 (6.2)	55-106	92 (9.5)	52-121
Tallahassee	87 (6.3)	54-105	93 (9.2)	52-122
Jacksonville	87 (5.9)	56-106	93 (8.7)	53-122
Melbourne	88 (4.9)	54-101	94 (7.6)	52-122
Tampa Bay	88 (4.5)	50-102	95 (7.2)	48-122
Miami/Key West	88 (3.6)	63-102	95 (6.3)	62-119
State	**88 (4.89)**	**50-106**	**94 (7.68)**	**48-122**
SD=Standard Deviation				

Table 1. Average temperature and heat index by National Weather Service region in Florida, May-October, 2005-2012.

All associations were assessed using a two-stage analysis approach. The first stage assessed the regional-level associations between the exposures and health outcomes of interest for each NWS region using Poisson regression models. The second stage used meta-analysis techniques to combine the regional results into one statewide measure of association (Gasparrini, 2012a). Rate ratios (RR) and 95% confidence intervals are reported. An RR is the ratio of the rate in an exposed group compared to or divided by the rate in a reference group. An RR equal to 1.50 can be understood as the rate in the exposed group is 50% greater than the rate in the reference group. Here, an RR describes the rate of disease or rate of ED visits on hotter days (exposed), compared to a reference of 88°F for temperature and 94°F for heat index. Reference levels were set at the statewide mean temperature and heat index for May through October. For each RR estimate provided, there is a 95% confidence interval around this estimate. This interval can be interpreted as the range in which the true estimate would fall 95% of the time.

Heat-Related Illness

Unlike other conditions of interest, HRI is not well defined nationwide. HRI morbidity and mortality is a legally reportable condition in few states (7%), but not Florida, and data on this condition are collected regularly by only 33% of responding health jurisdictions in the U.S. (Council of State and Territorial Epidemiologists, 2015). Most active surveillance on HRI is specific to extreme heat events that have been well-documented, such as the Chicago, Illinois heat wave of July 1995. Heat-related mortality can be documented through vital statistics data. From 1999 to 2003, excessive heat exposure was listed as the underlying cause of death in an average of 450 deaths per year nationwide. Another 240 deaths per year had hyperthermia listed as a contributing factor (Luber, Sanchez, & Conklin, 2006). For the purpose of this report, we assessed heat-related morbidity by examining all ED visits with either a primary or a secondary diagnosis of HRI (Table 2).

Heat-Related Illness	
Measures	1. Number of emergency department visits for heat-related illness
	2. Crude rate of emergency department visits for heat-related illness per 100,000 population
	3. Age-adjusted rate of emergency department visits for heat-related illness per 100,000 population
Numerator	*General:* Emergency department visits made by Florida residents during the time period of interest with the associated ICD-9-CM code of interest, including primary and secondary diagnoses
	Heat-Related Illness: ICD-9-CM code 992 and E900
	Data Source: Florida Agency for Health Care Administration
Denominator	*General:* Annual population estimates for entire state and all counties
	Data Source: Florida Community Health Assessment Resource Tool Set
Adjustment	*Method:* Direct age-adjustment using the 2000 U.S. Standard population
Geography	*Scope:* State, National Weather Service regions, and ZIP Code
	Scale: Region and ZIP Code experiencing high temperatures
Time Scale	*Period:* Annual with warm season defined as May to October, 2005 to 2012
	Scale: Annual, warm season
ICD-9-CM=International Classification of Disease, 9th Revision, Clinical Modification	

Table 2. Heat-related illness indicator.

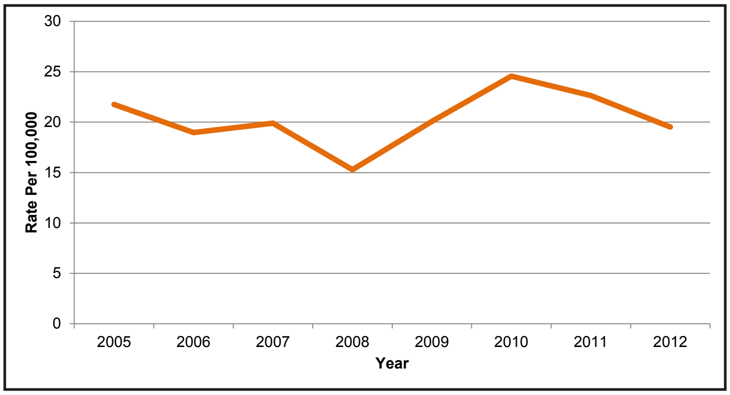


Figure 7. Rate of heat-related illness per 100,000 population, Florida, January-December, 2005-2012.

Heat-Related Illness: The average annual number of ED visits for HRI from 2005 to 2012 was approximately 3,800, with an average annual crude visit rate of 20 visits per 100,000 population (Figure 7). The annual number of visits has varied over time, with 2010 having the most reported visits (4,623) compared to a low case count in 2008 (2,849). Ninety percent of all HRI ED visits occurred during the warm season. HRI ED visits were more common among adults between the ages of 25 and 54 years (50%), males (73%), and non-Hispanic white residents (65%). Higher average rates of HRI ED visits occurred in the Panhandle and North Central Florida, with the highest rates in Jackson (55 per 100,000), Washington (53 per 100,000), and Suwannee (53 per 100,000) counties. Similar patterns were seen when assessing demographic characteristics during the warm season months only (May through October).

Heat and Heat-Related Illness

Temperature. Statewide, the strongest associations were seen between HRI and heat exposure. When assessing the relationship with temperature, statistically significant increases in HRI ED visit rates were seen at increasing temperatures above the reference level (88°F). There was a strong dose response relationship, with the rates increasing steadily as temperature increased (Figure 8). The same relationship was observed across all regions in Florida (Figure 9). Most regions showed a similar dose relationship. However, the rates of ED visits for HRI in both the Miami/Key West and Pensacola regions leveled off between 100 and 105°F. All regional associations were statistically significant.

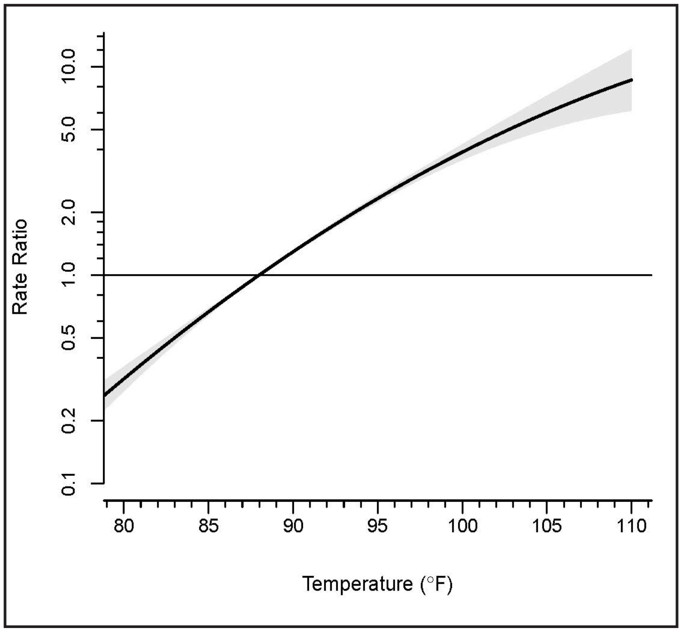


Figure 8. Associations between daily maximum temperature (°F) and heat-related illness, Florida, May-October, 2005-2012.

