Use of GIS in Plotting Early 19th Century Hurricane Information (Part 2)

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INTRODUCTION. Hurricanes are among the most dangerous and damaging storms on Earth (Malilay 1997). They have the potential to cause as much damage and loss of life as earthquakes (Diaz and Pulwarty 1997). Estimates put the average annual cost of hurricane damage in the United States at $4.8 billion dollars (Pielke and Landsea 1998). Encompassing a diameter of between 200 and 1300 kilometers and possessing wind speeds exceeding 33 ms^{-1} (≥74 mph), hurricanes are capable of inflicting widespread destruction. As a consequence, it is important to understand how often hurricanes occur and at what intensity.

Exposure to hurricane damage is a function of the population at risk, property at risk, and the level of preparedness (Pielke and Pielke 1997). There are more than 45 million people living along the coast from Brownsville, Texas to Eastport, Maine (Elsner and Kara 1999). As coastal population increases, the economic damage potential increases as well. For example, $3.1 trillion worth of coastal property was insured in 1993, compared to $1.9 trillion in 1988 (Pielke and Pielke 1997). Thus hurricanes pose a serious threat to the United States in both economic and human terms and better long-term risk assessments are needed. However, hurricane climate research is based largely on records spanning only the last 100 years or so (Elsner et al. 2000; Landsea et al. 1996). Accounts of hurricanes exist in a variety of documents that include compendiums sorted by region and date, documents with records for individual states, and personal research. Sources for these works include direct observations, ship records, newspaper accounts, personal letters and governmental archive reports.

This note reflects on efforts to collate available documental evidence of past hurricanes over the period 1800-1850. This period represents the years prior to the NOAA best-track dataset (Jarvinen et al. 1984), which begins with the year 1851. The purpose is to bring together historical archives into a single electronic reference, and to add value to the archives by plotting the information on maps. The result is a historical hurricane impact tool (HHIT) that can be used for scientific investigations of hurricane climate variability and change and that can serve as the basis for a reanalysis of early American hurricanes.

EARLY AMERICAN HURRICANES. David Ludlum's 1963 monograph entitled *Early American Hurricanes: 1492-1870* is a compilation of high-quality textual summaries of tropical cyclone activity over the western North Atlantic and Gulf of Mexico (Sharkov 2000). Major sources include Garriott (1900), Fassig (1913), Tannehill (1956) and Dunn and Miller (1960), which are based on the work of Poey (1855) and others. The monograph contains local newspaper accounts of damage reports from ships that were published in newspapers, personal letters and diaries, as well as records in archives that provide descriptions and dates for the storms. Some of the reports include meteorological observations. For example, below is an excerpt from the post surgeon at Ft. Brooke (near present-day Tampa, FL) during the September 25, 1848 hurricane:

'*The tide rose 15 feet above low water…the water commenced rising very fast at 10 A.M. and continued to rise until 2 P.M.' The surgeon also noted 't he fall of the barometer from a prestorm reading of 30.12"at 0900/24th and 29.92"at 2100 to a low of 28.18" sometime prior to 1500/25th, indicative of a storm of the severest type. By 1500 the glass had recovered to 28.55"an d the wind was coming out of the south.*' (Ludlum, 1963, p.154)

Ludlum (1963) is the primary source document for the HHIT. However, we also include data from more recent historical chronologies compiled by Ho (1989), Barnes (1998, 2001), Sandrik (1999), Cotterly (1999), Forty-Sixth Weather Squadron (1999), Roth (1998, 2000), Roth and Cobb (2001), and Prokop (2001). These works contain additional information about some of the storms listed in Ludlum (1963) as well as notes on storms not mentioned.

A GIS TOOL. *Overview.* Information from Ludlum (1963) and others is used to construct a series of mapped accounts of tropical cyclones from the period 1800-1850, inclusive, using a Geographic Information System (GIS). The HHIT is organized chronologically by year. Upon opening the GIS product and selecting the HHIT directory, a listing of years between 1800 and 1850 appears, appended with a suffix (apr) identifying the file as a GIS project. For each year, the tropical cyclones are organized chronologically by landfall date. Thirty-seven of the 51 years had evidence of at least one tropical cyclone. The HHIT includes evidence from 90 tropical cyclones during the 51-year period. Table 1 provides hurricane count statistics in 50-year periods. Seasonal distributions of tropical storm counts appear similar among the periods. The most active year prior to 1851 was 1837 with 10 tropical cyclones, 6 of which likely made direct landfall along the U.S. coast. The second most active year was 1844, with 8 tropical cyclones and 4 landfalls.

