

Final Report

Survey and Investigation of Buildings Damaged by Category III, IV and V Hurricanes in FY 2024-2025 – Hurricanes Helene and Milton

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1 INTRODUCTION

Researchers at the University of Florida coordinated and led efforts in the field to capture the performance of building structures impacted by Hurricanes Helene and Milton that made landfall on Florida's Gulf Coast, creating extreme storm surge impacts and high winds to several communities. Hurricane Milton additionally produced numerous tornadoes that caused extensive damage along the East Coast of Florida. Joint field efforts were performed with researchers from the National Science Foundation (NSF – supported) Structural Extreme Events Reconnaissance Network (StEER) – carrying out case study observations of damaged buildings and capturing Streetview photography and overhead photographs of the impacted communities using unmanned aerial vehicles (UAVs).

This report focuses on findings from the reconnaissance study, summarizing the performance of residential buildings by code-era in both the coastal communities and those affected by the tornadoes.

1.1 Objectives

The objective of this Final Report is to summarize the work completed as required by the five tasks in our Scope of Work. Specifically, the report describes detailed findings from the reconnaissance study, the design and execution of a virtual reconnaissance effort that expanded the depth and breadth of the on-site reconnaissance efforts and connects key observations from both to relevant provisions of the Florida Building Code.

1.2 Relevance to the Florida Building Code

This project stratifies building performance by building code era, hazard intensity, first floor elevation, and other notable features to facilitate an evaluation of building performance under the latest buildings codes contrasted with those from earlier code editions. Table 1 summarizes the various editions of the Florida Residential Building Code and their effective dates.

Specific code-related topics (and FBC Section numbers) that are evaluated include:

- Performance of breakaway walls relative to code provisions (Section R322.3.5)
- Placement of the coastal construction control line (Section R322.1.11),
- Performance of common roof cover (e.g., Section R903) and wall cladding (e.g., Table R703.3(1)) elements
- Floodplain construction (Section R301.2.4)
- Roof decking nailing (Section R803.2.3.1) and re-nailing (FBC-EB Section 706.7) requirements.

2 SUMMARY OF HURRICANE HELENE AND MILTON (2024) IMPACTS

Two major hurricanes (Category III or stronger) made landfall in Florida during the 2024 Hurricane Season. On September 26 2024, Hurricane Helene made landfall in Florida's Big Bend region, near the city of Perry, as a Category 4 storm with estimated 1-minute sustained wind speeds of 140 mph and a central pressure of 938 mbar (Webb et al. 2024). Two weeks later Hurricane Milton made landfall near Siesta Key, Florida on October 9, 2024, as a Category 3 storm with maximum sustained wind speeds estimated at 120 mph by the National Hurricane Center (Do et al. 2025) and a minimum central pressure of 958 mbar. The tracks of both hurricanes are shown in Figure 1, along with contours of the estimated peak 3-second gust wind speeds (in open terrain at

10 m height) for both storms from Applied Research Associates. The peak gust wind speeds were significantly lower than the reported maximum sustained winds at landfall. The peak gust wind speeds were also lower than the 700-yr MRI (mean recurrence interval) ASCE 7 design wind speeds by as much as 40 mph in Hurricane Milton. In Hurricane Helene, although the peak gusts approached the basic design wind speeds near Perry, FL, much of the region that experienced the highest winds was sparsely inhabited, resulting in limited impacts.

Table 1. Effective dates for each version of the Florida Residential Building Code.

Edition	Code Basis	Referenced ASCE 7	Effective Date	Nominal Effective Years
2001 FBC	1997 SBC	7-98	March 1, 2002	2002-2005
2004 FBCR	2003 IRC	7-02	October 1, 2005	2006-2008
2007 FBCR	2006 IRC	7-05	March 1, 2009	2009-2011
2010 FBCR	2009 IRC	7-05	March 15, 2012	2012-2015
2014 FBCR	2012 IRC	7-10	June 30, 2015	2016-2017
2017 FBCR	2015 IRC	7-10	December 31, 2017	2018-2020
2020 FBCR	2018 IRC	7-16	December 31, 2020	2021 - current
2023 FBCR	2021 IRC	7-22	December 31, 2023	2024 - current

Note: FBC = Florida Building Code; FBCR = Florida Building Code: Residential

The major impacts to built infrastructure were not directly caused by the hurricane wind fields of both storms. In Helene, the large wind field produced significant storm surge along much of the west coast of Florida (Figure 2), with inundations above ground level were measured as high as 17.5 ft according to the Coastal Emergency Risk Assessment (CERA 2025) best-track hindcast (Figure 2). Hurricane Milton also caused significant storm surge along the Florida’s west coast, primarily in the Cape Coral region and further south where the maximum water inundation above ground was estimated to be around 8 ft according to CERA (Figure 3). Hurricane Milton also produced 46 confirmed tornadoes, primarily affecting the communities along Florida’s east coast (Do et al. 2025). Several of the tornadoes were rated EF3 by the National Weather Service, with the strongest tornado having estimated 3-second gust wind speeds of around 155 mph, approaching design levels.

Hurricanes Helene and Milton had severe impacts in terms of loss of life in Florida. Hurricane Helene was responsible for 20 fatalities in Florida including indirect fatalities, while Milton was responsible for 32 fatalities, of which six were tornado-related fatalities (Do et al. 2025). Economic losses were also severe. As of November 2024, the Florida Office of Insurance Regulation reported total estimated insured losses of \$2.4B from Hurricane Helene (FLOIR 2025a) and \$4.3B from Hurricane Milton (FLOIR 2025b).

As Hurricane Helene traveled inland beyond Florida’s borders it produced devastating impacts in several states, notably Georgia, South Carolina and North Carolina. Helene generated a series of cascading hazards as it moved inland; including tornadoes, extremely intense rainfalls that contributed to unprecedented flooding and landslides in the western part of North Carolina, that destroyed several communities and isolated them for days after the event. Though the impacts beyond Florida are not the focus of this report, we note Hurricane Helene’s tragic loss of 230

persons and extremely high economic loss estimated at between \$78 Billion to \$110 Billion USD by various sources (Webb et al. 2024).

Additional details on the hazards and impacts of both storms can be found in the Preliminary Virtual Reconnaissance Reports (PVRR) published by StEER for Hurricane Helene (Webb et al. 2024) and Hurricane Milton (Do et al. 2025). PIs Prevatt and Roueche contributed to the synthesis of knowledge and writing of the StEER reports.

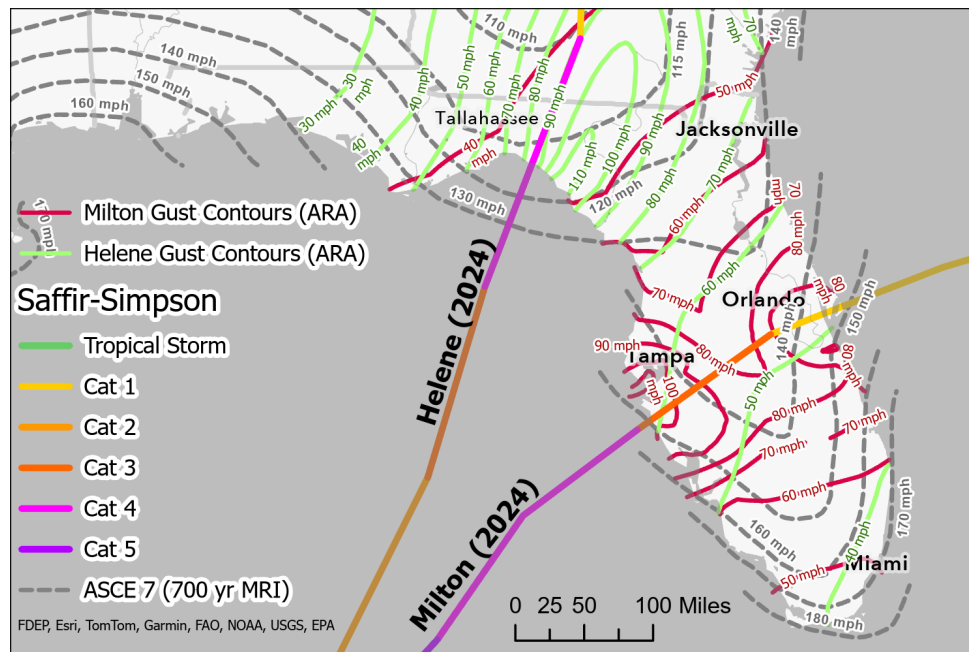


Figure 1. Hurricanes Helene and Milton tracks with peak 3-s wind gust contours overlaid as estimated by Applied Research Associates (ARA), along with the ASCE 7-16 700-yr basic wind speeds.

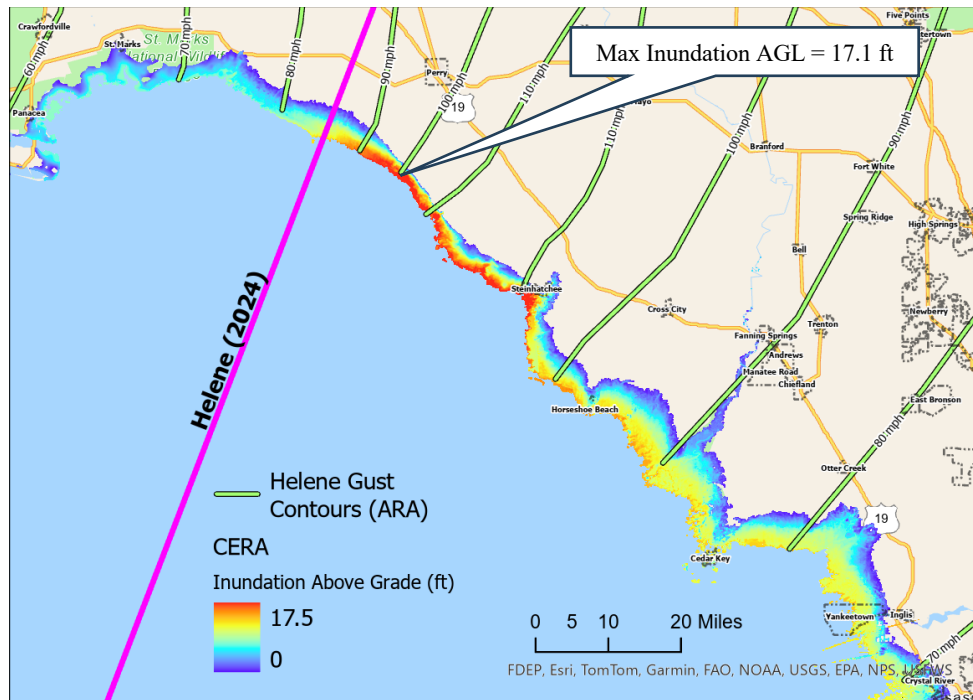


Figure 2. Hurricane Helene hazard levels in the Big Bend region of Florida. Peak gust wind speed contours are sourced from ARA. Maximum inundation above grade is sourced from the Coastal Emergency Risk Assessment (CERA) best track hindcast.