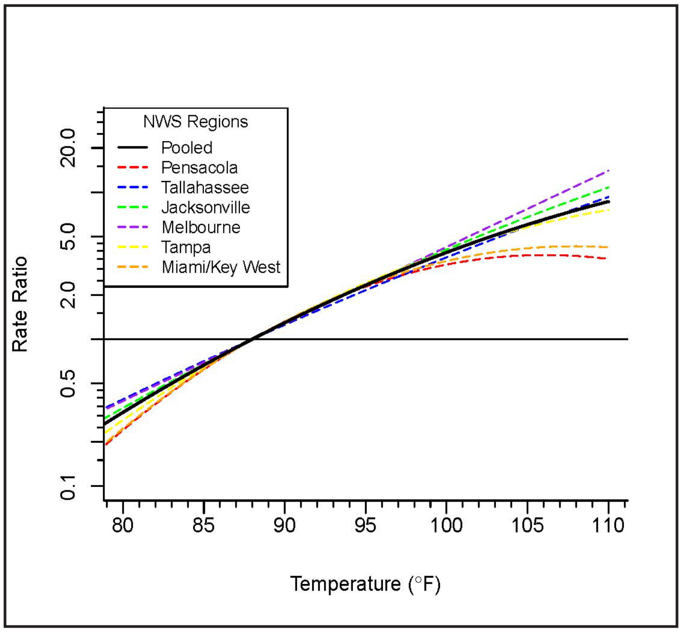


Figure 9. Associations between daily maximum temperature (°F) and heat-related illness, Florida National Weather Service regions, May-October, 2005-2012.

Heat Index. A similar significant positive relationship was seen between HRI and heat index statewide (Figure 10). Again, the rates of HRI ED visits increased steadily as heat index increased above the reference level (94°F). Regionally, there was little variation in this relationship (Figure 11), with only the Tampa region showing a tendency for ED visit rates to level off around 120°F. Rates in the Tallahassee region increased the most with increasing heat indices.

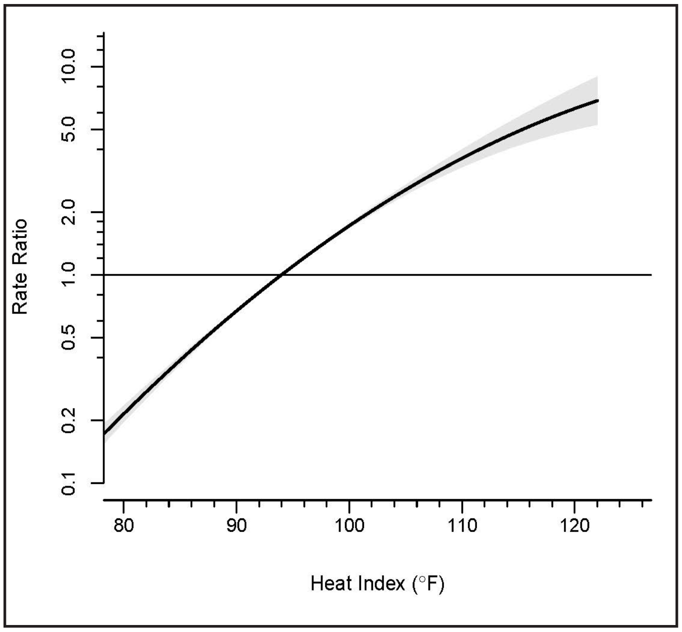


Figure 10. Associations between daily maximum heat index (°F) and heat-related illness, Florida, May-October, 2005-2012.

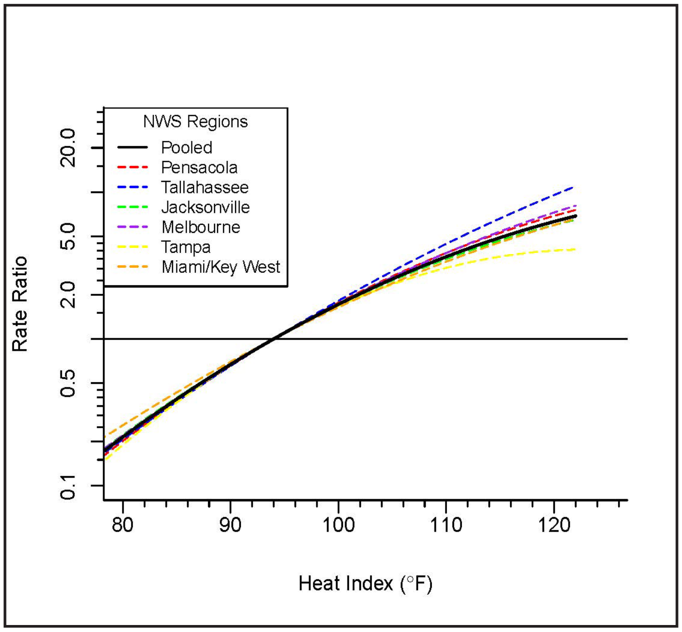


Figure 11. Associations between daily maximum heat index (°F) and heat-related illness, Florida National Weather Service regions, May-October, 2005-2012.

Cardiovascular Disease

Cardiovascular diseases are the leading cause of death worldwide, accounting for 30% of global deaths and 1 in 3 deaths in the U.S. Two cardiovascular diseases contributing substantially to this burden are myocardial infarction, or heart attack, and stroke. Annually, about 735,000 Americans experience a heart attack and 795,000 experience a stroke, with about 16% of events for each of these conditions being fatal. This burden is compounded by the long-term disability and complications associated with these diseases. Slightly less than 50% of individuals who have experienced a heart attack will have one or more recurrent episodes, and stroke is considered the leading preventable cause of disability in the U.S. (Mozaffarian et al., 2015). For the purpose of this report, we considered two categories of cardiovascular disease: myocardial infarction and ischemic stroke. ED visits for these conditions were based on either a primary or a secondary diagnosis (Table 3). Because of the serious nature of these conditions, many ED visits for heart attack and stroke result in hospital admission. Such visits are not captured in these analyses. For consistency across indicators, only ED visits were used. However, future heat-related analyses will consider hospitalizations for these conditions.

