S211 **Floridian Heatwaves in a Warming World: Frequency, Intensity, and Duration**

Shealynn R. Cloutier-Bisbee[1]*, Shawn M. Milrad[1] and Ajay Raghavendra[2]
[1]Embry-Riddle Aeronautical University, Daytona Beach, Florida
[2]University at Albany, Albany, New York

1. INTRODUCTION

There exists broad scientific consensus that heatwaves are increasing in frequency, duration, and intensity in a warming world, and are generally the most strongly linked extreme weather event to anthropogenic climate change. As the global climate has warmed (IPCC 2013), several types of extreme weather events (e.g., heatwaves, droughts, extreme precipitation events) have increased in frequency and/or intensity, and have been increasingly attributed to anthropogenic climate change (e.g., Coumou and Rahmstorf 2012; Perkins 2015). They are often referred to as the "silent meteorological killer" (Perkins 2015), particularly in locations with aging populations or underdeveloped infrastructure. It is not just daytime maximum temperatures that affect human life and health; warm nighttime minimum temperatures can also increase mortality and illness (Perkins 2015). Although one day of extreme warmth typically does not typically produce major impacts, periods of three days or more pose a huge threat.

Due to its predominantly maritime climate, few studies have examined heatwaves in Florida. Although Keellings and Waylen (2014; 2015) explored heatwave trends in the latter half of the 20th century, no study to our knowledge has comprehensively explored Florida heatwave trends through and including the first 15 years of the 21st century. However, Florida's older-skewed population and increasingly urban land areas make it particularly susceptible to the impacts of heatwaves on human life and health in the twenty-first century. This project will for the first time establish an objective heatwave metric, climatology, and trend analysis for major cities in Florida from 1950–2015.

The primary objectives of this paper are: *1.* Develop an objective metric for heatwaves in Florida. Currently there is no universally accepted definition of heatwaves (Perkins 2015), with different approaches used for length (e.g., 2 vs. 3 day duration), magnitude (e.g., 90th vs. 95th percentile), and temperature variable (e.g., maximum temperature, minimum temperature, mean temperature, heat index).

2. Establish a climatology and trend analysis of heatwaves in Florida, 1950 – 2015. Specific aspects that will be addressed in the trend analysis are: Frequency, duration, intensity, and sub-regional differences.

3. Evaluate large-scale meteorological conditions associated with heatwaves in Florida by studying the evolution of synoptic-dynamic atmospheric patterns (e.g, 500-hPa geopotential heights) from a composite standpoint.

The remainder of the paper is organized as follows. Section 2 provides

* *Corresponding author address:* Shealynn R. Cloutier-Bisbee, Embry-Riddle Aeronautical University, Meteorology Programs, Daytona Beach, FL 32114; email: sheabisbee@gmail.com

an overview of the data used and defines a heatwave. A motivation for the techniques used for an analysis of the data is also briefly highlighted. The results and conclusion are presented in section 3, and a summary along with future work is presented in section 4.

2. DATA AND METHOD

The statistical analysis and identification of heatwave events over different parts of Florida was conducted by using temperature data from the Applied Climate Information System (ACIS, http://scacis.rcc-acis.org/) for the airports listed in Fig. 1. Composite plots to study the dominant synoptic-dynamic meteorological features during heatwave events were generated using data from the NCEP/NCAR–2 Reanalysis (Kanamitsu et al., 2002) for the atmosphere, and composite sea surface temperature (SST) plots used data from NOAA's OISSTV2 (Reynolds et al., 2002) dataset.

The heatwave metric in this paper utilizes multiple temperature variables and various statistical thresholds of heatwave magnitudes and duration. Using temperature data retrieved for the airports listed in Fig. 1, heatwave events were identified separately for summer (Jun–Aug) and winter (Dec–Feb) months and the 95th percentile for the maximum, minimum, and average temperatures were calculated. To be considered a heatwave event, the maximum, minimum, or average temperature had to exceed the 95th percentile for three consecutive days with a gap of at least four consecutive days between events.

Using the heatwave definition and the maximum, minimum, and average daily temperature from the ACIS, trends in the frequency, intensity, and duration of heatwaves at each location were investigated. Finally, using reanalysis data, composite dynamic and thermodynamic patterns and mechanisms associated with these heatwaves are elucidated.