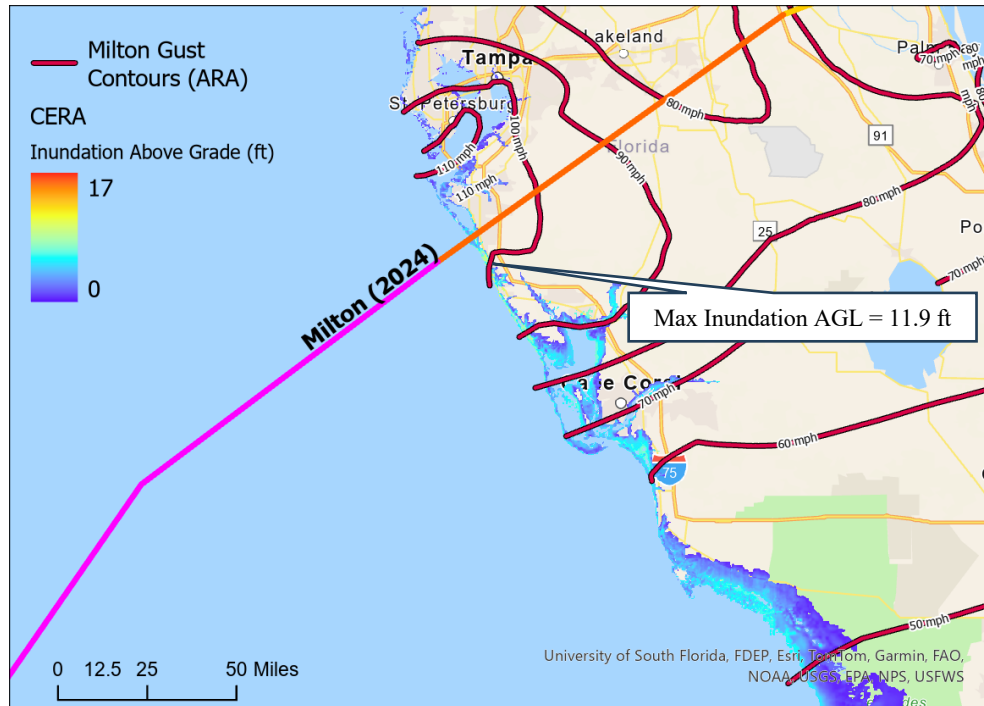


Figure 3. Hurricane Milton hazard levels in the Big Bend region of Florida. Peak gust wind speed contours are sourced from ARA. Maximum inundation above grade is sourced from the Coastal Emergency Risk Assessment (CERA) best track hindcast.

3 SUMMARY OF TASKS

There are five tasks in our scope of work, and this section outlines the status of each deliverable.

Task 1. The Contractor shall maintain data collection equipment and transport equipment as necessary for measuring intensity of land-falling hurricanes and documenting damage caused by those land-falling hurricanes.

Status: Completed.

Task 2. The Contractor may conduct one deployment training exercise (Thunderbolt Drill) in the field to ensure personnel are trained and familiarized with wind monitoring equipment and data collection procedures.

Status: Not Completed – Deemed Unnecessary.

Task 3. Perform field data collection preparation to include purchase and organization of data collection and recording equipment, performing vehicle maintenance, and documenting equipment and software available for database construction.

Status: Completed.

Task 4. Organize and execute an initial triage assessment of residential property damage resulting from a Category III, IV, or V hurricane.

- a. Deploy wind monitoring assets in the event of a land-falling hurricane.

Status: Completed. See Appendix A.

- b. Provide an initial triage assessment of residential property damage, including approximate extent of visible water depths, where evident.

Status: Completed.

- The PIs conducted initial triage assessment of the Horseshoe Beach community impacted by Hurricane Helene, observing mainly storm surge and wave impacts, and minor to moderate wind damage.
- The PIs conducted initial triage assessment in the interior regions following Hurricane Milton in Central Florida region, observing scattered minor wind damage (i.e., minor roof cover loss, or damage to flashing, Florida rooms, etc.) to single-family residential buildings that were not affected by the tornadoes.

Task 5. Organize and execute a formal survey and damage assessment effort as directed and approved by the program manager.

Status: Completed. See the following sections for details.

4 PERFORMANCE ASSESSMENTS

Performance of residential buildings regulated by the Florida Residential Building Code was assessed using both on-site investigations, conducted by members of the Structural Extreme Events Reconnaissance (StEER) network, and virtual investigations, which utilized a variety of supplemental imagery and data sources described later in this report.

4.1 On-Site Performance Assessments

- The PIs conducted an initial triage assessment of the Cedar Key and Horseshoe Beach communities that were impacted by Hurricane Helene, and observed mainly storm surge and wave impacts there, with only isolated evidence of wind damage.
- The PIs conducted an initial triage assessment on October 12th, following Hurricane Milton, in the Central Florida region, observing isolated minor wind damage to single-family residential buildings.
- The PIs conducted a formal survey and damage assessment of communities impacted by the tornadoes spawned by Hurricane Milton on the east coast of Florida. A total of 130 records were inspected between November 6-8, 2024, of which 76 were single-family residential structures whose construction would fall under the provisions of the Florida Building Code.
- The PIs assisted with planning and target selection for field assessments of coastal communities in the Big Bend region conducted by teams representing the NSF Structural Extreme Events Reconnaissance (StEER) network and the National Ocean Partnership Program (NOPP). A total of 104 records, including 97 single-family residences, were inspected on-site between November 10-11, 2024.
- The PIs coordinated and participated in the collection of over 297 km of surface-level panoramic imagery throughout impacted regions in the Big Bend region of Florida and communities on the east coast impacted by tornadoes. All the imagery is publicly available through the Mapillary platform.

4.2 Virtual Performance Assessments

Research teams conducted 173 on-site building performance assessments to single-family and/or multi-family residential structures following Hurricanes Helene and Milton for which detailed photographs and measurements were available. To capture a more robust and representative dataset that would enable analysis of performance across code eras, an additional 185 virtual performance assessments were also conducted using the surface-level panoramic imagery collected on-site, NOAA aerial imagery, and other public sources. The population of affected structures was somewhat limited due to the relatively small size of the coastal communities (e.g., Dekle Beach, Horseshoe Beach) and narrow damage paths in the tornadoes on the east coast. The structures selected for virtual performance assessments primarily consisted of single-family residential structures in the same regions as where on-site assessments were conducted that were not part of the on-site assessments for various reasons (e.g., accessibility). Figure 4 shows a summary of the single- or multi-family on-site and virtual performance assessments in each region.

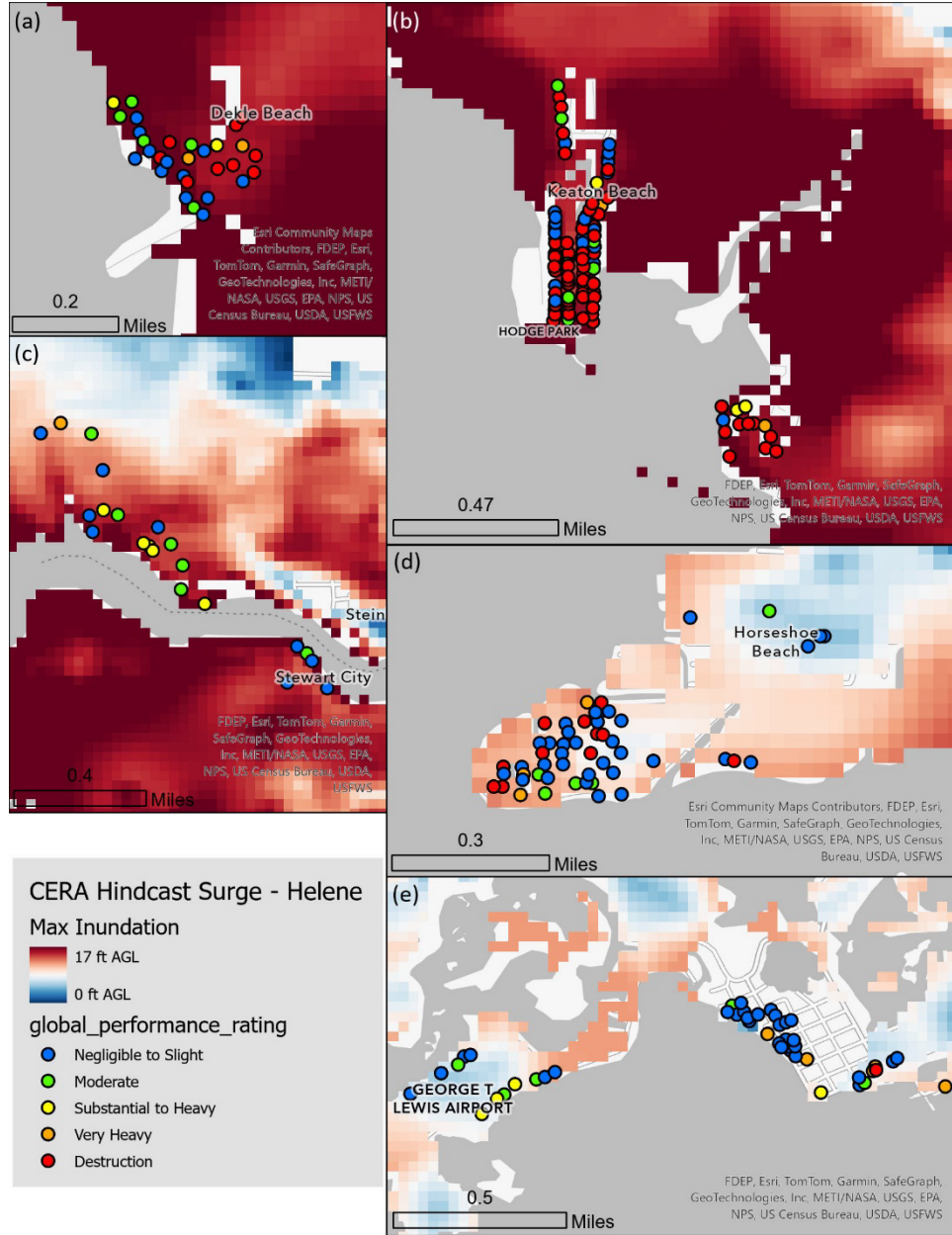


Figure 4. Spatial distribution of coastal assessments relative to Hurricane Helene CERA Hindcast Surge for (a) Dekle Beach, (b) Keaton Beach, (c) Steinhatchee, (d) Horseshoe Beach, and (e) Cedar Key.

4.3 Characteristics of Buildings in the Combined Performance Assessment Dataset

The total dataset of both on-site and virtual assessments contained 358 single-family or multi-family structures. Figure 5 summarizes various binned characteristics of structures in our dataset, including the code era of construction, type of occupancy, the peak estimated hurricane wind speed at each site, and the peak estimated storm surge inundation at each site. The population of affected structures was relatively limited due to sparsely populated regions in the Big Bend, where storm surge impacts were most severe, and due to the limited footprint of the tornadoes on the East Coast.

Structures built to the Florida Building Code were prioritized, but there were relatively few in these regions, as shown in Figure 5(a).