Myocardial Infarction and Ischemic Stroke	
Measures	1. Number of emergency department visits for health outcome
	2. Crude rate of emergency department visits for health outcome per 100,000 population
	3. Age-adjusted rate of emergency department visits for health outcome per 100,000 population
Numerators	*General:* Emergency department visits made by Florida residents during the time period of interest with the associated ICD-9-CM code(s) of interest, including primary and secondary diagnoses
	1. *Acute Myocardial Infarction:* ICD-9-CM code 410
	2. *Ischemic Stroke:* ICD-9-CM codes 434 and 436
	Data Source: Florida Agency for Health Care Administration
Denominator	*General:* Annual population estimates for entire state and all counties
	Data Source: Florida Community Health Assessment Resource Tool Set
Adjustment	*Method:* Direct age-adjustment using the 2000 U.S. Standard population
Geography	*Scope:* State, National Weather Service regions, and ZIP Code
	Scale: Region and ZIP Code experiencing high temperatures
Time Scale	*Period:* Annual with warm season defined as May to October, 2005 to 2012
	Scale: Annual, warm season

Table 3. Cardiovascular disease indicator.

Ischemic Stroke: Annual ED visits for ischemic stroke have increased over time (50%), from approximately 2,700 visits in 2005 to almost 4,000 visits in 2012. The average number of visits during this time was just over 3,000 per year, with an average annual crude visit rate of 16.6 visits per 100,000 population (Figure 12). Half of all stroke-related ED visits occurred during the warm season. Overall, ED visits for stroke were more common in Florida among adults 65 years of age and older (56%), females (51%), and non-Hispanic white residents (68%), with similar trends being present in the warm season months. Higher average annual age-adjusted rates of ED visits occurred in rural counties around the state including Baker (108 per 100,000), Calhoun (107 per 100,000), and Hardee (85 per 100,000) counties.

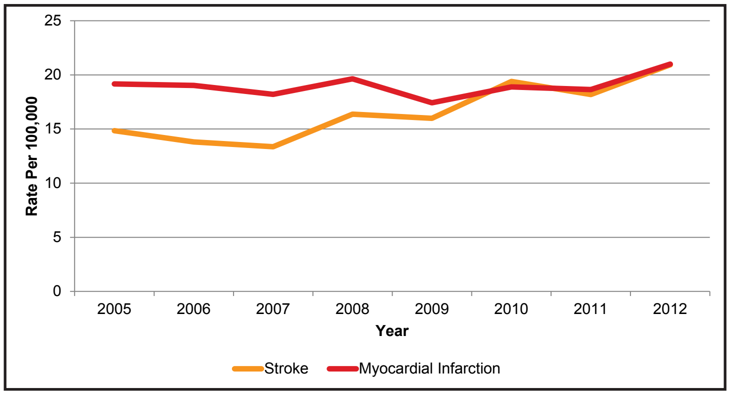


Figure 12. Rate of ischemic stroke and myocardial infarction per 100,000 population, Florida, January-December, 2005-2012.

Myocardial Infarction: The average number of annual ED visits related to myocardial infarction from 2005 to 2012 was 3,533, with an average annual crude visit rate of 19 visits per 100,000 population (Figure 12). During this time period, annual visits increased only slightly (17%), from about 3,400 in 2005 to 4,000 in 2012. Warm season ED visits for myocardial infarction accounted for 48% of the annual volume. Overall, ED visits for this condition were highest among individuals aged 55 to 84 years (62%), males (65%), and non-Hispanic white residents (75%), with no differences noted from May through October. Again, higher average annual age-adjusted rates of ED visits occurred in rural counties around the state including Taylor (109 per 100,000), Calhoun (93 per 100,000), and Hardee (91 per 100,000) counties.

Heat and Cardiovascular Disease

Ischemic Stroke:
Temperature. Ischemic stroke was not associated with temperature at the state level (Figure 13). However, there was some variation in this relationship by region (data not shown). The Tampa region showed a significant positive association with temperature, such that ED visits for stroke increased as temperature increased. However, the Tallahassee region showed a significant inverse association; stroke visits decreased as temperature increased. No other region had a significant association with temperature.

Heat Index. A positive, statistically significant, relationship between stroke and heat index was identified (Figure 14). As heat index increased above the reference level (94°F), stroke-related ED visits increased significantly. Most regional associations reflected the statewide relationship, with all showing a positive association and two being statistically significant (Tallahassee and Melbourne regions, data not shown).

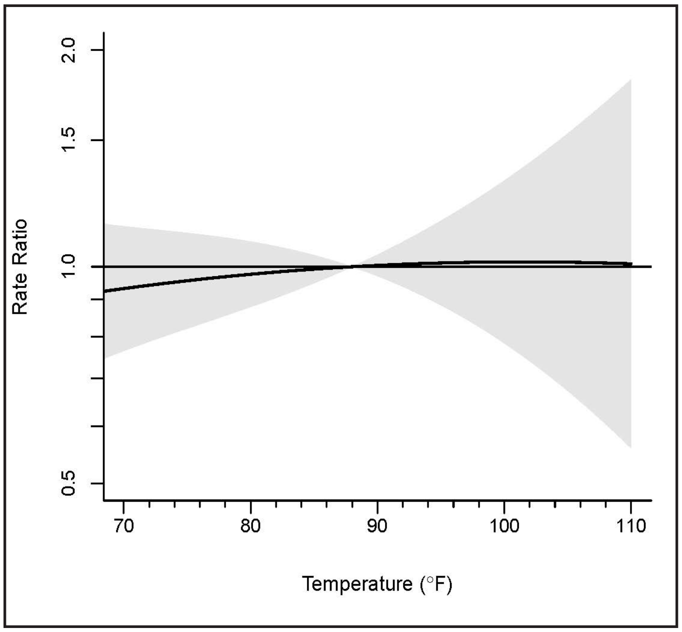


Figure 13. Associations between daily maximum temperature (°F) and ischemic stroke, Florida, May-October, 2005-2012.

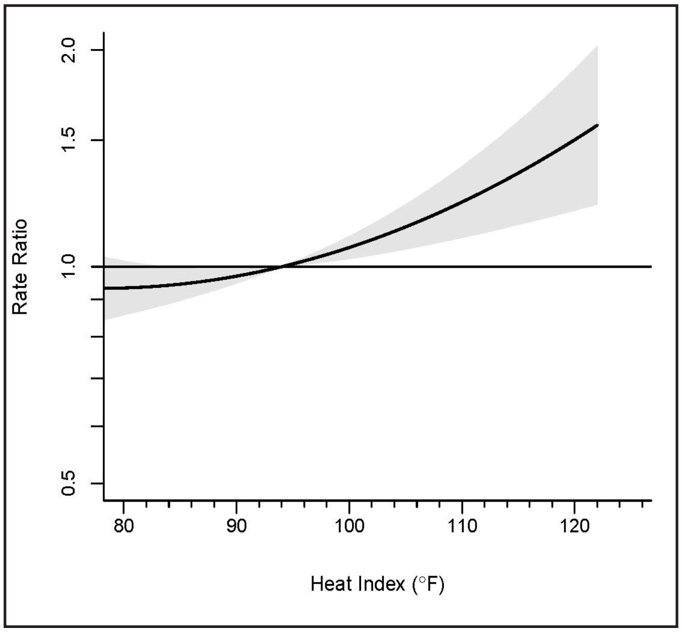


Figure 14. Associations between daily maximum heat index (°F) and ischemic stroke, Florida, May-October, 2005-2012.