Callouts. Descriptive information regarding hurricanes and tropical storms is input as callout boxes over base maps of the United States. The majority of callouts contain information verbatim from the source documents, with some minor paraphrasing to make the descriptions more compact. The boxes are positioned on the map near the geographic location described within and include a pointer to the location, if known. Instances in which the location is unknown utilize a text box rather than a callout box. Text and callout boxes are scale-dependent: changing the map scale changes the text scale in reciprocity. The layout (the view of each storm prepared for hard copy) includes a storm summary taken directly from the source documents. Statements not garnered from the original source documents are included in separate text boxes.

User's Manual. The HHIT uses Environmental Systems Research Institute's (ESRI) ArcView GIS software (version 3.1). Therefore, any user of the original project must have ArcView 3.1 or later installed on a PC in order to access the original HHIT. The project shapefiles (the files used by the GIS to display the hurricane information) must be installed to the user's hard disk. Once a project is selected, the project opens and displays the various menu icons available to the user. The two most commonly used menu icons are the "Vi ews" and the "Layouts". The "Views" ar e the core of each project, and contain the

descriptive information relating to the storm. The "Views" also contain the estimated track of the storm. They are chronologically organized by date of influence to the United States. The "Layouts" are designed as hardcopy layout tools. This is where a user will find finished descriptive maps, track maps, intensity estimations, and further storm descriptions.

Within the "Views" are callout descriptions for each storm. Upon opening a "View", the user sees a map display containing descriptive information for each storm and a selection of "Themes" from which to choose. Source documents are treated as separate "Themes" for each storm (Figure 1). The "Views" involving tracks have one "Theme" titled "Track". Toggling the checkbox for this "Theme" will alternately display and hide from view the track of the storm. Where no track is specified, "Track Unspecified" will appear in the "View". Estimated storm intensities at landfall are also included, but are present only in the "Layout" for each storm. The digital nature of the HHIT allows for editing and modification. For example, new documentary accounts of a particular storm can be added in the tool by adding a new "Theme". Entirely new storms can be added by creating a new "View". Additional years can be added by creating new projects with separate views for each storm.

Map Interpretation. Extreme caution must be exercised when interpreting information from these maps. Although we include storm track and intensity estimates for some storms, the potential for larger errors in track location and storm intensity is high. A preponderance of evidence can lead to a more definitive estimation of track and/or intensity for some well-documented cases. For most storms, however, track and intensity estimates can be considered baseline approximations. While these are not depicted for the tracks themselves, the intensity estimations provided in the current version of HHIT should be considered only within ±2 Saffir-Simpson categories. They provide a starting point for further track estimation and intensity studies. Three types of tracks are given in the HHIT. Those that are taken directly from Ho (1989) are colored blue, those taken directly from Tannehill (1956) are colored green, and those that are based on our analysis are colored red. Where estimates are possible, tracks are modified from solid to dotted lines to indicate weakening to tropical storm strength. Figure 2 is a map showing tracks depicted for the 1848 Tampa Bay hurricane.

SUMMARY. 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 information available from historical documents, tropical cyclone impacts in the United States are mapped for the years 1800-1850 using a GIS. The historical hurricane information tool (HHIT) is based on ESRI's ArcView GIS.

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. The collation of existing historical information about early 19th

century hurricanes into a single electronic source provides accessibility to the use of such information by scientists trying to understand hurricane climate variability and change. The digital nature of the HHIT makes it well suited for modification. For example, the inclusion of information about storms in the HHIT available from near coastal ships (see EC Framework V Project, 2003) would be a valuable addition.

The data contained within the HHIT needs to be treated with caution, but it is not necessary to completely ignore it. In fact, Elsner and Bossak (2001) and Elsner and Jagger (2004) demonstrate how to combine earlier records of lesser accuracy with later records of greater accuracy in making hurricane climate forecasts, which is of importance for insurance and reinsurance contracts (Michaels et al. 1997). The HHIT GIS tool is available through the Hurricane Climate Institute at Florida State University in a CD-ROM version and a viewable-only web version (http://garnet.acns.fsu.edu/~jelsner/www/).

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References

Barnes, J., 1998: *Florida's Hurricane History*. University of North Carolina Press, 330 pp.

Barnes, J., 2001: *North Carolina's Hurricane History*. The University of North Carolina Press, 319 pp.

Cotterly, W., 1999: *Maine hurricane history*. [Available online at pages.prodigy.com/poland_ema/history.htm].

Diaz, H.E., and R.S. Pulwarty, Eds., 1997: *Hurricanes: Climate and Socioeconomic Impacts*. Springer, 304 pp.

