UNIVERSITY OF GEORGIA
Warnell School of Forestry & Natural Resources

Publication WSFNR-22-33C

June 2022

Defining Historic Hurricanes: Wind, Water & Tree Devastation

Dr. Kim D. Coder, Professor of Tree Biology & Health Care / University Hill Fellow
University of Georgia Warnell School of Forestry & Natural Resources

Trees throughout the Southeast and South-Central United States have grown, spread, and reproduced under the disturbance pressures applied by hurricanes and associated weather events. Trees have been impacted in the short-term by damaging winds, fresh and sea water flooding, lightning, and soil anchorage issues. Over the long run, trees have been impacted by disturbance and successional patterns, and site resource issues from multiple storms changing reproduction / regeneration, climatic migration, site quality, and volume of ecologically viable space.

Both maritime forests and Coastal Plain forest systems have been periodically damaged with so regularity, by hurricanes and associated tornadoes, heavy rain initiated flooding, and lightning. Native trees and forests within striking distance of hurricanes show growth adjustments, mortality patterns, and accumulated damage in response to the challenge of these large storms systems. Trees and forests visually and structurally represent the storm history of their sites.

Wind Loading

The greatest tree damaging factor associated with hurricanes are the various forms of wind loads applied. A tree structurally is a tapered mast holding a crown (leaves, twigs, & branches) with relatively large drag, held upright by a stiff flat root plate and long woody roots. Figure 1 demonstrates a tree form under wind and gravity loads. The wind pushes on the sail and a tree is becomes a load wheel where the environment allows a tree to rolled up and out of the ground. The root plate and structural roots, soil strength, stem strength and mass, all resist the wind load.

Application of wind loads to trees is described in three forms: sustained wind speeds in miles per hour; peak gusts wind speed in miles per hour; and, pressure exerted on the above-ground / exposed tree surface area in pounds of pressure per square foot. Figure 2 provides a common scale of wind speed and loads impacted trees. In this figure, the Beaufort Wind Scale shows and identifying force number from 1-12, wind speed in miles per hour, and a wind force description. In addition, the author added an average wind pressure load for each wind force category in pounds per square foot on each tree surface area. Figure 3 shows the tree impacts from Beaufort wind scale force numbers.

Force Not Speed

Wind speed in miles per hour is used in weather description and expectations. Miles per hour is a commonly appreciated terms for speed / velocity which is easy to grasp. Mechanically in trees, it is not the velocity, but the force applied which loads tree components. As wind velocity increases, the

wind load on a tree increases greatly (geometrically increases). For example, as wind speed doubles in mph, wind load in pounds per square feet of tree surface quadruples. It is the total force applied in any moment which damaged trees.

The Beaufort wind scale ranges across speeds of less than 1 mph, up to 72 mph (force number 11). Each value can be described in words by an escalating level of modified force – calm, breeze, gale, and storm. Beaufort scale force number 12 is the final value given, and represents a wind speed greater than 73 mph which is termed a hurricane. The defining values for hurricanes are given by another wind scale.

Hurricane Wind Scale

Hurricanes are described by the modified Saffir-Simpson wind scale. Figure 4 shows this hurricane wind scale as slightly modified after 2012 by NOAA to correct some rounding error in speed measurement units. Hurricanes are represented by 5 categories, with category 1 being the first wind speed level above the top of the Beaufort wind scale. Each category of hurricane is separated by a different level of sustained wind speeds, with Category 5 extending above 157 mph.

Most people understand the changing hurricane intensity / severity with increasing category number. Figure 5 shows the terms used to describe each hurricane category, the tree and forest damage expected, and the length of time expected for power outages (associated partially with tree failures). The terms used begin with “dangerous” and end with “catastrophic.” Hurricane categories 3-5 are considered “major” hurricanes.

Categorizing Damage

It should be remembered low category hurricanes, tropical storm residuals of hurricanes, and associated weather events like tornadoes and lightning storms, can all be locally devastating even though sustained wind speed may have fallen from hurricane peak velocities. Trees, forests, and communities well inland from hurricane land-fall have been severely impacted by remnants of hurricanes. Hurricane category descriptions help summarize wind speed expectations.

Figure 6 gives the storm category, sustained wind miles-per-hour, wind force in pounds per square feet on an exposed tree surface, and general description of tree damage. Please remember increasing wind speeds greatly increase wind loads on trees. For example, a category 3 hurricane with roughly 120mph wind speeds would load every square foot of an exposed tree surface with about 38 pounds – almost double the wind load from a category 1 hurricane.

