

CHAPTER 7

SUMMARY AND CONCLUSION

Most U.S. hurricane climate research is based on records from the past 100 years or so. The official U.S. hurricane record currently extends back to 1851. To better understand these rare but potentially catastrophic events it is important to have the longest possible records. Combining various historical sources, tropical cyclone impacts in the United States have been collated back to the year 1800 (a 25% increase in the number of years from the official record) using a GIS. The Historical Hurricane Information Tool (HHIT) is based on ESRI's ArcView GIS 3.1.

Storm impacts in the United States and to vessels in adjacent coastal waters are manually input on a geographic map using callouts. Descriptive information such as damage reports, meteorological observations, and ship reports are included. Individual historical sources are treated as separate themes for each storm. Storms are listed chronologically by year. Additional value is added to the maps with the inclusion of a possible storm track. Estimated storm intensities at landfall are also included.

Many of the current sources of historical hurricanes are text based. The present work takes these documents and makes them accessible to hurricane researchers, emergency management officials, and climatologists. The cartographic nature of the items provides an enhanced perception of the swath of damage left behind by the storms. Estimated tracks and intensities may be utilized in statistical analysis incorporating these records. The digital nature of these projects makes them suited for editing and modification. The hurricane GIS tool will be made available on CD-ROM. Updates and expansions are anticipated. My work is a reproduction of the quantitative and qualitative information given in the available documents, and it provides an easily accessible source

of information about early American hurricanes that is geographical in nature and digital for ease of use.

The HHIT allows easy access to the hurricane information prior to 1851. The seasonal variability in U.S. hurricanes has been examined from an exploratory perspective. During each four 50-year intervals, including the period 1800-49, the greatest threat of a U.S. hurricane occurs between 8 September and 17 September. The seasonal distributions of landfalls all indicate a slower buildup to the peak with a more abrupt ending. The fewer number of landfalls over the first half of the 19th century is likely due to the fact that some storms went undetected.

More detailed applications have examined the uncertainty inherent in the earlier records in more detail, and it is not necessary to ignore these earlier records completely. In fact, studies (Elsner and Bossak 2001; Elsner and Jagger 2002) demonstrate the use of Bayesian statistics to combine earlier records of lesser accuracy with later records of greater accuracy in hurricane climate forecasts. By incorporating earlier records of U.S. hurricanes with later records, a better understanding of hurricane occurrences over time is developed. This understanding can be utilized, for example, in reinsurance contracts (Michaels et al. 1997) or weather derivatives in the futures market.

The HHIT GIS tool is available through the Hurricane Climate Institute at Florida State University (<http://garnet.acns.fsu.edu/~jelsner/www/>). The HHIT contains 90 tropical cyclone impacts: 56 U.S. hurricanes, 21 U.S. tropical storms, and 13 offshore hurricanes. A collated list consisting of early U.S. hurricanes has been established for use in statistical analysis. This dataset, combined with hurricane data from NOAA's Hurricane Reanalysis project, provides an unprecedented look at U.S. hurricane activity over the past 200 years (1801-2000).

Analysis of two hundred years of U.S. hurricane data reveals that the most active month for U.S. hurricanes is September, followed by August and October. June and July are the least active months. More activity is present in the 20th century than the 19th century, but this conclusion is subject to revision if new storm records are uncovered pertaining to the 1800-1850 period. The number of hurricanes to strike Florida in recent times is unusually low compared to long-term records. The ratio of major hurricanes to all landfalling hurricanes in the U.S. is highest during the 1801-1850 period.

The variables affecting U.S. hurricanes are possibly in a state of flux. Annual means for hurricane landfalls computed via a bootstrap procedure exhibit a change in the relationship between ENSO/NAO and U.S. hurricanes in the early 19th century data compared to later data. Reanalysis performed with increased sample sizes indicated a robust climate/U.S. hurricane relationship. When the data were analyzed with a change in the number of selected values utilized in the bootstrap, the relationships were still evident, although less significant. The influence of the PDO on U.S. hurricanes appears to have lessened over the last 200 years. However, the bootstrap procedure utilizes only the top and bottom terciles of data for each of the four 50-year periods. Therefore, the results indicated in the bootstrap may not be validated when conducting statistical analysis with all of the data.

The results from the Poisson regressions suggest a possible shift in the climate influences affecting U.S. hurricanes over the last 200 years. ENSO and the NAO are found not to be statistically significant in explaining U.S. hurricanes from 1801-1850, and the PDO and NAO exhibit their greatest influence on Gulf coast hurricanes. Conversely, the PDO is not significant in the later period data, while ENSO and the NAO are the dominant U.S. hurricane climate influences out of the three climate variables examined. The results of this work add one more piece of information to the climate puzzle and are worthy of additional investigation. An additional Poisson regression model which incorporates an indicator variable and interaction terms was utilized to investigate the mean number of U.S. landfalls in the first epoch (1800-1850) in comparison to the second epoch (1851-2000). The results demonstrated no evidence to suggest a significant difference in the mean landfall numbers between the first epoch and the second epoch for each of the three climate variables included. Conditioning plots were created, and these plots demonstrate no obvious significant difference in the U.S. hurricane landfall means. However, the lack of substantial data points in the regression model may have affected the results. Generally, the more data points present, the more likely a statistically significant result will be found.

Elsner et al. (2001) has noted changes in the relationship between ENSO and U.S. hurricanes (as well as teleconnections to the NAO) throughout the 20th century. One study utilizing tree-ring proxies for the PDO (D'Arrigo et al. 2001) noted evidence of less

pronounced interdecadal variability after the mid-nineteenth century. Another study has examined North Pacific modes and U.S. droughts along the east coast (Barlow et al. 2001). The authors suggest that circulation changes due to SST anomalies in the North Pacific cause a disruption the inflow of maritime air from the Gulf of Mexico (possibly offering a physical explanation for the significance of the PDO along the Gulf coast in the 1851-1900 period in explaining hurricane landfalls there), causing a drought along the eastern coastline.

It is hypothesized that the cause of the PDO possibly being the dominant mode of climate influence on U.S. hurricanes between 1801-1850 is cooler global temperatures during this period. The large number of volcanic eruptions which occurred in the first half of the 19th century (after about 1802) likely resulted in a stratospheric dust cloud that cooled the planet slightly, and led to the PDO's dominance. In the last 150 years, as the climate has warmed, the influence of the PDO on U.S. hurricanes has waned dramatically. However, the actual physical explanation for these noted trends is worthy of continued study.

Future work in this topic may include the addition of additional sources of information about historical U.S. hurricanes (such as the digitization of U.S. Army fort data by Andsager and Nicodemus 2003) and the continuing progress of NOAA's Reanalysis project (Landsea et al. 2003) as well as addressing issues of uncertainty in the early 19th Century U.S. hurricane dataset.