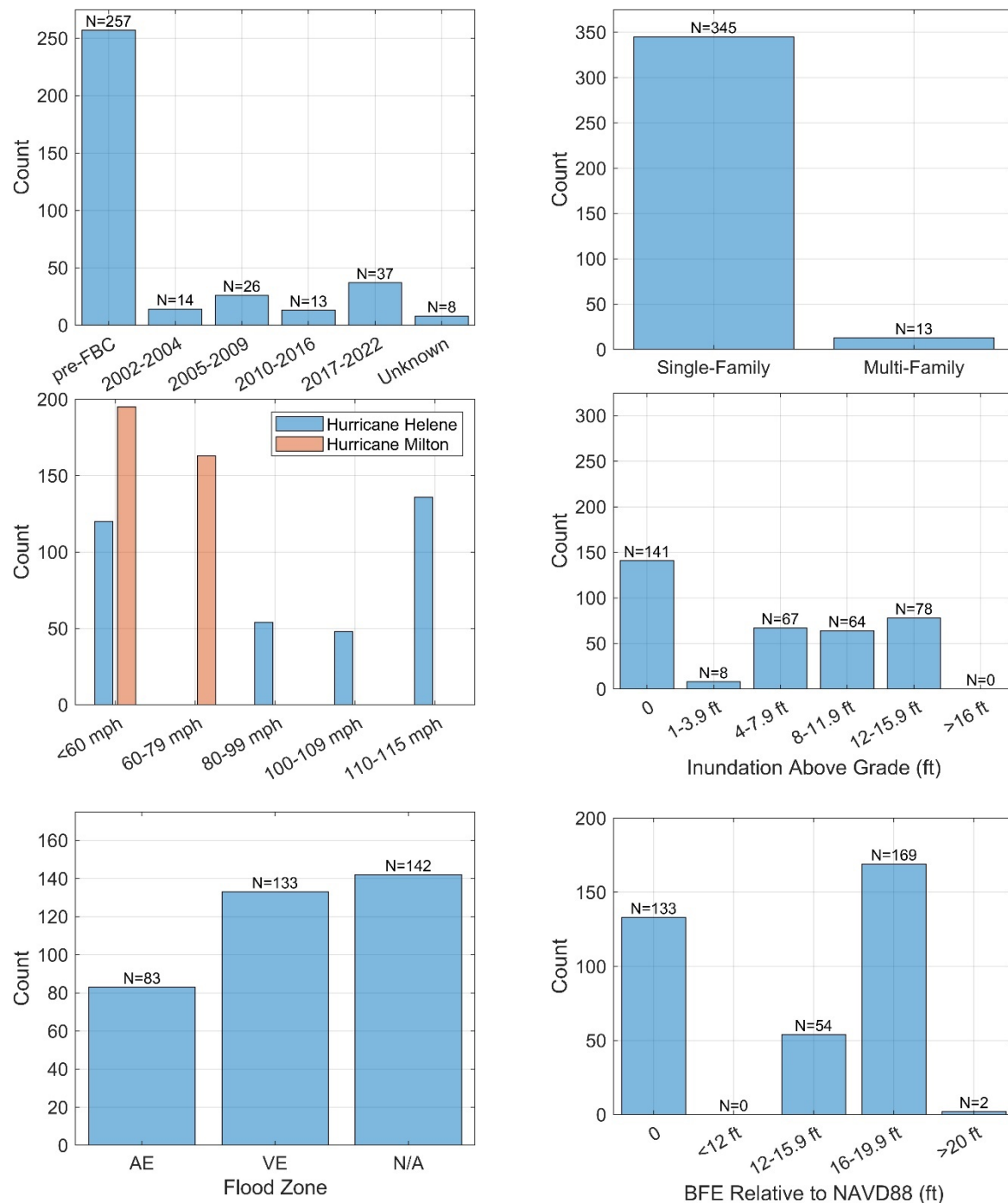


Figure 5. Distribution of samples across various stratification levels, including (a) building code construction era, (b) occupancy, (c) peak 3-s gust wind speed (excluding tornado effects) as estimated by ARA, (d) inundation levels above grade as estimated by CERA, (e) assigned flood zone according to the current FEMA FIRM maps, and (f) base flood elevation assigned to each building in the current FEMA FIRM maps.

5 DATA ENHANCEMENT AND QUALITY CONTROL

The objective of the data enhancement and quality control (DEQC) process was to (1) bring as many assessments as possible, both virtual and on-site, up to a common level of attributes and features (listed in Appendix E), and (2) minimize the number of errors in the final dataset used for analysis. To accomplish this objective requires the synthesis of many different data sources (Table 2) through both manual and automated procedures. Manual procedures were primarily completed by a team of trained graduate and undergraduate engineering students at Auburn University and the University of Florida. A few of the attributes are described in more detail below.

Table 2. Primary data sources in use for performing data enrichment and analysis tasks.

Name	Provider	Data Class	Description	Use to Project
StEER Performance Assessments	Structural Extreme Events Reconnaissance Network	Performance Assessments	On-site post-Helene and Milton photographs and basic attributes for select buildings	Starting point for data enhancement
Surface-Level Panoramas	Structural Extreme Events Reconnaissance Network / SiteTour 360	Imagery	297 km of street-level panoramic imagery captured post-storm	Classify building performance and building attributes
USGS Flood Event Viewer	United States Geological Society	Hazard Intensity	Water height measurements as recorded by wave height sensors	Associate observed storm surge with building performance
Wind Maps	ARA, NIST, FEMA	Hazard Intensity	Interpolated 3-s gust and 1-min sustained wind speeds, standardized to 10 m height and open terrain, throughout the affected regions	Associate estimated wind speeds with building performance
Hurricane Helene and Milton Aerial Imagery	National Oceanic and Atmospheric Administration	Imagery	Post-Helene and Milton nadir imagery with approximately 15 cm ground sample distance.	Classify building performance and building attributes
Statewide Parcel Data	Florida Office of Insurance Regulation; Florida Geographic Database Library	Public Records	Public parcel data for the state of Florida	Define common building attributes
National Lidar Project	United States Geological Survey / Multiple	3D Model	Lidar point clouds and derived products covering the affected counties	Measurements of select building attributes such as mean roof height and first floor elevation

5.1 Height of Lowest Horizontal Structural Member

The height of the Lowest Horizontal Structural Member (LHSM) defines the elevation in feet of the lowest horizontal member of the elevated floor relative to the average ground plane elevation around the building. To estimate the height to the LHSM first required determining whether a building was elevated or not. For structures with breakaway walls that failed during the storm or with only partial enclosures below the elevated floor, the determination of whether it was elevated or not was relatively straightforward. For other structures, a combination of pre-hurricane street-

level imagery from Google Street View (looking for features such as exterior stairs extending to an elevated floor), checking county records (specifically number of stories and floorplan layouts), real estate records, and elevation certificates where present was used to evaluate whether the first finished floor was elevated or not. The level of confidence in this evaluation was generally high based on the source of the available information.

If a home was assessed as having an elevated first floor, the height to the lowest horizontal structural member, if not measured on-site, was estimated using one or more of (1) coastal lidar point clouds, (2) the Pictometry Eagleview platform, which allows for height measurements to be made, or (3) visual cues such as counting the number of masonry blocks used in the piers, or counting the number of steps. These methods are visualized in Figure 6. The measurements were spot-checked with elevation certifications where available and found to be in good agreement within approximately +/- 1 ft.

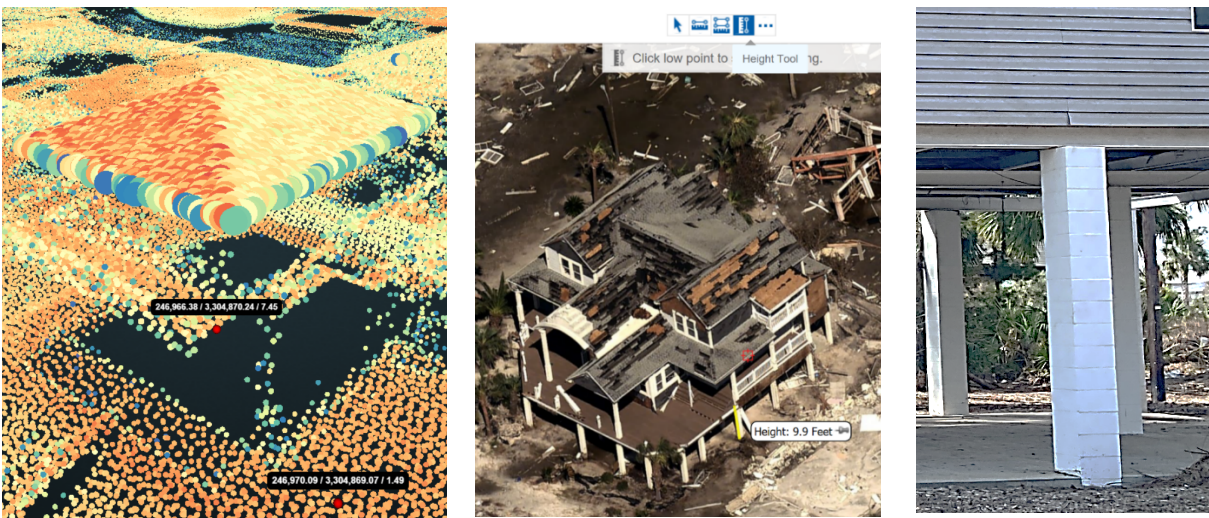


Figure 6. Estimating height to lowest horizontal structural member using (a) lidar point clouds, where each point has an XYZ position in meters, (b) Pictometry Eagleview platform, and (c) visual cues, such as number of 8-inch masonry blocks. Where possible, multiple methods were used to confirm measurements.

5.2 Foundation Category

The foundation category defines the system responsible for transferring all lateral and vertical loads to the soil. The on-site or virtual assessment teams selected the best option from a list of common foundation types, several of the common ones of which are provided in Figure 7.



Concrete slab-on grade



Cast-in-place concrete piers.
No joints in the piers are visible.



Ground anchors and strapping



Wood piers (≤ 8 ft spacing)



Reinforced masonry piers. Note the presence of rebar in the columns.



Unreinforced masonry stem wall

Figure 7. Examples of building foundation types (a) concrete slab-on-grade, (b) cast-in-place concrete piers, (c) ground anchors and strapping, (d) wood piers (≤ 8 ft spacing), (e) reinforced masonry piers, (f) unreinforced masonry stem wall.

5.3 Collapse, Partial Collapse, or Building Off the Foundation

This attribute was used to indicate whether the building was partially collapsed, fully collapsed, or shifted off its original foundation. Partially collapsed refers to having some walls or foundation members that have collapsed, bringing portions of the roof down also. A building deemed to have shifted off the foundation may not have had any wall collapse, but the building would be noticeably shifted laterally from its original location. This field indicates that the damage is a significant life safety hazard and typically results in a total loss to the structure. Examples are shown in Figure 8.



(a) Collapsed



(b) Partially collapsed



(c) Shifted off foundation

Figure 8. Examples of (a) collapsed, (b) partially collapsed, and (c) shifted off foundation.