Falling Back Then Failing

Considering the above ground surface area of a large tree (sail surface or drag area), the wind load applied in total pounds can be tremendous. Also note, for each category of hurricane, wind loads increase by more than 10 pounds of load per square foot of tree surface. Tree adjust and fall-back against the wind using flexible leaves, twigs, and branches, as well as limited wobble in the stem base and root plate area. As wind loads mount, tree failures accumulate, either losing branches, snapping stems, or up-rooting.

Hurricane History

To appreciate hurricane damage to trees, forests, lives and property, a review of historical hurricane land falls impacting the coast of Georgia can be helpful. The book by Fraser, 2006 is excellent

and yields a wonderful historical context (pre-2004) to our time. I have selected hurricanes and their remnants which had severe impacts to the Atlantic coast of Georgia, damaging shipping, ports, property, communities, trees, forests, and lives. One of the first hurricanes of record was "The Great Hurricane" of 1752, a category 3 storm. Savannah (1804) and St. Marys (1813) were hit by category 3 hurricanes. The St. Marys hurricane generated catastrophic damage to the barrier islands with a 19 feet tall storm surge. (Fraser, 2006)

Georgian & Sea Islands

Darien, Georgia received a double hurricane strike 30 years apart (1824 & 1854). The 1854 hurricane was a slow moving category 3 storm. In 1881 St. Catherine's was struck by a category 2 hurricane. This storm has been called the "Georgia Hurricane" in historical descriptions. The Georgia hurricane is the 10th deadliest in US history, with its 15 feet tall storm surge doing great damage. (Fraser, 2006)

The "Sea Islands Hurricane" of 1893 made land fall at Wassaw Island as a category 3 storm. This hurricane was the 7th deadliest hurricane in US history, generating a 16-30 feet tall storm surge across the coastal area. A dispatch listed Tybee Island covered by 6 feet of water. A large tropical storm (not listed as a hurricane) hit the Georgia coast in 1896. Gust wind speeds of 108 mph were recorded on Tybee Island. A newspaper stated Brunswick had been "wrecked." (Fraser, 2006)

Tidal Wave?

In 1898 a category 4 hurricane made land fall near Cumberland Island. It has been listed as the "Georgia Tidal Wave" and considered one of the strongest hurricanes to ever hit the United States. This hurricane generated a storm surge of 16 feet on barrier islands and along the coast. The next major storm was listed as a tropical storm in 1911, probably a remnant of a hurricane farther South. (Fraser, 2006)

The San Felipe / Okeechobee hurricane banged ashore in South Florida in 1928 as a full category 4 storm. It was devastating across Florida, but tracked North along the Georgia coast causing great damage even though it was downgraded to a tropical storm. Another tropical storm hit Georgia's coast in 1947 which generated 75 - 110 mph winds, and a 12 feet storm surge, at Tybee Island. (Fraser, 2006; NOAA archives)

Modern Hurricanes

For many communities in Georgia, the modern age of hurricane land falls began in 1964 with hurricane Dora. Dora hit Darien as a slow moving category 2 storm which pounded St. Simons and Brunswick. Hurricane David (1979) struck Ossabaw Island as a category 1. Hurricane Hugo as a category 4 struck well North of Georgia at Georgetown, SC, but caused significant damage along Georgia's coast. (Fraser, 2006; NOAA archives)

Hurricane Alberto (1994) made land fall along the Gulf Coast but slowed down over Georgia dropping 27 inches of rain in Americus, Georgia in a short time. Rivers and streams were scoured out, bottomland forests were drowned, and many communities flooded. The next year hurricane Opal made land fall as a Gulf coast category 3 storm and generated 70mph winds in Northwest Georgia. Hurricane Allison (2001) hammered the Fall line of Georgia with strong winds and heavy rains. (Fraser, 2006; NOAA archives)

Residual Damage

From the history of hurricanes impacting Georgia, it is clear the initial land fall with wind, rain, and freshwater / seawater flooding can be devastating. In addition, both Atlantic and Gulf coast hurricanes, as they diminish in severity over land, can still generate intense strings of tornadoes, torrential rains (15 - 28 inches in a short time), heavy lightning activity, and strong sustained winds (up to 75 mph gusts), which can combine to damage all Georgia community trees. (Fraser, 2006; NOAA archives)

From 1750 to 2016, Georgia's Atlantic Coast has seen 12 hurricanes, including two category 4, and six category 3 storms. In addition, 39 major tropical storms have impacted Georgia's Coast. Inland Georgia has not escaped hurricane and tropical storm associated damage. Non-coastal Georgia has been damaged by 26 hurricanes / tropical storm remnants in recorded history. It should be noted, especially in early years, hurricanes and tropical storms were not well separated nor differentiated. (Fraser, 2006)

Summarizing Georgia Hurricanes

Figure 7 provides a different view of hurricane strikes on the Georgia Coast and across Georgia's inland areas from 1851-2010. Coastal Georgia has received 23 total hurricane strikes and damage, ranging from category 1 through category 4 storms. Inland Georgia has been hit with 9 category 1 hurricanes. Across this ~160 years of time, Georgia has been impacted by hurricanes once every 5 years, on average.