Dunn, G.E., and B.I. Miller, 1960: *Atlantic Hurricanes*. Louisiana State University Press, 326 pp.

EC Framework V Project, 2003: *Climatological Database for the World's Oceans: 1750-1850*, EVK1-CT-2000-0090.

Elsner, J.B., and A.B. Kara, 1999: *Hurricanes of the North Atlantic: Climate and Society*. Oxford, 488pp.

Elsner, J.B., Jagger, T., and X. Niu, 2000: Changes in the rates of North Atlantic major

hurricane activity during the 20th century. *Geophys. Res. Lett.*, **27**, 1743-1746.

Elsner, J.B., and B.H. Bossak, 2001: Bayesian analysis of U.S. hurricane climate. *J. Climate,* **14**, 4341-4350.

Elsner, J.B., and T.H. Jagger, 2004: A hierarchical Bayesian approach to seasonal hurricane modeling, in review.

Fassig, O.L., 1913: Hurricanes of the West Indies. *Bulletin X. Wash. Weather Bureau.* 28 pp.

Forty-Sixth Weather Squadron, Eglin Air Force Base, Florida, 1999: *Western Florida panhandle hurricanes*. [Available online at www.eglin.af.mil/weather/hurricanes/history.html].

Garriott, E.B., 1900: *West Indian Hurricanes.* Bulletin H, Wash. Weather Bureau, U.S. Dept. of Agriculture; 69 pp.

Ho, F.P., 1989: *Extreme Hurricanes in the Nineteenth Century.* NOAA Technical Memorandum, NWS HYDRO-43, Office of Hydrology, Silver Springs, Maryland, 134 pp.

Jarvinen, B. R., C. J. Neumann, and M. A. S. Davis, 1984: A tropical cyclone data tape for the North Atlantic Basin, 1886--1983: Contents, limitations, and uses. NOAA Tech. Memo. NWS NHC-22, Coral Gables, FL, 21 pp.

Landsea, C.W., Nicholls, N., Gray, W.M., and L.A. Avila, 1996: Downward trends in the frequency of intense Atlantic hurricanes during the past five decades. *Geophys. Res. Lett.*, **23**, 1697-1700.

Ludlum, D.M., 1963: *Early American Hurricanes: 1492-1870.* American Meteorological Society, 198 pp.

Malilay, J., 1997: Tropical Cyclones. *The Public Health Consequences of Disasters*. E. Noji, Ed., Oxford University Press, 207-227.

Michaels, A., Malmquist, D., Knap, A., and A. Close, 1997: Climate science and insurance risk. *Nature*, **389**, 225-227.

Pielke, Jr., R.A., and C. W. Landsea, 1998: Normalized hurricane damages in the United States: 1925-1995. *Wea. Forecasting*, **13**, 621-631

Pielke, Jr., R.A., and Pielke, Sr., R.A., 1997: *Hurricanes: Their Nature and Impacts on*

Society. John Wiley and Sons, 279 pp.

Poey, A., 1855: A chronological table comprising 400 cyclone hurricanes which have occurred in the West Indies and in the North Atlantic within 362 years, from 1493-1855. *The Journal of the Royal Geographical Society*, **25**, 291-328.

Prokop, P., 2001: *Savannah hurricane history*. [Available online at files.raycommedia.com/wtoc/tropical/history.htm].

Roth, D., 1998: *Louisiana tropical cyclones*. [Available online at www.srh.noaa.gov/lch/research/laearly19hu.htm].

Roth, D., 2000: *Texas tropical cyclones.* [Available online at www.srh.noaa.gov/lch/research/txhur.htm].

Roth, D., and H. Cobb, 2001: *Virginia tropical cyclones*. [Available online at www.hpc.ncep.noaa.gov/research/roth/vaerly19hur.htm].

Sandrik, A., 1999: *Chronological Listing of Tropical Cyclones affecting North Florida and Coastal Georgia 1565-1899*. In review, 55 pp.

Sharkov, E. A., 2000: *Global Tropical Cyclogenesis*. Spring Publishing, London, 370 pp.

Tannehill, I.R., 1956: *Hurricanes, their nature and history*. Princeton University Press, 308 pp.

Figure Captions

Figure 1: Portion of a layout view for the September 1848 Tampa Bay hurricane. Once a "View" for a particular storm is opened, a list of "Themes" is available in the left margin. Each theme can be toggled on and off via a checkbox in the upper left-hand corner. Each theme represents descriptive information about a tropical cyclone from a particular historical source document.

Figure 2: Sample track and intensity estimation for the September 1848 Tampa Bay hurricane. The track in red is based on our analysis. Intensity and track estimations should be interpreted with extreme caution.