3. RESULTS AND CONCLUSIONS

While all seven stations were analyzed using the predefined metric in section 2, the results presented in this manuscript are limited to Tallahassee (KTLH) and Tampa (KTPA).

a) Frequency: When investigating the frequency of heatwaves over this time period, bar graphs were compiled of the number of heatwaves per year (see Fig. 2). The plots in Fig. 2 show a strong increase in the number of heatwaves in the 2000–2015 time period.

b) Intensity and Duration: Compiling daily departure data from the ACIS for each airport and creating a line graph displaying the average departure of the entire duration of a heatwave event assisted in analyzing the intensity and duration of heatwave events (see Fig. 3). From Fig. 3, we can argue that there has been insignificant change in the intensity of the heatwave events over the past 65 years. However, Fig. 3 suggests that the duration of heatwaves at KTPA and KTLH may be increasing.

c) Composite 500-hPa heights: Composite 500-hPa height anomalies were constructed for the heatwave events in an attempt to identify dominant synoptic conditions driving the heatwave events. During the summer months, the composites show a 500-hPa ridge situated directly over the Florida panhandle (see Fig. 4) which would promote strong descent and surface heating in KTPA and KTLH. During the winter, the ridge is shifted to the north, suggestive of lower-tropospheric warm-air advection into Florida from the Caribbean. These high-pressure anomalies coupled with the anomalously high SSTs (see poster handout) create favorable conditions for heatwaves to occur, especially at night. A study done by Keellings and Waylen (2014) also showed an increase in heatwave frequency and duration across most of the state.

4. SUMMARY AND FUTURE WORK

Scientific consensus is that heatwaves are increasing in frequency, intensity and duration. During this study it was shown that heatwaves are increasing in frequency and duration throughout the state of Florida. These observational results are consistent with precipitation and drought trends from Dai et al. (2017) who found the frequency of precipitation was decreasing, but the number of extreme precipitation events would increase in a warmer climate. A corollary to Dai et al. (2017) from this work would include that the duration and frequency of heatwave events will increase towards the late 21st century.

Some of the causes for this increase in heatwave activity are the warming of the oceans around the coasts of Florida coupled with the persistence and location of the upper-tropospheric ridge (see Fig. 4) that is situated in that area during the heat wave events.

SST anomalies were composited for the maximum, minimum, and average SST anomalies from 1982–2015. These composites show anomalously high SSTs around the coast of Florida during heatwave events.

Future work will include exploring the causes of the increase in the duration of heatwaves and the large-scale physical mechanisms responsible for the heatwaves. Since heatwaves are generally associated with blocking high pressure systems that act to warm and moisten the incipient air mass particularly in Florida's maritime tropical climate. The hypothesis is that extreme precipitation events at the end of heatwaves may be increasing in frequency and intensity with the heatwaves. The next phase of this project includes analyzing possible links between heatwaves in Florida and extreme precipitation events.

5. ACKNOWLEDGEMNT

An ERAU Internal Research (FIRST) Grant in 2016–17, has graciously supported this research. Author SCB received supplementary funding from the Office of Undergraduate Research (IGNITE initiative).

6. REFERENCES

Coumou, D., and S. Rahmstorf, 2012: A decade of weather extremes. *Nature Clim. Change,* **2**, 491–496.

Dai, A., R. M. Rasmussen, C. Liu, K. Ikeda2, and A. F. Prein, 2017: Changes in Precipitation Characteristics over

North America by the Late 21st Century Simulated by a Convection-Permitting Model. *Clim. Dyn.*, submitted.

Kanamitsu, M., and Coauthors, 2002: NCEP–DOE AMIP-II Reanalysis (R-2). Bull. Amer. Meteor. Soc., **83**, 1631–1643.

Keellings, D., and P. Waylen, 2014: Increased risk of heat waves in Florida: Characterizing changes in bivariate heat wave risk using extreme value analysis. *Appl. Geog.,* **46**, 90–97.

Keellings, D., and P. Waylen, 2015: Investigating teleconnection drivers of bivariate heat waves in Florida using extreme value analysis. *Clim. Dyn.,* **44**, 3383–3391.