5.4 Global Performance Rating

The Global Performance Rating defines the overall performance of the facility, using the criteria outlined in Table 3. The performance is defined in terms of structural and non-structural damage levels. In this context, structural damage is damage to any elements designed by a structural engineer or to any elements that are necessary for the safe performance of the structure. This includes roof trusses, rafters or beams, wall framing, columns, bracing, and more. Structural also includes roof and wall sheathing (i.e., decking, substrate), since these elements are typically used as diaphragm elements. Non-structural elements focus on the building envelope (roof cover, wall cladding, doors, windows). The Global Performance Rating was defined for each structure based on information that is directly visible or could be confidently inferred from photographs or other available evidence.

Table 3. Global Performance Rating criteria for wind damage to single-family residential structures.

Global Performance Rating	Short Description	Illustrative Example	Presence or Extent of Failure in [1]:				
			Roof or Wall cover	Window or door	Roof/Wall substrate (decking) [6]	Roof struct. [7]	Wall struct. [2]
Negligible to slight (0): No structural damage, slight non-structural damage.	<i>No visible exterior damage</i>		0%	No	No	No	No
	<i>Damage confined to envelope</i>		> 0% and ≤ 15%	1 [4]	No	No	No
Moderate (1): Slight structural damage, moderate non-structural damage.	<i>Load path preserved, but significant repairs required</i>		> 15% and < 50%	> 1 and ≤ the larger of 3 and 20% [5]	1 to 3 panels	No	No
Substantial to heavy (2): Moderate structural damage, heavy non-structural damage.	<i>Major impacts to structural load path</i>		> 50%	> the larger of 3 and 20% and ≤ 50%	> 3 and ≤ 25% [3]	≤ 15%	No
Very heavy (3): Heavy structural damage, very heavy non-structural damage.	<i>Total loss. Structural load path compromised beyond repair.</i>		> 50%	> 50%	> 25%	> 15%	>0%
Destruction (4): Very heavy structural damage.	<i>Significant life safety threat due to structural damage.</i>		> 50%	> 50%	> 50%	>50%	>25%
Descriptions are primarily applicable to residential buildings, but the same guidelines can generally be applied to other building types. [1] A building is considered to be in the damage state if any of the shaded damage indicators in the corresponding row are observed. [2] Wall structure refers to walls in living areas only. The ground floor of elevated structures often have breakaway walls that can be easily damaged by storm surge. This damage should be ignored in assigning the overall damage rating. [3] Percentage of total area. [4] Number of windows or doors. [5] Percentage of total number of windows or doors. [6] Percentage of total number of roof decking or wall sheathing sheets. [7] Percentage of total number of purlins, girders, trusses, or rafters.							

6 PERFORMANCE OF BUILDINGS SUBJECTED TO COASTAL HAZARDS

Both hurricanes Helene and Milton produced strong coastal hazards. Hurricane Helene subjected coastal structures to storm surge inundation up to 17 ft in the Big Bend regions of Florida, while Hurricane Helene produced an estimated 12 ft of storm surge inundation, with the highest impacts between Sarasota and Venice, just south of Tampa. This study focuses on the coastal impacts in the Big Bend region of Florida due to Hurricane Helene. Some details of the coastal impacts from Hurricane Milton are available in (Do et al. 2025).

6.1 Code Elevation Requirements and Vulnerability Assessment

The Big Bend region of Florida lacks sandy beaches and thus falls outside the provisions of the Florida Coastal Construction Line. Therefore, the primary coastal provisions that must be met for structures in the Big Bend region relate back to Section R322 of the Florida Building Code Residential (FBCR). This section currently requires that structures in Coastal A or V flood zones have a minimum elevation to the LHSM at least 1 ft above the BFE¹. Prior to the 2017 FBCR, structures in Coastal A flood zones were only required to have a first-floor elevation greater than 1 ft above the BFE. The difference between these two requirements is illustrated in Figure 9.

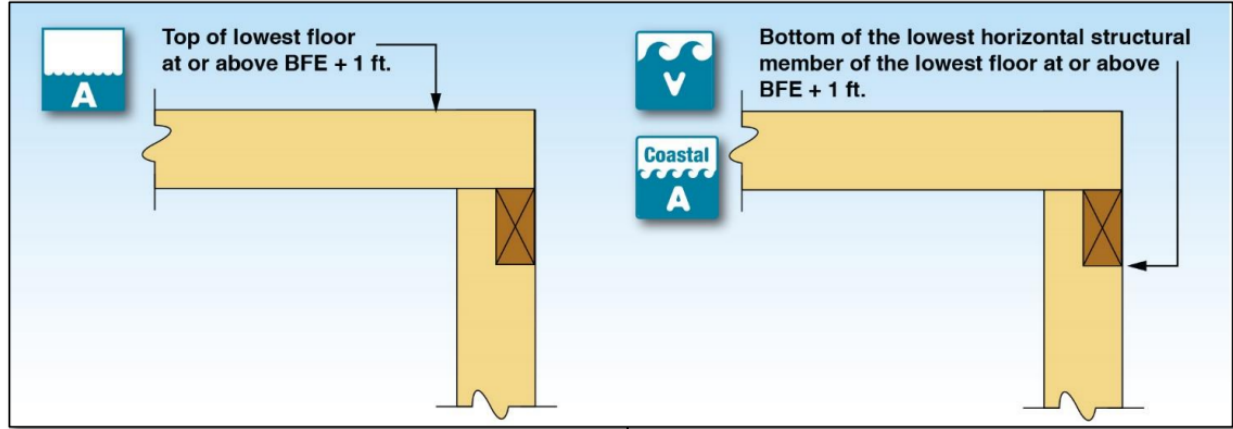


Figure 9. Flood elevation requirements for flood zones A, Coastal A, and V per the 2017 FBCR and later (Source: FBC).

Given these provisions, for this study, the vulnerability of coastal structures in the Big Bend region to storm surge was estimated by calculating the freeboard of the lowest horizontal structural member as defined in Equation 1:

$$FB_{LHSM} = LHSM_{AGL} + GroundElev_{NAVD88} - BFE_{NAVD88} \quad \text{Eq 1}$$

where FB_{LHSM} is the freeboard of the lowest horizontal member, $LHSM_{AGL}$ is the height to the lowest horizontal structural member relative to average grade elevation, $GroundElev_{NAVD88}$ is the bare earth ground elevation relative to the NAVD88 datum, and BFE_{NAVD88} is the FEMA FIRM base flood elevation relative to the NAVD88 datum. The available freeboard to the LHSM was calculated for each structure by code era (Figure 10), revealing that 64% of pre-FBC buildings included in the study had a freeboard less than 1 ft (i.e., minimum elevation to LHSM was below the current BFE + 1 ft requirement for Coastal A and V zones), while 38% of post-FBC buildings had a freeboard less than 1 ft. All the post-FBC buildings with freeboard less than 1 ft were constructed before the 2017 FBC. Of pre-2017 FBC structures, 20% had no freeboard, which may be indicative of changes to the BFE over time, as well as some uncertainty in the estimation of the elevation to LHSM.

¹ The specific language of the code and ASCE 24 related to elevation requirements refer to the Design Flood Elevation (DFE) or BFE, whichever is higher. For consistency, it is assumed in this study that the BFE and the DFE are the same for Flood Design Class 2 structures in these regions.

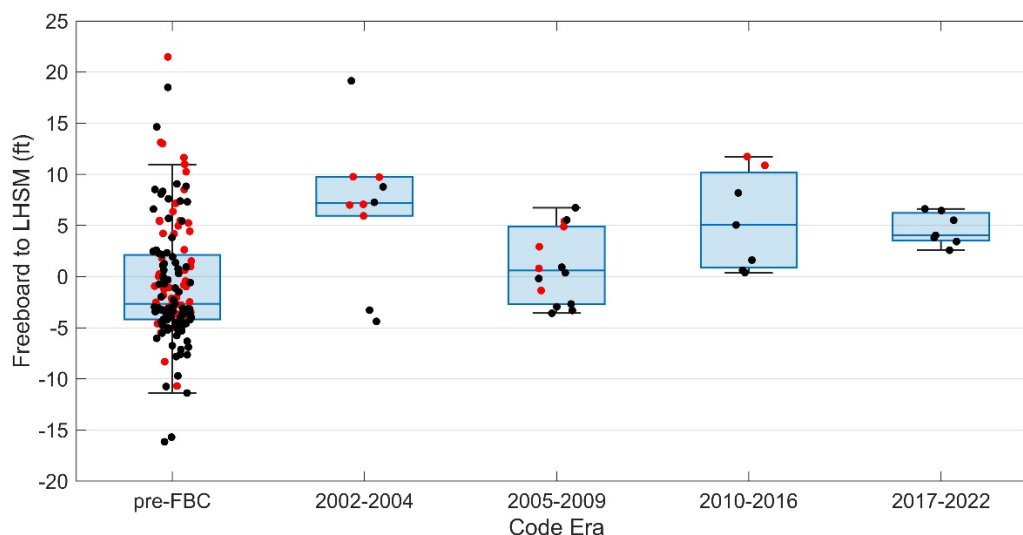


Figure 10. Elevation of the bottom of the lowest horizontal structural member relative to the current base flood elevation by code era and flood zone (red = Zone AE and black = Zone VE).

6.2 Overview of Damage Sustained by Buildings Subjected to Coastal Hazards

Of the 221 structures in the study that were subjected to coastal hazards, 39% experienced no observable damage to the main living areas (not accounting for failure of breakaway walls, access stairs, or similar), while 36% were destroyed. Damage was most widespread in the communities of Keaton and Dekle Beach, where over 50% of the structures were classified as destroyed, most washed completely off their foundations. Steinhatchee suffered the least damage despite experiencing higher inundation levels than Cedar Key and Horseshoe Beach. Located in an inlet, Steinhatchee is surrounded by natural features that could reduce the water flow velocity and wave action for a scenario like that experienced during Hurricane Helene (Figure 11).

Examining the overall performance by code era (Figure 12), the effect of the Florida Building Code was obvious. There were 43 post-FBC² residential structures in the study, and none experienced any significant structural damage (Table 4). No structures built to the Florida Building Code suffered more than Moderate damage based on the criteria outlined in Table 3. Further, of the 78 structures that were observed to have collapsed, partially collapsed or shifted off its foundation, none were post-FBC homes. In contrast, 44% of pre-FBC homes were destroyed, most of them completely swept off their foundation. Only four structures in the study dataset were constructed to the 2017 Florida Building Code, but none suffered significant damage despite experiencing higher surge inundation (as estimated by the CERA modeling) on average relative to the other code eras. Several pre-2017 FBC structures did sustain significant non-structural damage due to water inundation and loss of wall cladding or roof cover.

The variability in performance noted above was strongly correlated with the amount of freeboard. The median inundation above the LHSM was -3.7 ft for structures deemed not destroyed (defined as not collapsed, partially collapsed, or shifted off its foundation), and +3.85 ft for those that were destroyed. Inundation above the LHSM was not a perfect predictor of destruction however, as 36 of the 115 (16%) structures that were not destroyed were estimated to have experienced inundation

² Post-FBC here and throughout the remainder of this report is intended to represent structures built to the 2001 Florida Building Code or the 2004 and subsequent editions of the Florida Building Code Residential.

above the LHSM, and 17 of the 78 structures that were destroyed had an inundation less than the LHSM (Figure 13). A variety of reasons could explain the variability in performance, including uncertainty in the true inundation height above ground, the role of water flow velocity and wave height hazards on top of the inundation, poor performance of breakaway walls, and the construction era of the homes as discussed previously.