TABLE 1. Summary statistics of seasonal U.S. hurricane activity. Counts from the period 1851-1999 are from the NOAA best-track dataset.

Period	No. Years	No. Hurricanes	Mean Date	Median Date	Coefficient of Skewness	Mode Interval
1800-1849	50	51	Sept. 6	Sept. 10	-0.879	Sept. 8-17
1850-1899	50	89	Sept. 5	Sept. 10	-0.741	Sept. 8-17

1900-1949	50	90	Sept. 1	Sept. 4	-0.211	Sept. 8-17
1950-1999	50	75	Sept. 2	Sept. 7	-0.441	Sept. 1-7, Sept. 8-17

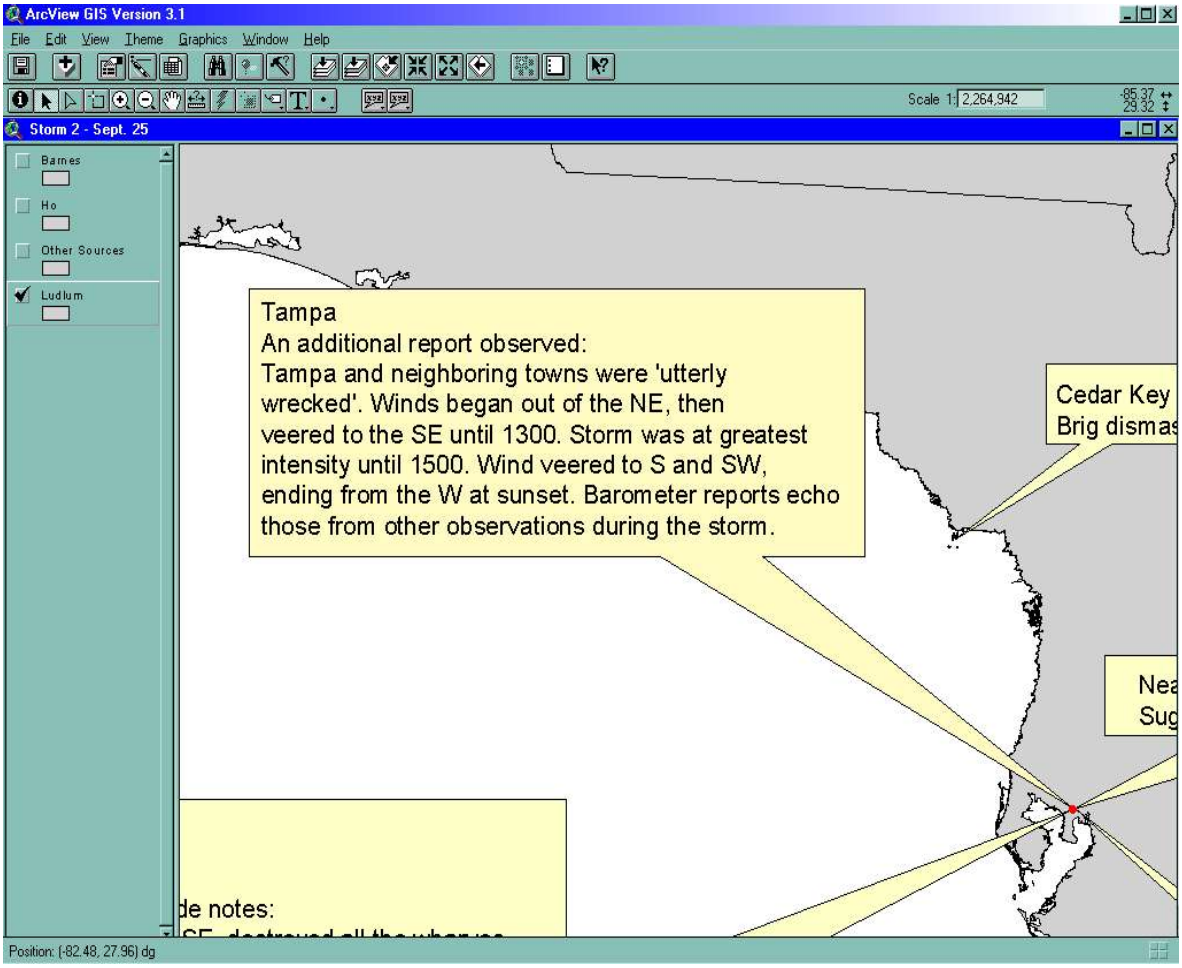

Figure 1.

Figure 2.

Storm 2 - 1848 - Possible Track