Perkins, S. E., 2015: A review on the scientific understanding of heatwaves––Their measurement, driving mechanisms, and changes at the global scale. *Atmos. Res.*, **164**, 242–267

Reynolds, R.W., N.A. Rayner, T.M, Smith, D.C. Stokes, and W. Wang, 2002: An improved in situ and satellite SST analysis for climate. J. Climate, **15**, 1609–1625.

Airports Used

KDAB	**Daytona Beach**
KJAX	**Jacksonville**
KEYW	**Key West**
KMIA	**Miami**
KMCO	**Orlando**
KTLH	**Tallahassee**
KTPA	**Tampa**

Figure 1: Number of heat wave events each year from 1950–2015 for Tampa (KTPA, left) and Tallahassee (KTLH, right).

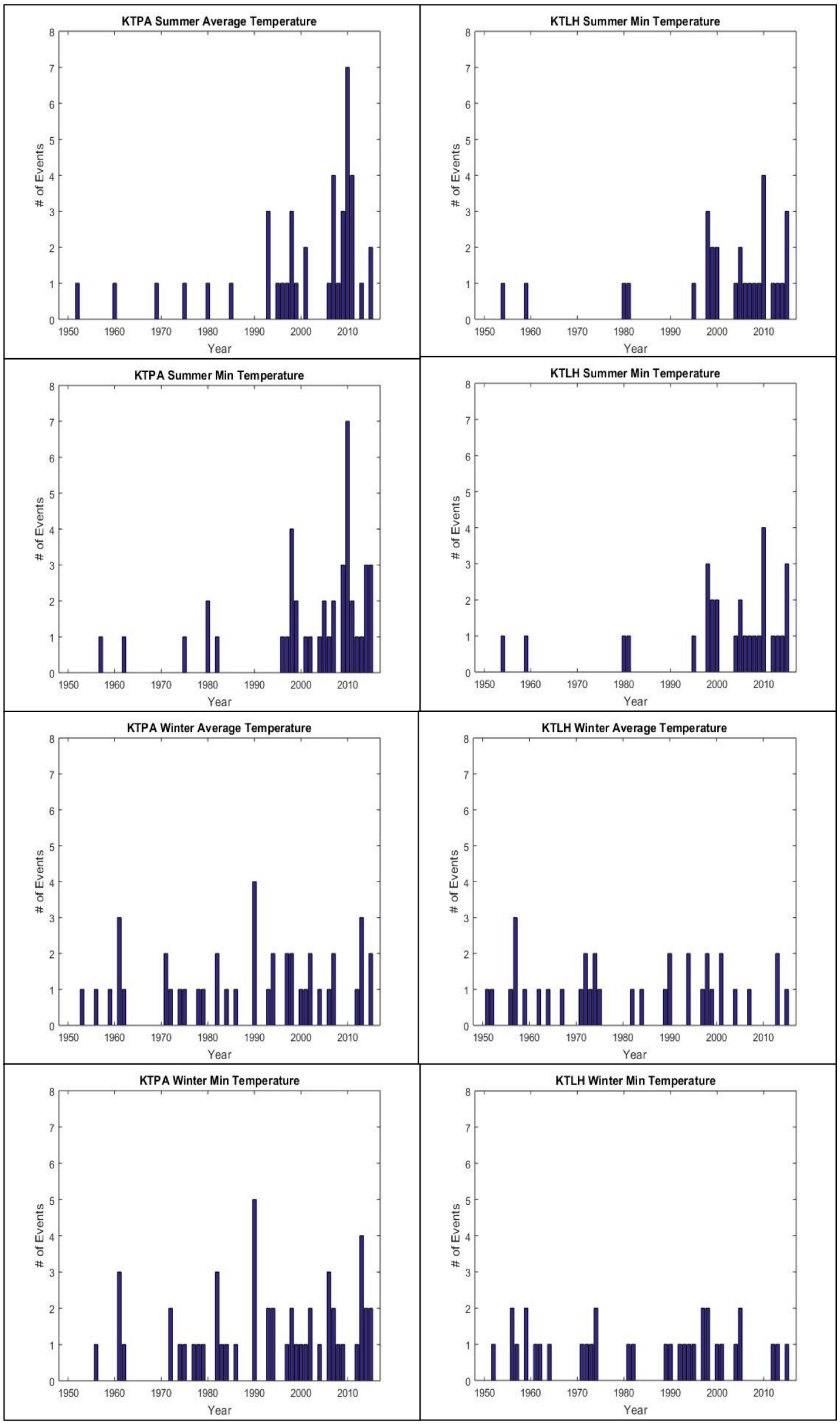

Figure 2: Number of heat wave events each year from 1950–2015 for Tampa (KTPA, left) and Tallahassee (KTLH, right).