Myocardial Infarction:
Temperature. Statewide, ED visits for myocardial infarction increased slightly as temperature increased above the reference level (88°F); however, this association was not significant (Figure 15). There were some important variations regionally. The Pensacola and Tampa regions showed statistically significant increased ED visit rates as temperature increased. The Jacksonville and Melbourne regions showed inverse associations, though these associations were not significant (data not shown).

Heat Index. The relationship between ED visits for myocardial infarction and heat index was positive and statistically significant (Figure 16). As heat index increased, the rate of ED visits increased. Most regions demonstrated a similar association, with the Melbourne and Tampa regions being statistically significant. Only the Miami/Key West region showed an inverse relationship between ED visits for myocardial infarction and heat index, though this association was not significant (data not shown).

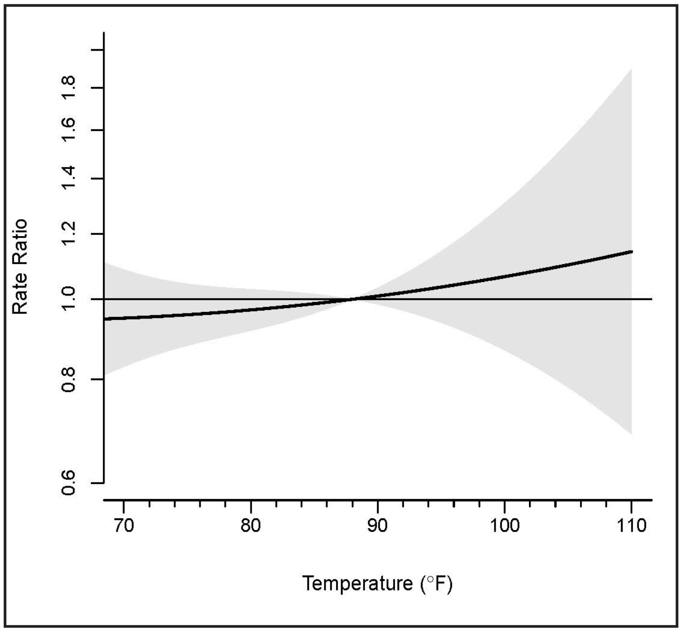


Figure 15. Associations between daily maximum temperature (°F) and myocardial infarction, Florida, May-October, 2005-2012.

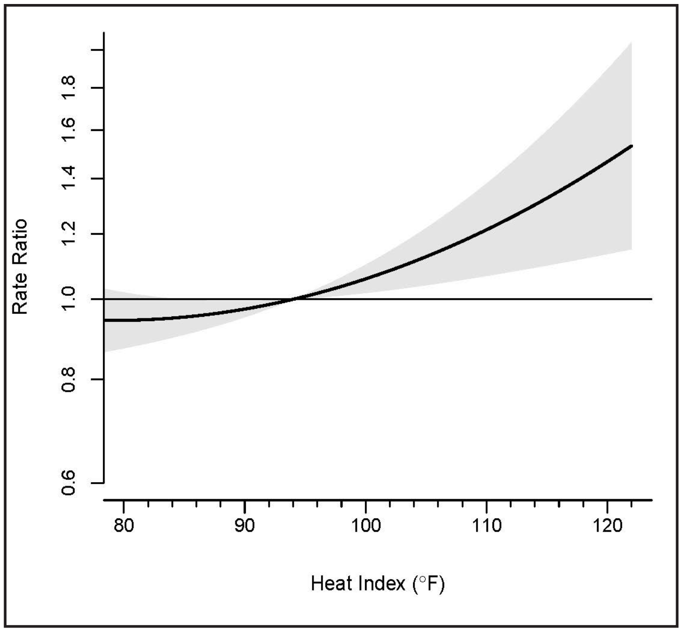


Figure 16. Associations between daily maximum heat index (°F) and myocardial infarction, Florida, May-October, 2005-2012.

Mental Health and Behavioral Disorders

A mental health disorder is defined as any health condition that is “characterized by alterations in thinking, mood, or behavior (or some combination thereof) associated with distress and/or impaired functioning” (U.S. Department of Health and Human Services, 1999). Depending on the source, between 19% and 25% of the U.S. adult population has some form of mental health disorder, with about 20% of these being classified as a serious mental health disorder with substantial functional impairment (U.S. Department of Health and Human Services, 2013a; Reeves et al., 2011). The economic burden of mental health disorders was estimated at around $300 billion dollars in the U.S. in 2002, making this an important public health problem (Reeves et al., 2011). Additionally, mental health disorders disproportionally affect women and certain minority groups (U.S. Department of Health and Human Services, 2013a).

Behavioral disorders related to substances also pose a serious public health burden in the U.S., where the estimated prevalence of dependency or abuse of substances is estimated at 7% for alcohol and 3% for illicit drugs. Substance-related disorders disproportionately affect males and younger individuals between the ages of 18 and 25 years (U.S. Department of Health and Human Services, 2013b).

For the purpose of this report, we focused on two categories of mental health and behavioral disorders that have strong associations with heat in the literature: organic psychotic conditions and substance-related disorders. ED visits for these outcomes were based on either a primary or a secondary diagnosis (Table 4). While we are missing individuals who received mental health and substance-related services outside of an ED setting, ED visit data currently represent the best available statewide data source to examine such associations.

Organic Psychotic Conditions and Substance-Related Disorders	
Measures	1. Number of emergency department visits for health outcome
	2. Crude rate of emergency department visits for health outcome per 100,000 population
	3. Age-adjusted rate of emergency department visits for health outcome per 100,000 population
Numerators	*General:* Emergency department visits made by Florida residents during the time period of interest with the associated ICD-9-CM code(s) of interest, including primary and secondary diagnoses
	1. *Organic Psychotic Conditions:* ICD-9-CM codes 290-294
	2. *Substance-Related Disorders:* ICD-9-CM codes 291-292, 303-305
	Data Source: Florida Agency for Health Care Administration
Denominator	*General:* Annual population estimates for entire state and all counties
	Data Source: Florida Community Health Assessment Resource Tool Set
Adjustment	*Method:* Direct age-adjustment using the 2000 U.S. Standard population
Geography	*Scope:* State, National Weather Service regions, and ZIP Code
	Scale: Region and ZIP Code experiencing high temperatures
Time Scale	*Period:* Annual with warm season defined as May to October, 2005 to 2012
	Scale: Annual, warm season

Table 4. Mental health and behavior disorder indicator.