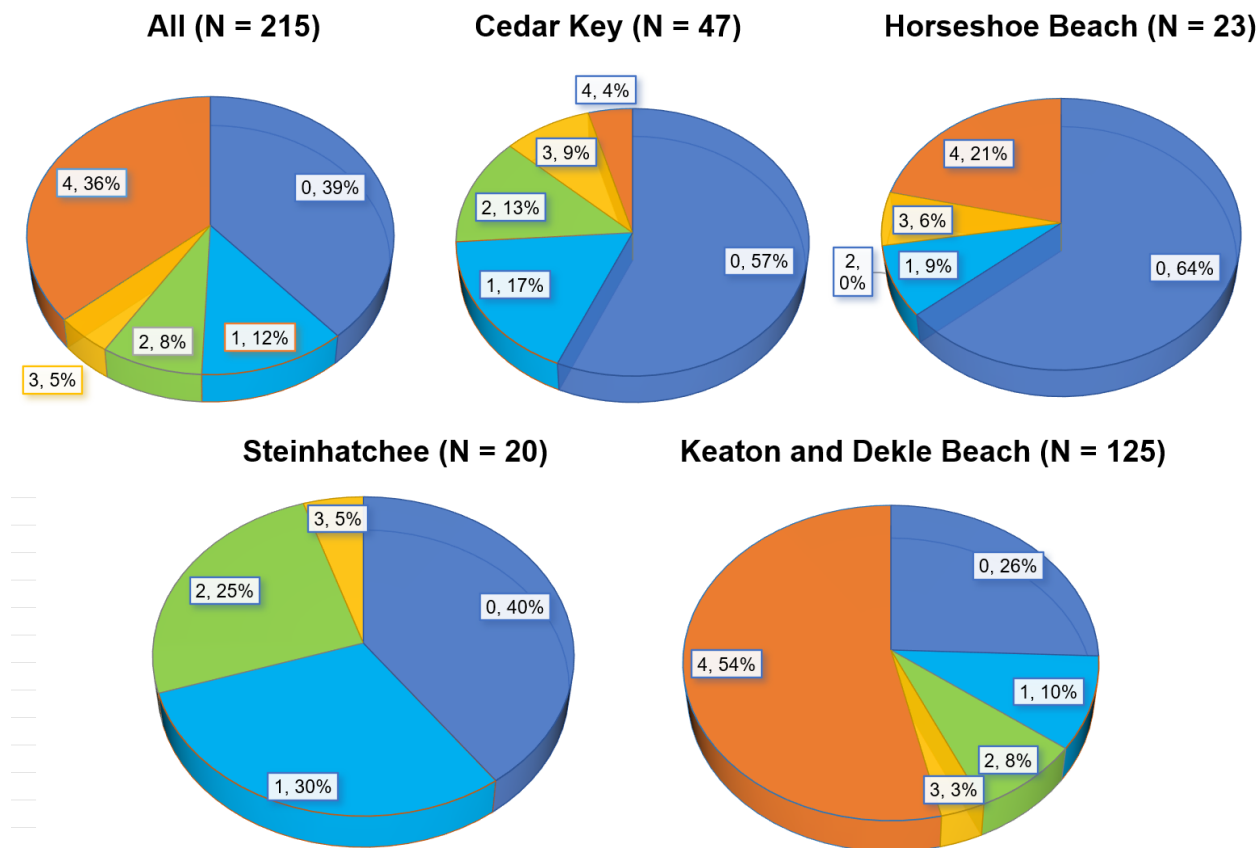


Figure 11. Distribution of global performance ratings in coastal regions by community. The numbers in each chart label refer to the numeric value of the global performance rating as defined in Table 3 and provide the percentage of structures in the given community that experienced that performance rating.

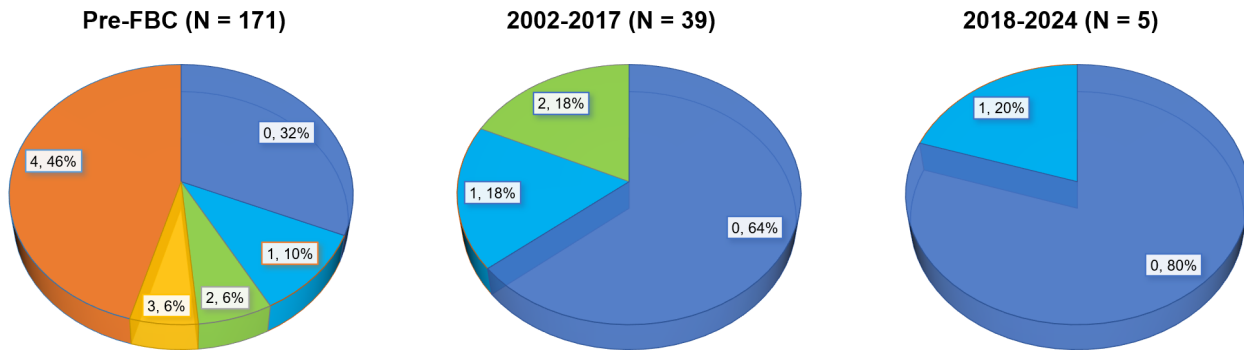


Figure 12. Distribution of global performance ratings by construction era. The numbers in each chart label refer to the numeric value of the global performance rating as defined in Table 3, and provide the percentage of structures in the given community that experienced that performance rating.

Table 4. Distribution of performance ratings for residential structures subjected to coastal hazards in the Big Bend region of Florida

		Construction Era			
		Pre-FBC	2002 - 2017	2018 - 2024	All
Number of Structures		178	39	4	221
Performance Rating	Negligible to Slight	32%	64%	80%	39%
	Moderate	11%	18%	20%	12%
	Substantial to Heavy	6%	18%	0%	8%
	Very Heavy	6%	0%	0%	5%
	Destroyed	46%	0%	0%	36%
Mean GPR		2.2	0.5	0.2	1.9
Mean Surge Inundation (CERA), ft		9.8	9.7	9.9	9.7
Mean Elevation to LHSM, ft		10.1	14.2	15.6	11.0

GPR = global performance rating (see Table 3).

Mean Surge (CERA), ft = average estimated surge inundation above ground level in ft based on hindcast ADCIRC simulations sourced from CERA.

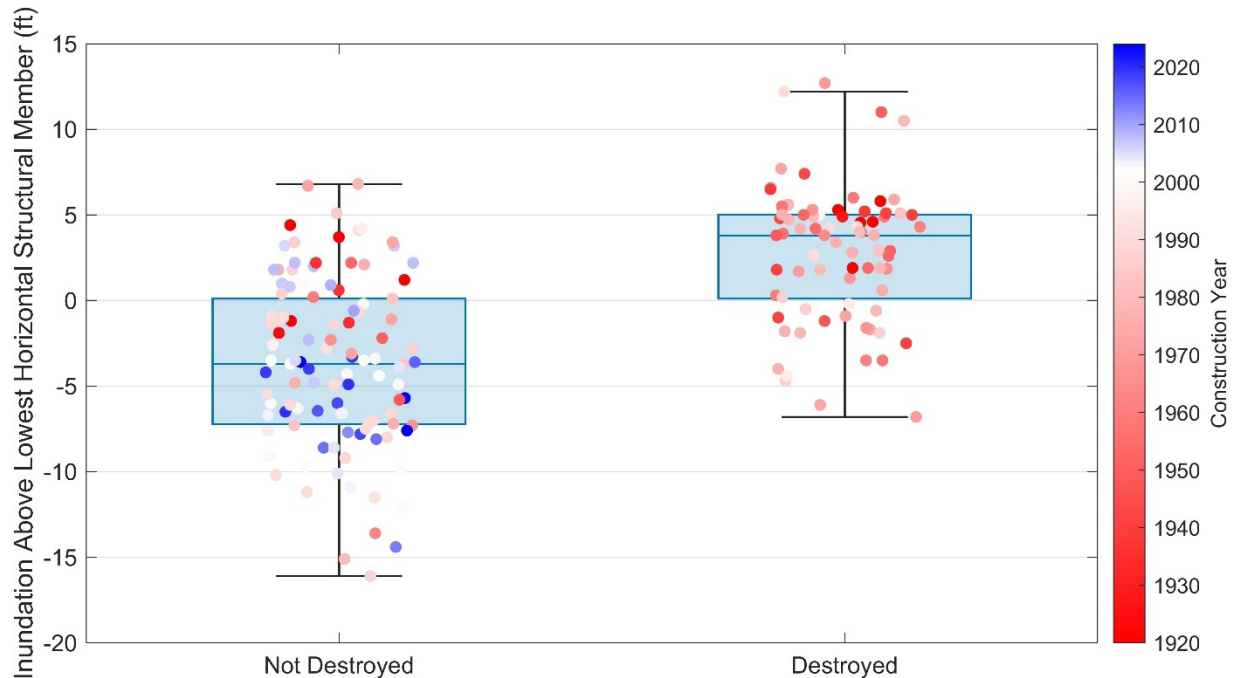


Figure 13. Inundation above the lowest horizontal structural member (LHSM) for not destroyed and destroyed structures identified by year of construction.

6.3 Performance of Structures Affected by Wind and Storm Surge Inundation in the Big Bend Region

The following observations are taken from the performance assessments that were conducted by StEER, with support from PIs Prevatt and Roueche, in the Big Bend region of Florida. These observations are not comprehensive but serve to broadly illustrate some key themes. The observations are based on a deployment by the Structural Extreme Events Reconnaissance (StEER) network led by Dr. Shafiq Alam from the University of Hawaii. Dr. Alam also led the written summary, which is included in the StEER Early Access Reconnaissance Report (EARR) (Alam et al. 2025).

Observed Performance (extracted from the StEER EARR)

The following observations are based on a review of street-view panoramas captured by the Level 2 FAST team and a forensic performance assessment conducted by the Level 3 FAST team. These findings are supplemented by year-built data and other relevant information gathered by StEER's Data Enrichment and Quality Control (DEQC) librarians. Photographs taken by the Level 3 FAST team, along with images shared on the DesignSafe Slack channel, are included to support key observations. Where necessary, pre-storm imagery from Google Maps is provided for context. Precise locations and imagery sources for all photos are detailed in the Appendix. This analysis complements the Media Repository compiled by the Virtual Assessment Structural Teams (VAST) and published under the same project: PRJ-5669 (Kyprioti et al. 2024).