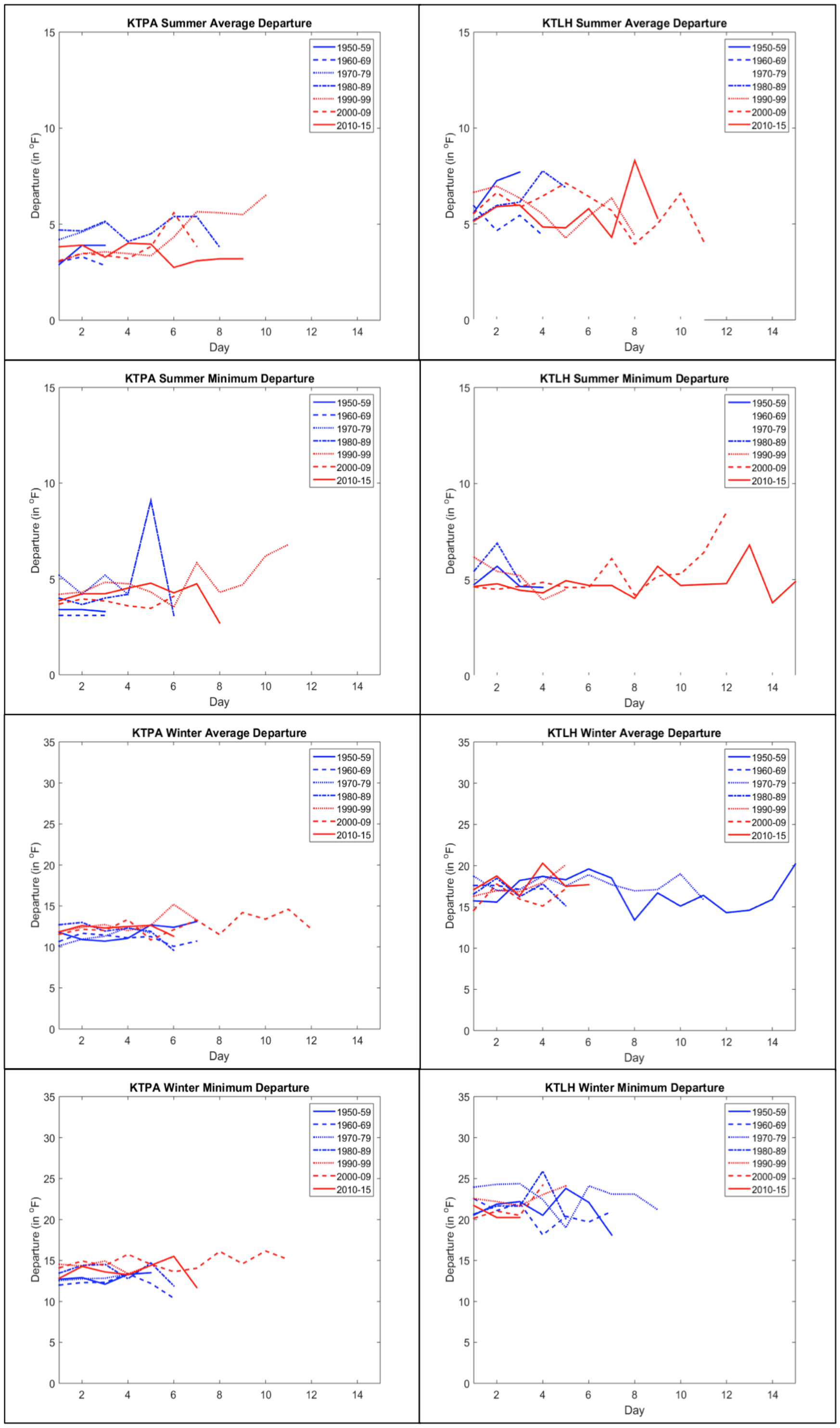

Figure 3: Average departure per decade for the entire duration of the heatwave event for Tampa (KTPA, left) and Tallahassee (KTLH, right).