Organic Psychotic Conditions: Organic psychotic conditions are a sub-category of psychoses, meaning conditions that are characterized by altered perception of reality, that include dementias, alcohol- and drug-induced mental disorders, transient mental disorders (e.g., delirium), and persistent mental disorders (e.g., amnestic disorder and dementias not classified elsewhere). The average number of annual ED visits related to these conditions from 2005 to 2012 was 35,072, with an average annual crude visit rate of 188 visits per 100,000 population (Figure 17). During this time period, annual visits increased by 103%, from about 24,000 in 2005 to 48,000 in 2012. Warm season ED visits for organic psychotic conditions accounted for 50% of the annual volume. Overall, ED visits for these conditions were highest among individuals aged 75 years and over (83%), females (65%), and non-Hispanic white residents (79%), with similar demographic trends in the warm season. Higher average annual age-adjusted rates of ED visits occurred in the Panhandle, with the highest rates in Gulf (315 per 100,000) and Escambia (280 per 100,000) counties.

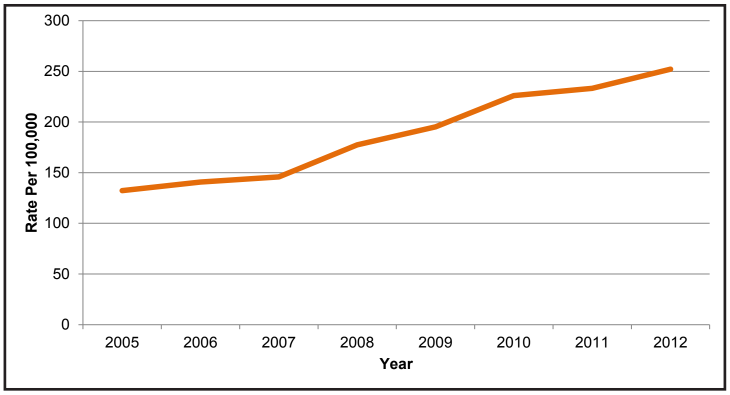


Figure 17. Rate of organic psychotic conditions per 100,000 population, Florida, January-December, 2005-2012.

Mental Health and Behavioral Disorders

Substance-Related Disorders: The substance-related disorders considered are alcohol- and drug-induced mental disorders, alcohol and drug dependence, and nondependent abuse of drugs. Annual ED visits for substance-related disorders have increased over time (65%), from approximately 433,000 visits in 2005 to almost 713,000 visits in 2012. The average number of visits during this time was just under 584,000 per year, with an average annual crude visit rate of 3,133 visits per 100,000 population (Figure 18). Just over half (52%) of all substance-related ED visits occurred during the warm season. Annually, ED visits for these disorders were more common in Florida among adults between the ages of 25 and 54 years (67%), males (51%), and non-Hispanic white residents (74%). No differences in demographic trends were noted during the warm season. Higher average annual age-adjusted rates of ED visits occurred in the Panhandle (Escambia County: 9,354 per 100,000 and Santa Rosa County: 8,411 per 100,000) and Central Florida (Putnam County: 11,820 per 100,000 and Marion County: 7,106 per 100,000).

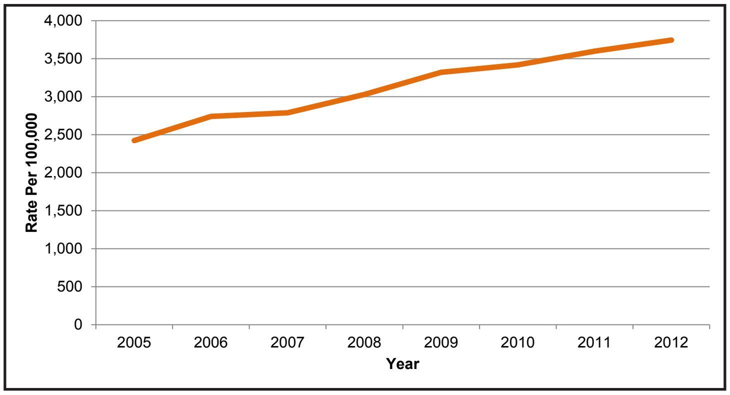


Figure 18. Rate of substance-related disorders per 100,000 population, Florida, January-December, 2005-2012.

Heat and Mental Health and Behavioral Disorders

Organic Psychotic Conditions:
Temperature. Statewide, ED visits for organic psychotic conditions tended to decrease as temperature increased (Figure 19); however, these associations were not significant at any temperature. Most regions showed very little change in ED visits for this condition as temperature increased. However, for the Tallahassee and Melbourne regions, a significant inverse association was seen. ED visits for organic psychotic conditions in these regions decreased substantially as temperature increased, driving the statewide relationship (data not shown).

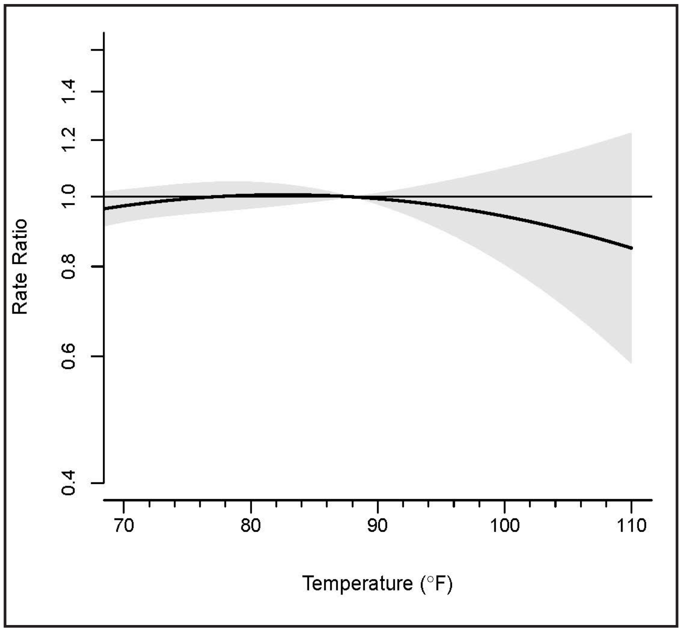


Figure 19. Associations between daily maximum temperature (°F) and organic psychotic conditions, Florida, May-October, 2005-2012.