In the surveyed communities of Dekle Beach, Keaton Beach, Steinhatchee, and Horseshoe Beach, storm surge and waves were the primary drivers of damage, with surge inundation levels exceeding 15 feet above ground level. From preliminary review of StEER FAST assessment following observations stand out:

- In the affected communities, **the performance of single-family dwellings appeared to be closely linked to their freeboard elevation**, as shown in Figure 14. Homes built on slab-on-grade foundations or elevated up to 10 feet to the lowest horizontal structural member (LHSM) were either washed away or suffered significant damage. In contrast, many homes elevated to 16–20 feet on concrete piers experienced minimal damage to the livable floor, with impacts primarily limited to stairs and decks built at the 8–10 foot level. Conversations with residents and contractors indicated that many of these homes had their freeboard increased after the 1993 "Storm of the Century," which contributed to their improved performance during this event.
- **The performance of multi-story, multi-family condominiums varied across the surveyed communities.** Figure 15 shows some examples of multi-family building performance. While all structures experienced negligible to slight structural damage, many sustained substantial to heavy non-structural damage, significantly driving losses. Buildings with lower elevations of 8–10 feet to the LHSM were particularly affected, as surge levels exceeded these heights, resulting in the destruction of contents on the first livable floor. Additionally, some condominiums experienced wind damage to siding and balcony ceilings across multiple floors.
- **In addition to direct lateral hydrodynamic loading on structures, storm surge and waves caused several other impacts**, including the uplift of slabs and floor systems, as well as significant scouring around piles and other structural elements, compromising the stability of both single-family and multi-family homes. Figure 16 illustrates these effects.
- **Critical facilities performed well**, based on both the in-depth forensic assessment conducted by the Level 3 FAST team and surface-level panoramas obtained by Level 2 FAST (see Figure 17). Two such facilities—a post office and a fire station, built in 1948 and 1935, respectively—are located adjacent to each other in Horseshoe Beach and experienced little to no damage. The only observed impact was a slight inward displacement of one of the fire station's large doors, likely due to debris impact and damming. Similarly, two schools—one in Cedar Key (built in 2003) and another in Steinhatchee (built in 2022)—showed no visible damage. All these facilities are situated further inland within their respective communities, reducing their exposure to storm surge and wave forces. Additionally, the higher wind design standards applied to these relatively newer structures contributed to their resilience, preventing wind damage in this below-design-level wind event.
- **Compared to the generally poor performance of RV and mobile/manufactured homes in previous hurricanes, those in the affected Big Bend coastal areas fared significantly better during Hurricane Helene.** Many were elevated 8–12 feet on wooden or concrete piers (see Figure 18), improving their resilience. While at-grade mobile homes were often displaced from their foundations, **elevated ones** largely remained intact, with damage primarily limited to ground-story enclosures.
- **Breakaway walls, commonly used to enclose elevator shafts, utilities, and storage areas in both single- and multi-family homes, performed as designed.** However, when these walls failed, they often exposed electrical utilities to surge and wave damage, leading to a loss of functionality in otherwise structurally undamaged homes. Utility damage was more prevalent in multi-family condominiums than in single-family homes as many of those were built above LHSM (see Figure 19).

- **Structural wind damage was relatively minimal in this below design-level wind event,** with only isolated instances of roof failures and siding and soffit losses observed in older residential buildings constructed before the adoption of the Florida Building Code in 2001 (Fig. 20).



Figure 14. Impact of floor elevation on the survivability of coastal homes: (a) pre-storm and (b) post-storm views of a slab-on-grade single-family home on Dekle Beach Blvd, built in 1996, which was completely washed away during Hurricane Helene; (c, d) pre-storm and (e, f) post-storm views showing the contrasting performance of two elevated homes on Keaton Beach Rd, FL. Home (1), built in 2000, features wooden columns with a **7-foot elevation** to the lowest horizontal structural member (LHSM), whereas home (2), constructed in 1977, is supported by cast-in-place concrete columns with a **20-foot elevation** to the LHSM.



Figure 15. Performance of multi-family condos during Hurricane Helene: (a) substantial to heavy damage to a condo built in 2007 near the Steinhatchee Marina, elevated on an **8-foot wooden foundation** and (b) interior view of a second-story room showing water damage to the drywall of that condo; (c) minimal structural damage to a condo on Keaton Beach Rd, built in 2005 on **18-foot concrete columns** to the lowest horizontal structural member (LHSM); however, wave and surge damage primarily affected the (d) ground-floor utility enclosure and stairway decks; (e) a multi-family condo on Main Street in Horseshoe Beach, built in 2005 on **12-foot concrete piers**

along the shoreline, experienced minimal damage, with (f) the most notable impacts being damage to the enclosed breakaway space at the open ground level and the loss of balcony ceilings at multiple floor levels due to wind.



Figure 16. Examples of uplift, scour, and erosion effects on coastal buildings during Hurricane Helene: (a) uplift of a slab-on-grade floor deck and (b) scour around the post foundation of a single-family home in Dekle Beach built in 1983; (c) erosion and scour affecting the open ground story floor slab and waterfront of a single-family home built in 1980 in Horseshoe Beach; and (d) scour and erosion around the foundation of multi-story Seashore Landing Condominiums in Cedar Key, constructed in 1995.



Figure 17. Performance of essential facilities in coastal areas affected by Hurricane Helene: (a) the Horseshoe Beach Post Office, built in 1948, sustained no damage; (b) the Horseshoe Beach Fire Station, constructed in 1935, exhibited visible damage, including a large door blown inward, likely due to debris impact and damming; (c) Cedar Key School, built in 2003, remained undamaged; and (d) the elementary school in Steinhatchee also showed no visible damage. All these facilities are located further inland within their respective communities, reducing their exposure to surge and wave impacts.



Figure 18. Performance of RVs and manufactured homes during Hurricane Helene in Steinhatchee, FL: (a) pre-storm and (b) post-storm views of a manufactured home park; The red triangle in (a) approximates the location of streetview in (b); (c) an elevated manufactured home built in 2001 with an 8-ft elevation to the LHSM survived, while neighboring slab-on-grade homes were washed away; (d) high water mark (HWM) reaching the LHSM, preserving the contents of the livable floor in the same home; (e) another elevated manufactured home, built in 2004 with an 11-ft elevation to the LHSM; and (f) the higher freeboard in this home prevented surge and wave exposure to the steel I-beam LHSM.



Figure 19. Examples of poor wind performance in buildings within the affected community: (a) a one-story home on Dekle Beach Blvd, built in 1998 on **16-foot elevated reinforced masonry piers**, experienced roof structure and sheathing failure. The home featured an **8-foot elevated deck** extending over the entire floor plan, which, along with part of it enclosed by wood framed walls the living area built on it, likely failed due to surge and wave loading; (b) siding damage observed on the same home; (c) soffit partially removed along the eave of a house constructed in 1983, Dekle Beach and (d) vinyl siding that was installed over existing wood siding system of house (originally constructed in 1945) was partially stripped from the northeast elevation (i.e., gable end) siding damage on elevated buildings located in Dekle Beach, constructed in **1983 and 1945**, respectively.



Figure 20. Performance of breakaway walls and utilities during Hurricane Helene: (a) designed failure of breakaway walls exposing the elevator shaft in a multi-story condominium on Keaton Beach Rd, built in 2005; (b) water damage to utilities in the open ground story of a multi-story condominium built in 2007, north of the Steinhatchee Marina; (c) enclosed utilities in the ground story of a multi-story condominium south of the Steinhatchee Marina; and (d) an elevated air-conditioning unit elevated to **13 ft above** ground in Horseshoe Beach home built in 1995 that remained undamaged.

7 PERFORMANCE OF BUILDINGS SUBJECTED TO WIND HAZARDS

Hurricanes Helene and Milton both produced significant wind hazards. For Hurricane Helene, peak surface wind speeds (3 second gusts, 10 m height above ground, open exposure) as estimated by ARA were 123 mph offshore, and 114 mph over land in Keaton Beach, FL. Estimated wind speeds approached, though never exceeded, the ASCE 7-22 basic wind speeds for Category II structures in this region (Figure 21(b) and Table 5).

In the landfall region of Hurricane Milton, peak hurricane wind speeds were estimated at 114 mph, well below the ASCE 7 basic wind speeds in this region (between 140 mph and 150 mph for Risk Category 2 structures). However, multiple strong tornadoes were spawned by Hurricane Milton in the central and east coast regions of Florida, and the National Weather Service estimated that the peak wind speeds in several of the tornadoes approached design levels. Appendix B provides the complete list of confirmed tornadoes and their hazard and path characteristics.

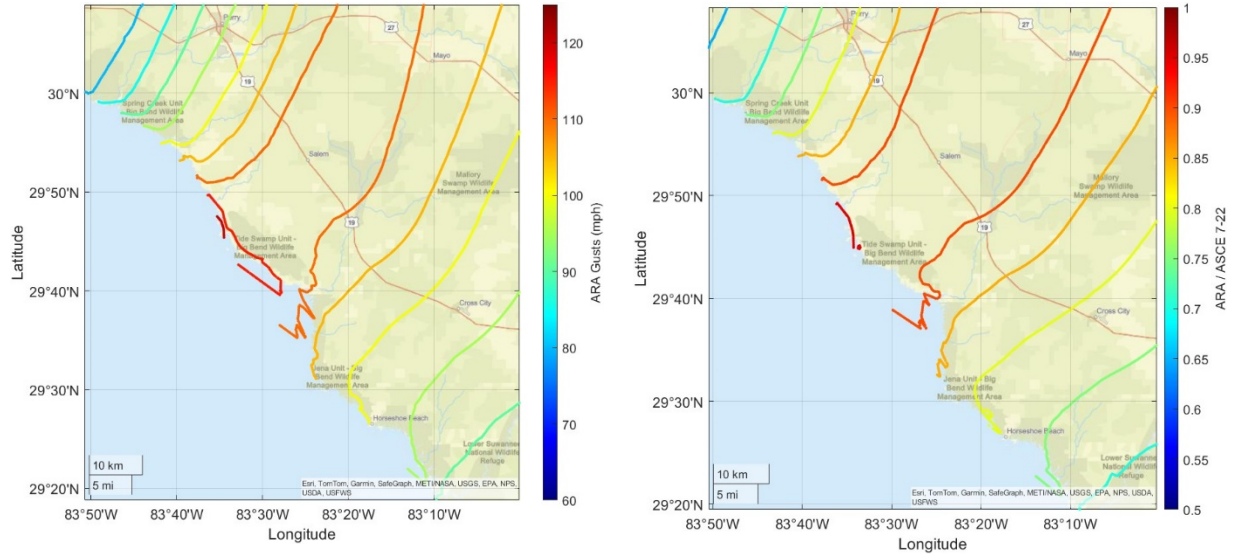


Figure 21. Hurricane Helene wind hazards near design levels. (Left) Peak 3-second gust contours from ARA. (Right) Contours representing the ratio of the peak 3-second gust wind speeds from ARA to the ASCE 7-22 basic wind speeds for Risk Category II structures.

Table 5. ARA estimates of wind speed and ASCE 7-05, 7-10, 7-16, and 7-22 basic wind speeds.