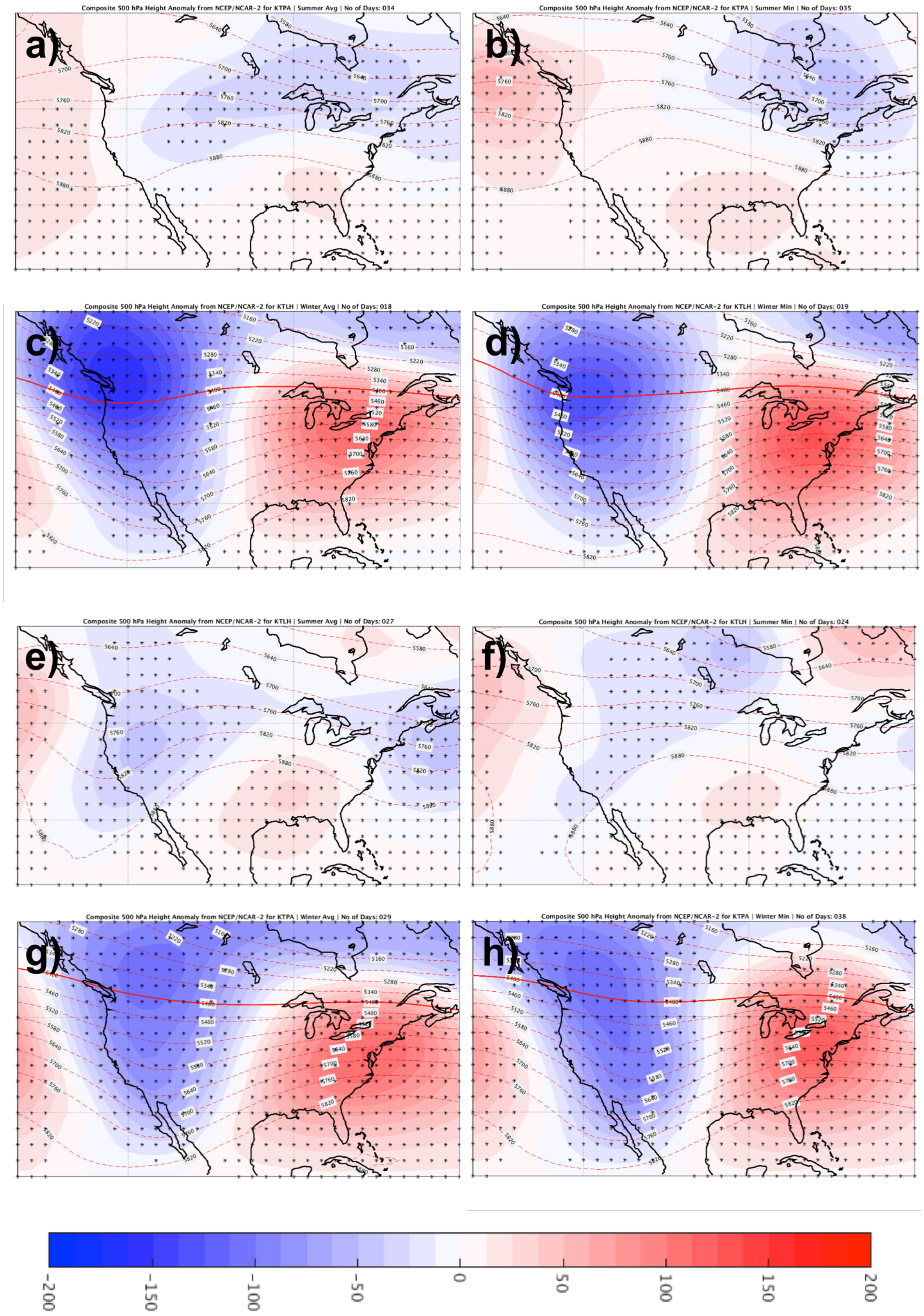

Figure 4: 500-hPa height composite anomalies (shaded, m) and composite mean (red contours, m) for KTPA (a-d) and KTLH (e-h) plotted for summer (a,b,e,f) and winter (c,d,g,h) seasons for all heatwave events between 1982–2015 using the average (left) and minimum (right) temperature thresholds. Grid points that are statistically significant at the 95th percentile are marked with an asterisk.