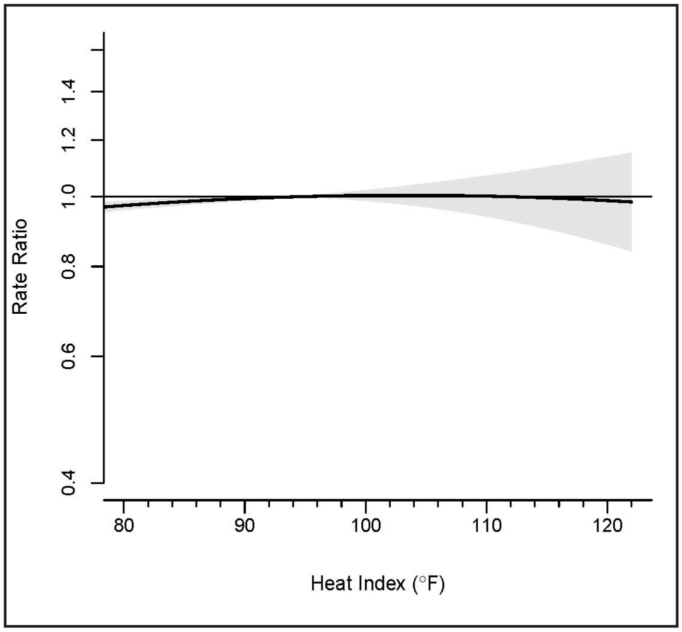


Figure 20. Associations between daily maximum heat index (°F) and organic psychotic conditions, Florida, May-October, 2005-2012.

Heat Index. Heat index was not associated with organic psychotic conditions at the state level (Figure 20). However, differences were noted when examining this relationship by region. Heat index was positively associated with organic psychotic conditions in the Jacksonville and Melbourne regions and negatively associated with this health outcome in the Tampa and Miami/Key West regions. Only the Pensacola and Tallahassee regions showed no association between heat index and organic psychotic conditions (data not shown).

Substance-Related Disorders:
Temperature. Similarly, ED visits for substance-related disorders tended to decrease as temperature increased statewide (Figure 21). These associations were not statistically significant at any temperature. Most regions showed very little change in ED visits for this condition as temperature increased. However, the Tallahassee and Melbourne regions had a significant inverse association, such that ED visits for substance-related disorders showed a large decline as temperature increased (data not shown).

Heat Index. There was no association between substance-related ED visits and heat index statewide (Figure 22). However, all but the Melbourne region showed modest, though significant, associations. The Pensacola, Tallahassee, and Jacksonville regions had small positive associations between substance-related ED visits and heat index, while the Tampa and Miami/Key West regions had modest inverse associations (data not shown).

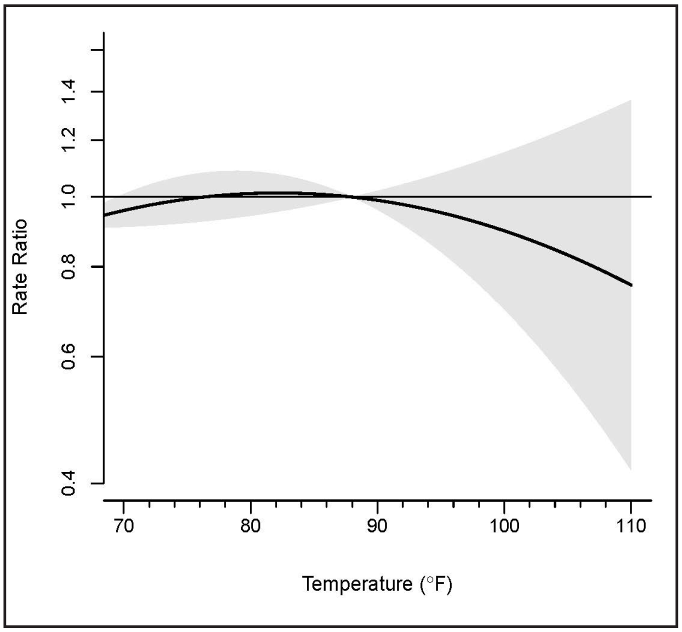


Figure 21. Associations between daily maximum temperature (°F) and substance-related disorders, Florida, May-October, 2005-2012.

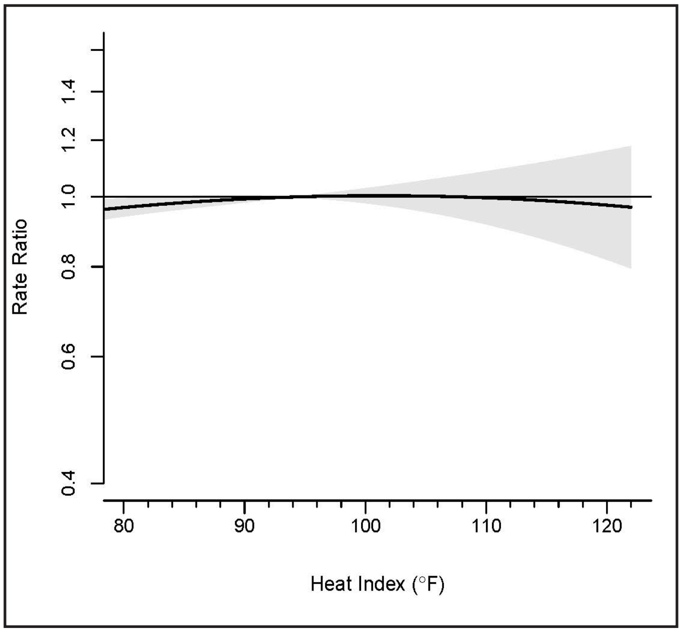


Figure 22. Associations between daily maximum heat index (°F) and substance-related disorders, Florida, May-October, 2005-2012.

Respiratory Disease

Respiratory diseases are public health priorities as prevalence, costs, and rates of ED visits and hospitalizations are increasing. In the U.S., asthma affects approximately 8% of adults and 10% of children (Centers for Disease Control and Prevention, 2014). Because chronic respiratory disease can often be controlled with proper education, clinical treatment, medication regimen, and environmental management, ED visits may be considered indicators of poorly controlled disease rather than of total prevalence or incidence. The change in rate of ED visits and hospitalizations, however, can be used as a proxy to track changes in the severity of these diseases over time (Florida Department of Health, 2013). For the purpose of this report, ED visits for asthma were based on either a primary or a secondary diagnosis (Table 5).