Another view of hurricane damage in Georgia is to look at general hurricane tracks across the landscape. Figure 8 is a map of Georgia with category 1-4 hurricane tracks identified. The blue lines represent Gulf Coast land falls and the red lines represent Atlantic coast land falls. This figure does not present every track, nor precise tracking, but is meant to present historic lines of tree damage.

Conclusions

Trees and forests, especially along the coast, are at great risk from hurricane damage. Damage is generated primarily from wind loads pushing trees to structural failure. Once damaged, tree are susceptible to pest attack, further mechanical injuries, and, if damage is too great, mortality within 3 - 5 years. Understanding hurricanes as a tool of tree life and death can help in risk management and tree health care, both in reaction to damage and building expectations of future damage.

Selected Literature:

Blake, E.S. & E.J. Gibney. 2011. The deadliest, costliest, and most intense United States tropical cyclones from 1851 to 2010 (and other frequently requested hurricane facts). National Weather Service, National Hurricane Center. NOAA Technical Memorandum NWS-NHC-6. Pp.47.

Fraser, W.J. 2006. **Lowcountry Hurricanes: Three Centuries of Storms At Sea and Ashore**. University of Georgia Press, Athens, Georgia. Pp.319.

NOAA. 2012-2018. National Oceanic and Atmospheric Administration, United States Department of Commerce. WEB-based archives.