Site	ARA Peak (mph)	ASCE 7-05 ^[1] (mph)	ASCE 7-10 (mph)	ASCE 7-16 (mph)	ASCE 7-22 (mph)
Keaton Beach, FL	114	147 (0.78) ^[2]	123 (0.93)	116 (0.98)	122 (0.93)
Dekle Beach, FL	111	147 (0.76)	123 (0.9)	116 (0.96)	122 (0.91)
Steinhatchee, FL	108	152 (0.71)	124 (0.87)	118 (0.92)	124 (0.87)
Horseshoe Beach, FL	99	156 (0.63)	126 (0.79)	124 (0.8)	127 (0.78)
Cedar Key, FL	85	158 (0.54)	130 (0.65)	130 (0.65)	130 (0.65)

^[1] Converted to equivalent 700-yr return period wind speeds to match ASCE 7-10+

^[2] Values in parentheses represent the ratio of the ARA peak gust wind speed and the ASCE 7 basic wind speed.

7.1 Overview of Wind Performance in the Landfall Regions

Wind damage was observed to be almost exclusively non-structural in the landfall regions of both Hurricanes Helene and Milton. For Hurricane Helene, in the landfall region, the prevalence of destruction from storm surge limited the observations of wind-induced damage, especially in pre-FBC structures which were frequently destroyed by storm surge. Roof cover loss was observed in 12% of the structures that were assessed and were not completely destroyed by storm surge

(N=156), and roof sheathing or structure loss in only 3% of the same. These percentages held for both pre- and post-FBC structures as shown in Table 6.

The one post-FBC structure observed with wind-induced structural damage was a two-story, elevated, multi-family residential building in Steinhatchee, FL constructed in 2007 (Figure 22). Peak wind gusts at its location were estimated at 109 mph by the ARA wind field model. The building sustained visible damage to approximately 50% of the standing seam metal roof cover, approximately 20% of the roof sheathing, and approximately 5% of the wood rafter roof structure. Damage occurred on the coastward-facing elevation of the gable roof, which contained a large porch overhang at both story levels. By the time field teams arrived on site, the damage had been partially repaired.

In addition to the roof damage summarized above, wall cladding damage was also observed in a few structures. The damage was primary observed to fiber-cement cladding systems, but this was also the dominant wall cladding system used in these regions, and there was insufficient diversity of damage and wall cladding systems to enable a statistical comparison to be made.

In the landfall region of Hurricane Milton, a review of post-event aerial imagery showed very isolated roof cover damage (~2-3% in the regions with the highest modeled wind speeds), almost exclusively to asphalt shingle roofs. The precise age of these roofs was not collected as part of this study and no formal data collection was performed in this region.

Table 6. Structures with observed wind-induced roof damage in the landfall regions of Hurricane Helene.

Sample Set	Roof Cover	Roof Sheathing	Roof Structure
All Structures (N=156)	19 (12%)	4 (2.6%)	4 (2.6%)
Non-FBC Only (N=112)	13 (12%)	3 (3%)	3 (3%)
Post-FBC Only (N=44)	6 (14%)	1 (2.3%)	1 (2.3%)



Figure 22. Wind damage to a multi-family residential structure in Steinhatchee, FL constructed in 2007. This was the only post-FBC structure with observed wind-induced structural damage. Left image shows an aerial view of the structure captured prior to repairs. The right image shows the structure with repairs at the time the field team was on site.

7.2 Overview of Wind Performance under Tornado Hazards

Hurricane Milton produced at least 46 tornadoes in Florida, all in the highly sheared environment in the front-right quadrant of the wind field as is typical for cyclone-induced tornadoes. The National Weather Service used the provisions of the Enhanced Fujita (EF) Scale to estimate the intensity of the tornadoes given the damage caused by the tornadoes, with the results summarized in Appendix B. The strongest tornado, rated EF3 with estimated peak winds of 155 mph, had a path length of 21.2 miles and a maximum width of 500 yards as it passed through the Fort Pierce, Spanish Lakes, and Vero Beach communities in St. Lucie County. Another EF3 tornado, also rated EF3 with estimated peak winds of 140 mph, had a path length of 29.1 miles and a maximum width of 450 yards through Palm Beach County. The performance assessments collected by the research team primarily focused on the EF3 Spanish Lakes tornado and an EF2 tornado that impacted communities in Stuart, FL. The PIs were unable to gain access observe the impacts of the EF3 Palm County tornado.

The distribution of assigned damage ratings across all residential structures within the study impacted by tornadoes is provided in Figure 23. The pre-FBC structures again tended to experience higher damage levels, with 26% of those structures classified with heavy damage or destruction, and 55% experiencing negligible to slight damage. In comparison, post-FBC structures overall were classified with heavy damage or destruction in only one home, and 68% experiencing negligible to slight damage.

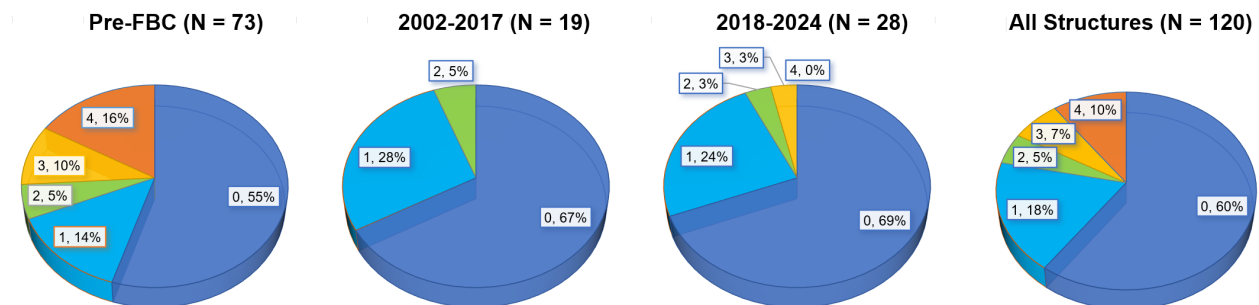


Figure 23. Distribution of global performance ratings by major code eras. The numbers in each chart label refer to the numeric value of the global performance rating as defined in Table 3, and provide the percentage of structures in the given community that experienced that performance rating.

Figure 24 shows illustrative damage in the Spanish Lakes community, where site-built, concrete masonry block homes (constructed in 2009 or later) with wood roofs were located adjacent to 1980s era manufactured homes, many of which lacked proper anchorage. Despite multiple manufactured homes being tossed, flipped, or otherwise completely destroyed, no site-built homes suffered any observable structural damage. Several homes with composite asphalt shingle roofs did suffer minor to moderate roof cover loss, and the mechanically-fastened metal roofs on several homes were observed to have some deformations due to debris impacts and deformed edges where

some flashing was removed. Several homes experienced the collapse of the garage doors when located on windward walls with respect to the tornado path. A debris missile (piece of roof decking) also passed through an impact-rated window in one home. Each of these damage observations appeared to be linked to the large debris cloud that was likely present due to the frequent catastrophic failure of adjacent manufactured homes. A gated community of 2004-2005 era homes just south of the Spanish Lakes community (Figure 25) suffered significant roof cover loss to tile roofs based on aerial imagery, but no visible structural damage appears to have occurred. A community of 1980s-era site-built homes just north of the Spanish Lakes community only suffered isolated roof cover loss. However, based on the lack of tree damage, the tornado may have lost intensity as it moved through this community.

Further south in the same EF3 Spanish Lakes tornado, the Cobblestone neighborhood of single-family homes constructed in 2020 and later was impacted with a mixture of damage (Figure 26). The research team found two homes with significant structural damage, and the remainder with varying levels of damage to the roof cover. All homes were concrete masonry block homes with wood-frame truss roofs and composite shingle roofs. The only two homes that suffered structural damage were both oriented such that the garage doors were on the primary windward wall relative to the tornado path and were the only homes nearest to the tornado that were oriented as such. The garage doors were properly pressure-rated for the region, but it appeared that the combination of wind pressure and asphalt shingle debris impact collapsed the garage doors inward, allowing the wind to pressurize the interior of the home and cause the premature structural failures, consisting of the fracture of wood truss members and uplift of roof deck. Where roof decking failures occurred, the failure mechanism was predominately fastener pull-through. The roof decking was fastened with 8d ring-shank roof sheathing nails at approximately 4:6 spacing. In every observable case, the fasteners remained in the roof trusses indicating they had pulled through the roof decking. The failures in the roof structure occurred due to fracturing of the truss members and separation of the truss interior joints. No failures were observed in the roof-to-wall connection straps, which were observed to be USP MITek HTA 20 embedded straps.

In Stuart, FL, the research team investigated damage caused by an EF2 tornado to both wood-frame and concrete masonry block homes (Figure 27(a)). Most of the homes in the community were pre-FBC, but the load path still included hurricane straps and clips. Plywood roof decking was fastened with nails and/or staples. Damage was somewhat sporadic and could not be clearly linked to any specific construction details. Not all pre-FBC homes in the direct tornado path were destroyed, but those that were destroyed (e.g., complete roof uplift, collapse of walls) were all pre-FBC. The few post-FBC homes in the community, including one home that appears to have been near the center of the tornado path, performed well outside of some minor flashing damage and tree-related damage to a corrugated metal roof. One home was constructed in 1977 but permit records indicate it was retrofitted in 2017 with impact resistant windows and doors, and in 2020 with a metal roof and re-nailing of the roof deck. Despite these retrofits, the roof deck was uplifted off about 40% of the roof, with the failures all appearing to have occurred due to fastener pull-through (Figure 27(b-c)). Fastener pull-through was the dominant failure mechanism for roof deck failures in the other homes inspected in Stuart, FL as well.



Figure 24. (a) Contrasting damage to site-built and manufactured homes in the Spanish Lakes community struck by an EF3 tornado (max wind speeds estimated at 134 mph by the NWS in this community). The left home is concrete masonry block site built (constructed in 2009) and suffered roof cover loss and minor soffit and flashing damage. The right home is a manufactured home (constructed in 1982) with major structural roof and wall damage. (b) Damage to a single-width garage door and metal roof suffered by a concrete masonry block home (constructed in 2020). The garage door was located on the primary windward wall relative to the tornado path. The damage appeared to be primarily caused by wind-borne debris.

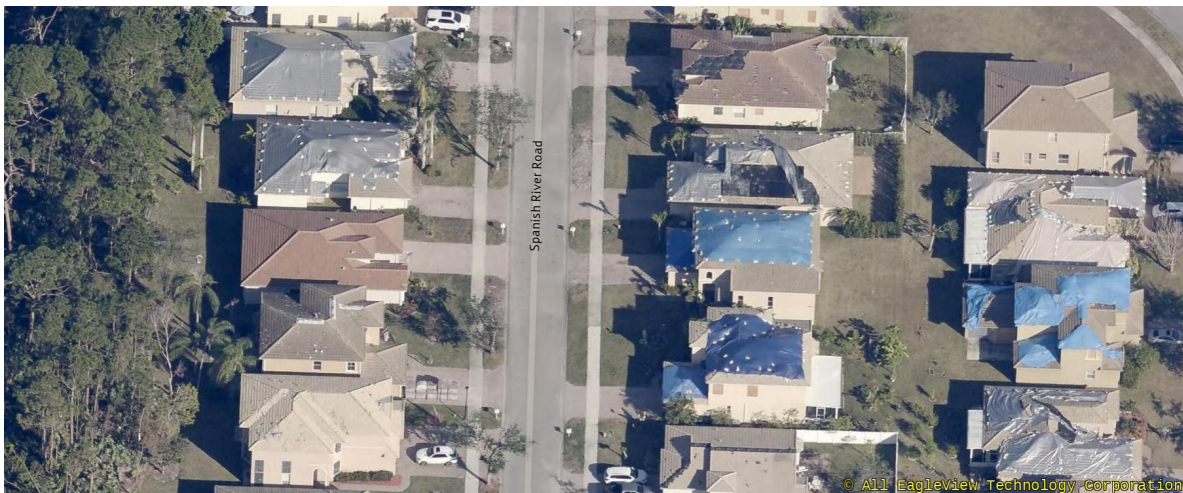


Figure 25. Significant roof cover loss to tile roofs on homes constructed in 2004-2005 in a gated community just south of the Spanish Lakes community. No structural damage was observed based on the available aerial imagery.