Asthma	
Measures	1. Number of emergency department visits for asthma
	2. Crude rate of emergency department visits for asthma per 100,000 population
	3. Age-adjusted rate of emergency department visits for asthma per 100,000 population
Numerators	*General:* Emergency department visits made by Florida residents during the time period of interest with the associated ICD-9-CM code of interest, including primary and secondary diagnoses
	Asthma: ICD-9-CM code 493
	Data Source: Florida Agency for Health Care Administration
Denominator	*General:* Annual population estimates for entire state and all counties
	Data Source: Florida Community Health Assessment Resource Tool Set
Adjustment	*Method:* Direct age-adjustment using the 2000 U.S. Standard population
Geography	*Scope:* State, National Weather Service regions, and ZIP Code
	Scale: Region and ZIP Code experiencing high temperatures
Time Scale	*Period:* Annual with warm season defined as May to October, 2005 to 2012
	Scale: Annual, warm season

Table 5. Respiratory disease indicator.

Asthma: Asthma is a chronic lung disease characterized by inflammation of the airways and recurring attacks of symptoms such as wheezing, coughing, and chest tightness. Annual ED visits for asthma have increased over time (43%), from approximately 219,000 visits in 2005 to almost 313,000 visits in 2012. The average number of visits during this time was just over 257,000 per year, with an average annual crude visit rate of 1,380 visits per 100,000 population (Figure 23). About 43% of all asthma-related ED visits occurred during the warm season. Annual asthma-related ED visits were more common among children between the ages of 0 and 9 years (28%), adults between the ages of 25

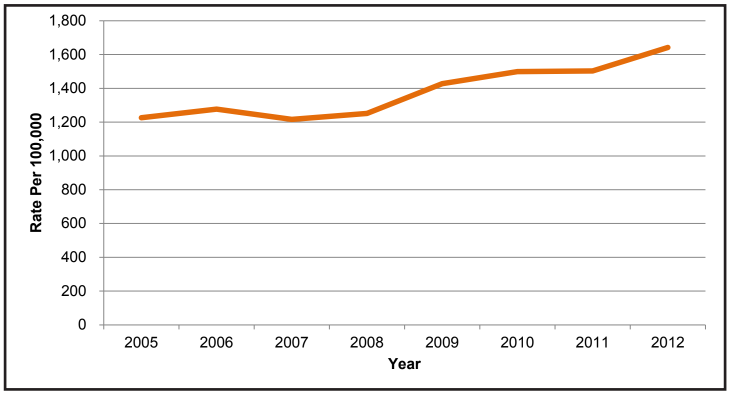


Figure 23. Rate of asthma per 100,000 population, Florida, January-December, 2005-2012.

and 54 years (37%), females (59%), and non-Hispanic white residents (46%), with similar patterns seen May through October. Higher average annual age-adjusted rates of ED visits occurred in the Panhandle and Central Florida, with the highest rates in Escambia (3,190 per 100,000), Polk (2,602 per 100,000), and Marion (2,511.4 per 100,000) counties.

Heat and Respiratory Disease

Asthma:
Temperature. In general, the rate of ED visits for asthma was higher during periods of higher temperatures. Rate ratios reflected this increase; for temperatures higher than the reference temperature (88°F), there was a positive association with asthma ED visits. However, this association was not significant at any temperature (Figure 24). Regionally, all regions except Tallahassee showed a statistically significant positive association between temperature and asthma. Tallahassee showed a strong inverse association, such that as temperature increased, rate of asthma-related ED visits decreased (data not shown).

Heat Index. When we examined the heat-asthma relationship using heat index, the rate of ED visits showed a decreasing trend as heat index increased above the reference value (94°F; Figure 25). Again, this negative association was not statistically significant at any heat indices. The Miami/Key West region showed positive and significant associations (increasing rate of asthma-related ED visits for increasing heat index). The Tallahassee region had a similar positive trend, but it only reached statistical significance at the highest heat indices. However, two regions also had strong and significant negative associations: the Tampa and Melbourne regions. The rates of ED visits in the remaining two regions did not change as heat index increased (data not shown).

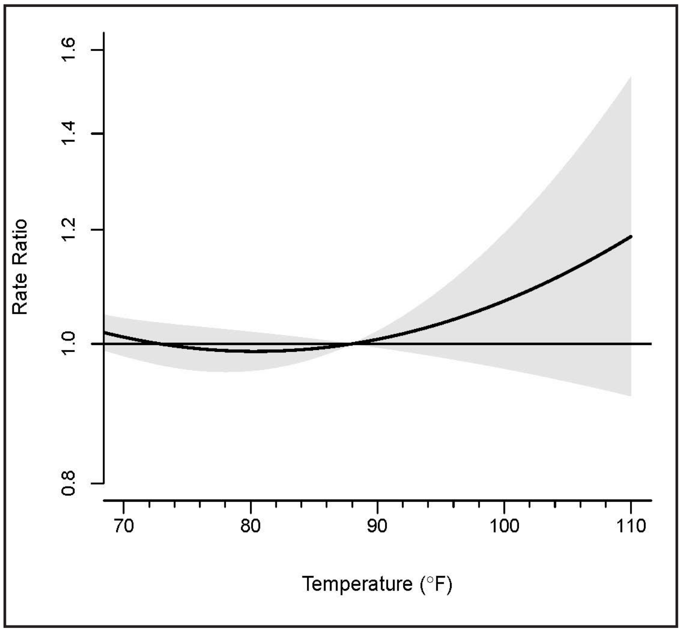


Figure 24. Associations between daily maximum temperature (°F) and asthma, Florida, May-October, 2005-2012.

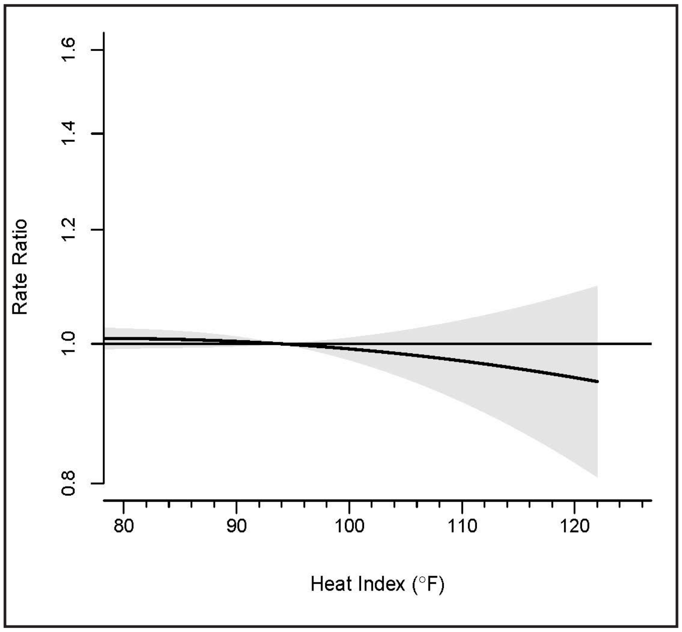


Figure 25. Associations between daily maximum heat index (°F) and asthma, Florida, May-October, 2005-2012.