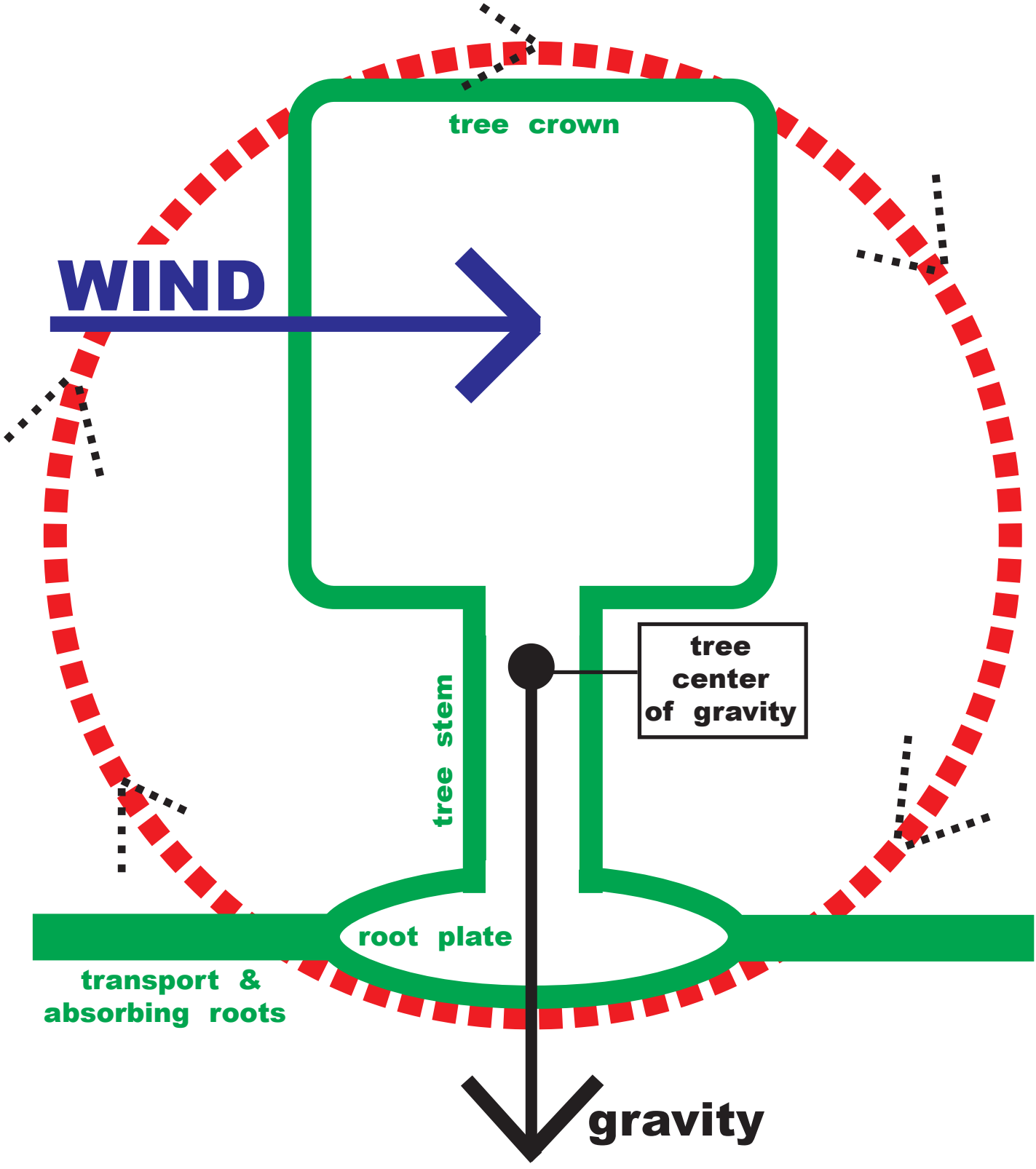

Figure 1: Wind and gravity loads on trees generating a load wheel rolling a tree up and out of the soil.

force number	wind speed mph	mid-point wind pressure* lbs/ft²	wind force description
0	< 1	< 0.003	calm
1	1-3	0.01	light air
2	4-7	0.08	light breeze
3	8-12	0.26	gentle breeze
4	13-18	0.63	moderate breeze
5	19-24	1.2	fresh breeze
6	25-31	2.1	strong breeze
7	32-38	3.2	moderate gale
8	39-46	4.8	fresh gale
9	47-54	6.7	strong gale
10	55-63	9.2	whole gale
11	64-72	12	violent storm
12	> 73	>14	hurricane

(* column is not part of wind scale but added by author)

Figure 2: Beaufort wind scale force number, wind speed, wind load pressure on trees, and wind force description.

force number	wind speed mph	mid-point wind pressure* lbs/ft²	tree impacts
0	< 1	< 0.003	
1	1-3	0.01	
2	4-7	0.08	leaves rustle
3	8-12	0.26	small twigs move
4	13-18	0.63	large twigs move
5	19-24	1.2	small trees sway
6	25-31	2.1	large branches move
7	32-38	3.2	large trees sway
8	39-46	4.8	twigs break
9	47-54	6.7	small & medium / branch break
10	55-63	9.2	trees break or uproot
11	64-72	12	forests destroyed
12	> 73	> 14	massive tree loss

(* column is not part of wind scale but added by author)

Figure 3: Beaufort wind scale force number, wind speed, wind load pressure on trees, and associated tree impacts.

Modified Saffir-Simpson Hurricane Wind Scale

cat. 1 – 74 - 95 mph
cat. 2 – 96 - 110 mph
cat. 3 – 111 - 129 mph
cat. 4 – 130 - 156 mph
cat. 5 – >157 mph

Figure 4: Modified (NOAA - 2012) Saffir-Simpson hurricane wind scale categories and associated sustained wind speed in miles-per-hour. Note category 3, 4, & 5 are considered major hurricanes.

HURRICANE CATEGORY NAMES / TREE DAMAGE

Cat. 1 – Dangerous

branches broken, some trees toppled – power out for days

Cat. 2 – Extremely Dangerous

shallow rooted trees snapped or uprooted – power out for week

Cat. 3 – Devastating Major

many trees snapped or uprooted – power out for weeks

Cat. 4 – Catastrophic Major

most trees snapped or uprooted – power out for many weeks

Cat. 5 – Catastrophic Major

massive tree loss – power out for month

Figure 5: Saffir-Simpson hurricane wind scale category numbers, names, and tree damage with associated power outage descriptions.

storm category	wind speed mph	mid-point wind pressure* lbs/ft^2	tree impacts
1	74-95	19	branch & tree failures
2	96-110	28	major tree failures
3	111-129	38	large tree failures – leaves gone
4	130-156	54	massive tree blow-downs
5	> 157	> 63	most trees down

(* column is not part of wind scale but added by author)

Figure 6: Saffir-Simpson hurricane wind scale categories, wind speed, wind load pressure & tree impacts.