Respiratory Disease

Summary Conclusions

- Due to the subtropical climate, Florida has historically been vulnerable to both continuous summer heat and extreme heat events. This vulnerability may become more pronounced in the future.
- Heat exposure can affect human health via many biological pathways, directly and indirectly.
- The heat/health relationship varies statewide by region and by exposure measure for each health condition of interest.
- There is a strong positive association between HRI and both temperature and heat index. This relationship is the same at the state level and across all regions.
- The associations between heat and the cardiovascular diseases of interest (ischemic stroke and myocardial infarction) are positive and stronger when using heat index as the exposure metric than when using temperature.
- There were no significant associations between daily heat metrics and the mental health and behavioral disorders of interest in Florida, though ED visits for both tended to decrease with increasing temperature.
- Though the associations were not significant, asthma showed an inconsistent relationship with heat statewide. As temperature increased, the rate of asthma-related ED visits tended to increase. However, the rate of ED visits tended to decrease as heat index increased.

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We wish Laurel Harduar Morano the best as she finishes her PhD in epidemiology at the University of North Carolina Chapel Hill and defends her dissertation on HRI and heat in Florida. Thank you for the fantastic analysis summarized in this report!

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For more information on geographic, social, and medical vulnerability to hazards in Florida, please see *Climate-Sensitive Hazards in Florida: Identifying and Prioritizing Threats to Build Resilience against Climate Effects* by Emrich, C.T., Morath, D.P., Bowser, G.C., Reeves, R. at the Hazard and Vulnerability Research Institute, available at www.floridahealth.gov/environmental-health/climate-and-health/brace/index.html.

The following software was used for analysis and displaying results: Geographic Information System (GIS) ArcMAP v.10.0 (ESRI: Redlands, CA); SAS v9.3 (SAS Institute: Cary, NC); InDesign CS6 (Adobe: San Jose, CA); and R (R Development Core Team: Vienna, Austria).

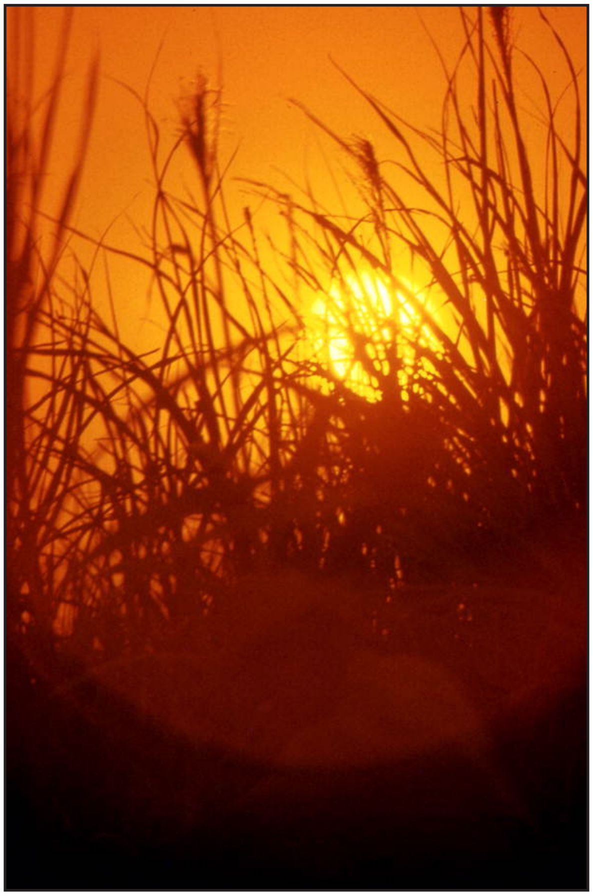
Appendix 1: Data Sources

Agency for Health Care Administration (AHCA): AHCA, managed by the Executive Branch of the Florida state government, is the main health policy and planning entity responsible for managing the state's Medicaid program, licensing the 41,000 state health care facilities, and sharing health care data (ahca.myflorida.com). AHCA has been collecting hospital discharge and ED data since 1988 and 2005, respectively. These data sources contain a detailed record of each hospitalization and ED visit, and each record lists the primary and contributing diagnoses, patient demographics, and billing information. Hospital discharge data also contain information on primary and secondary procedures. Some of the strengths of using AHCA data include the following: AHCA data provide comprehensive statewide coverage and have many years of historical data available; hospital discharge and ED data provide DOH the ability to study non-notifiable diseases and injuries, and provide additional data to augment and evaluate notifiable disease information; and AHCA data provide overall and categorical health care charges that can be used to estimate cost. Limitations of AHCA data include the absence of data from federal facilities, a six-month to one-year lag in access to data due to internal reporting and validation processes, limited available identifiers, and questionable clinical accuracy as with any study relying solely on ICD-9-CM codes.

Florida Automated Weather Network (FAWN): FAWN received state legislative fund appropriations in 1997 and was initiated at the University of Florida Institute of Food and Agricultural Sciences into an existing county Cooperative Extension Service network (fawn.ifas.ufl.edu/). The network initially included 11 sites and has since been expanded to include up to 40 sites throughout rural Florida. FAWN station data included hourly data calculated as the average of readings taken every 15 minutes. Temperature is measured in degrees Celsius, 2 meters from the ground, and relative humidity is also measured at each of these stations.

National Weather Service (NWS) First-Order Weather Stations, NCDC: NWS weather stations data are maintained by NCDC, a part of the National Oceanic and Atmospheric Administration (www.ncdc.noaa.gov/). The NCDC is the home of a national and international archive of climatic and weather-related data sets ranging from “paleoclimatology data to centuries-old journals to data less than an hour old.” The mission of the NCDC is to collect, maintain, and share these data for use by the public, industry, governments, researchers, and others. Data sources for NCDC’s archives include land-based weather observation stations, satellite, radar, weather balloons, ships, and weather buoys, among many others. Therefore, NCDC data are the primary source of weather-related data for these analyses. Most of the NCDC data used in these analyses were obtained from our collaborators/partners at the Florida State University Center for Ocean-Atmospheric Prediction Studies who conducted quality checks and post-download processing of the data for use. Hourly data included temperature measured in degrees Celsius, dewpoint (measured), and relative humidity (calculated).

Appendix 2: Discrepancies Between Reporting Sources



Please note that there may be differences between the ED visits reported in this report and ED case counts or rates reported by other programs within DOH, including the Florida Environmental Public Health Tracking Network, Florida Community Health Assessment Resource Tool Set, and the Florida Asthma Program. For example, in this report, we included all visits with an asthma diagnosis of interest as either the primary or contributing cause of the visit, whereas in other Florida reports, only visits with a primary diagnosis may be reported.

Folklife Collection. (198-). Photograph Sun setting over a sugar cane field - Clewiston Region, Florida. State Archives of Florida, Florida Memory, floridamemory.com/items/show/121525.

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