Hurricane Strikes Georgia Coast & Inland Georgia (1851-2010)

category =	1	2	3	4	total
COAST	15	5	2	1	23
INLAND	9	0	0	0	9

(average 1 every 5 years)

Figure 7: Number of hurricane strikes to coastal and inland areas of Georgia over a period of 159 years by hurricane wind scale category number.
(Blake & Gibney, 2011)

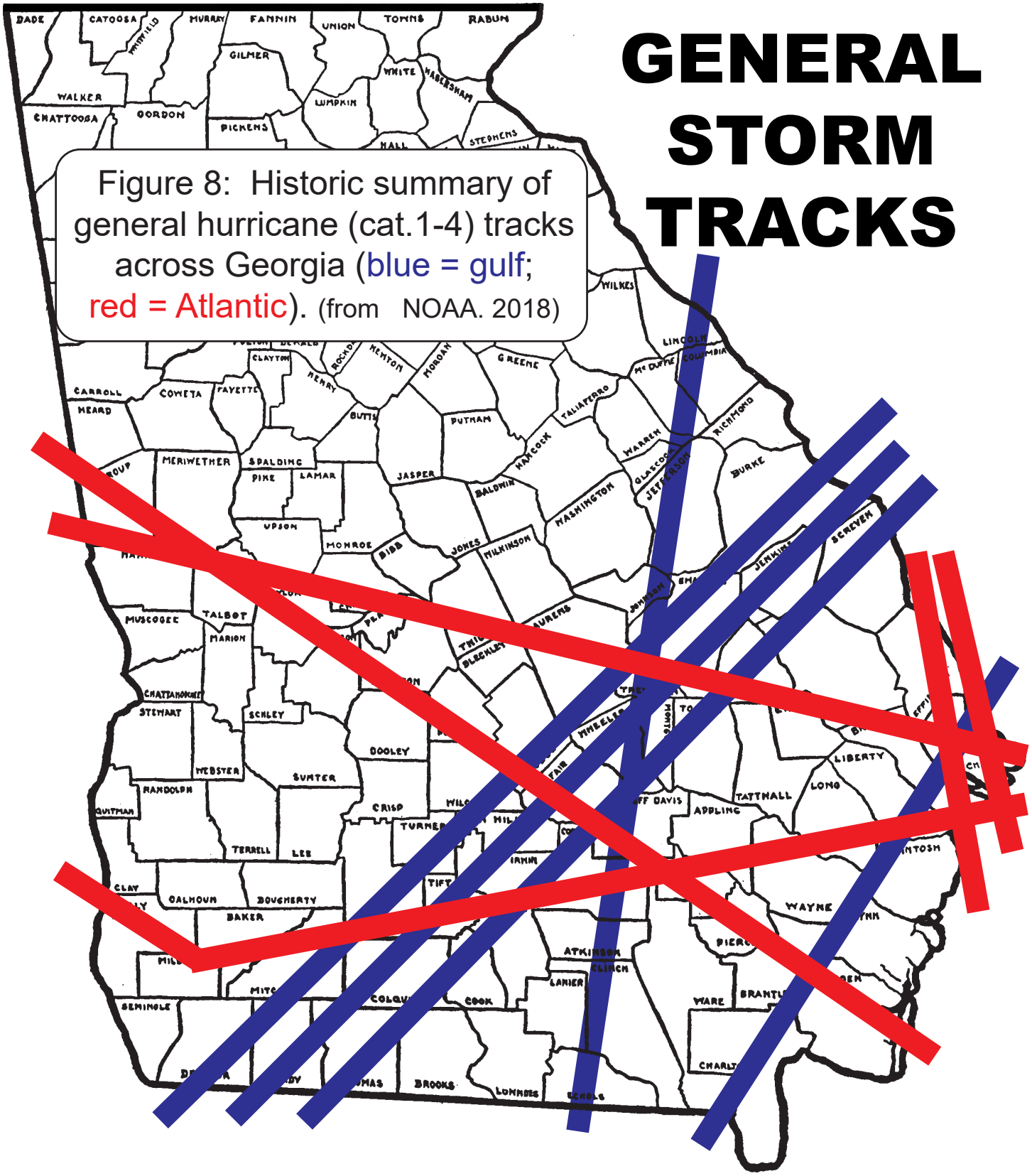

Figure 8: Historic summary of general hurricane (cat.1-4) tracks across Georgia (blue = gulf; red = Atlantic). (from NOAA. 2018)

Citation:

Coder, Kim D. 2022. Defining historic hurricanes: Wind, water & tree devastation. Warnell School of Forestry & Natural Resources, University of Georgia, Outreach Publication WSFNR-22-33C. Pp.13.