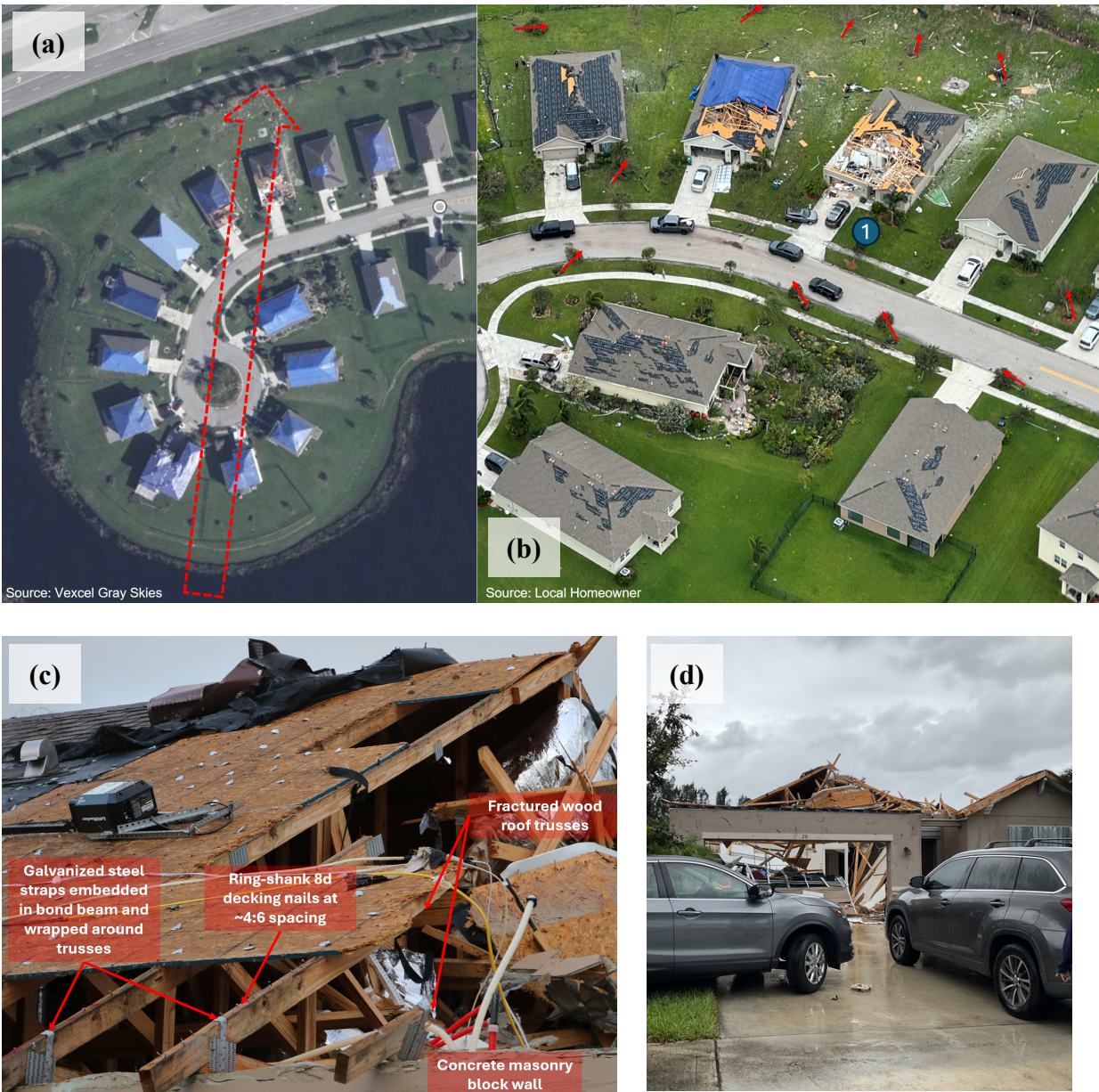


Figure 26. (a) Aerial view of observed damage to a collection of homes constructed in 2019 and later. The red dashed arrow indicates the approximate tornado path. (b) Oblique view of the damage with the red arrows in the right figure indicating approximate wind vectors based on observed tree-fall directions. All homes were constructed of concrete masonry block exterior walls with wood truss roofs and composite asphalt shingles. The two homes with structural roof damage were the only two homes with garage door failures. The garage doors were oriented on the primary windward wall as the tornado translated past. (c) Roof load path and other details for the home indicated by (1) in (a). (d) The garage door blown inward and subsequent roof structure damage (photo shared by the homeowner).

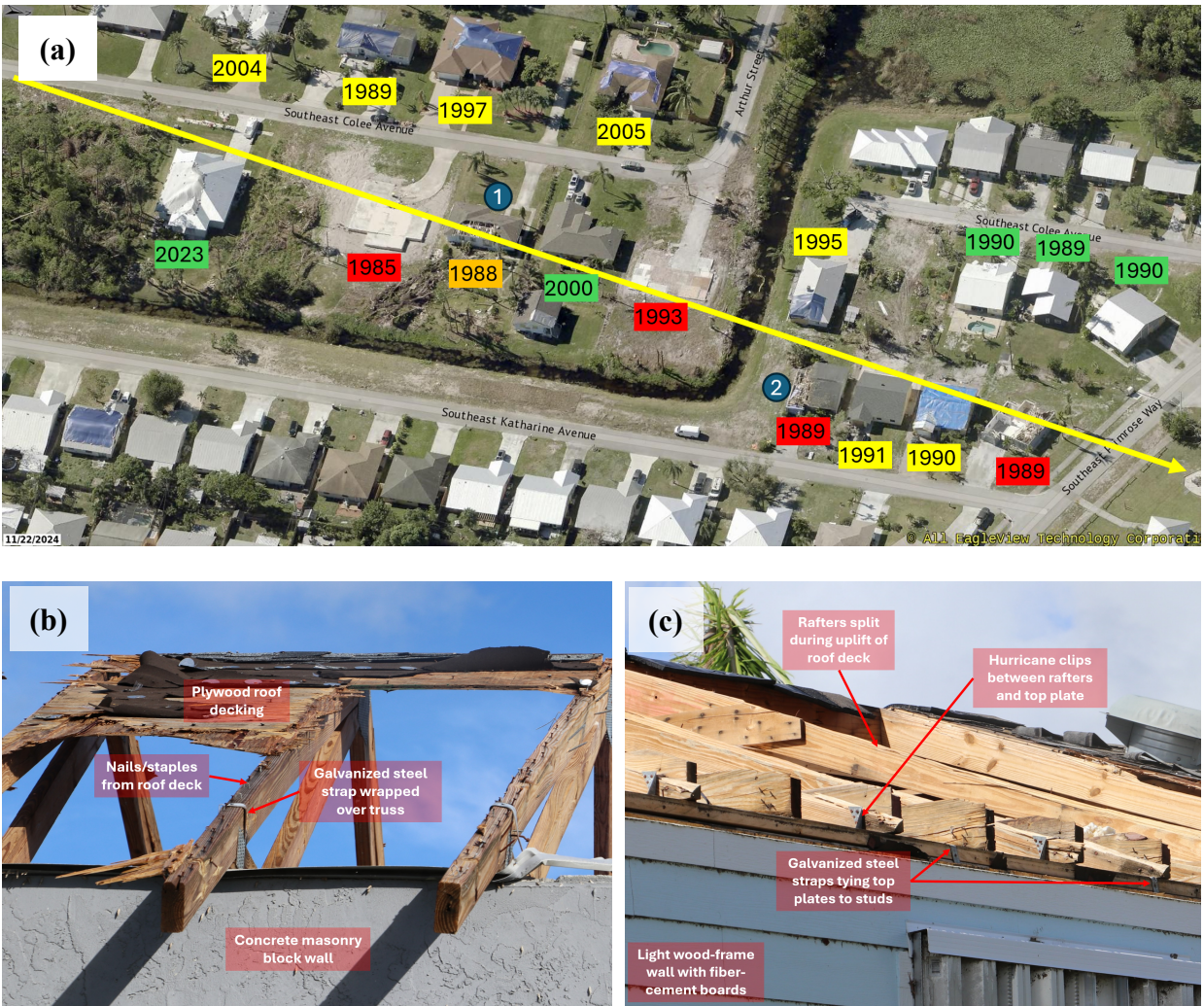


Figure 27. (a) EF2 tornado path through a community in Stuart, FL with damage ratings and year of construction overlaid. The two homes with bare slabs were wood-framed homes that lost their roofs and had most walls collapse. Debris had been cleaned up by the time the photograph was taken. Several post-FBC homes suffered roof cover damage that required re-roofing, but no structural damage was observed. (b) Roof load path details for a typical pre-FBC concrete masonry block home (indicated by (2) in (a)). (c) Roof load path details for a pre-FBC light wood-frame home (indicated by (1) in (a)).

7.3 Relevance of Garage Doors

Garage door requirements are provided in Section 609.4 of the Florida Building Code Residential. Doors are required to withstand 60% of the ASCE 7 wind pressures. Where located in wind-borne debris regions, doors are further considered glazed openings and are therefore required to be impact-rated per Section 609.6 of the FBCR.

As highlighted in Section 7.2, tornado-induced wind loads caused the failure of multiple garage doors in post-FBC structures. The label of one of the doors and corresponding Florida Product Approval summary is shown in Figure 28, indicating it had design pressures of 36 psf. Whether it was impact rated or not was unclear. Another garage door label for a 2007 home in the Spanish

Lakes community is also shown in Figure 28. This garage door was not oriented facing the oncoming tornado and did not fail. The label indicates it was not impact rated.

In the Cobblestone community, the garage door failures propagated to significant roof sheathing and structure damage. In site-built homes within the Spanish Lakes community, the garage door failures did not propagate to further structural damage. Research performed by the Insurance Institute for Business and Home Safety (BMS 2019) and others (Kovar et al. 2018; Roueche and Prevatt 2013) have shown that garage doors can act as damage amplifiers, as failures increase the positive internal pressure, increasing uplift pressure on the roof. The importance of garage doors can be illustrated by evaluating how the uplift pressure on a typical edge sheathing panel in a hip roof changes with wind speed and internal pressure condition (Figure 29). Similar effects could be expected for other roof shapes, pitches, and roof components.

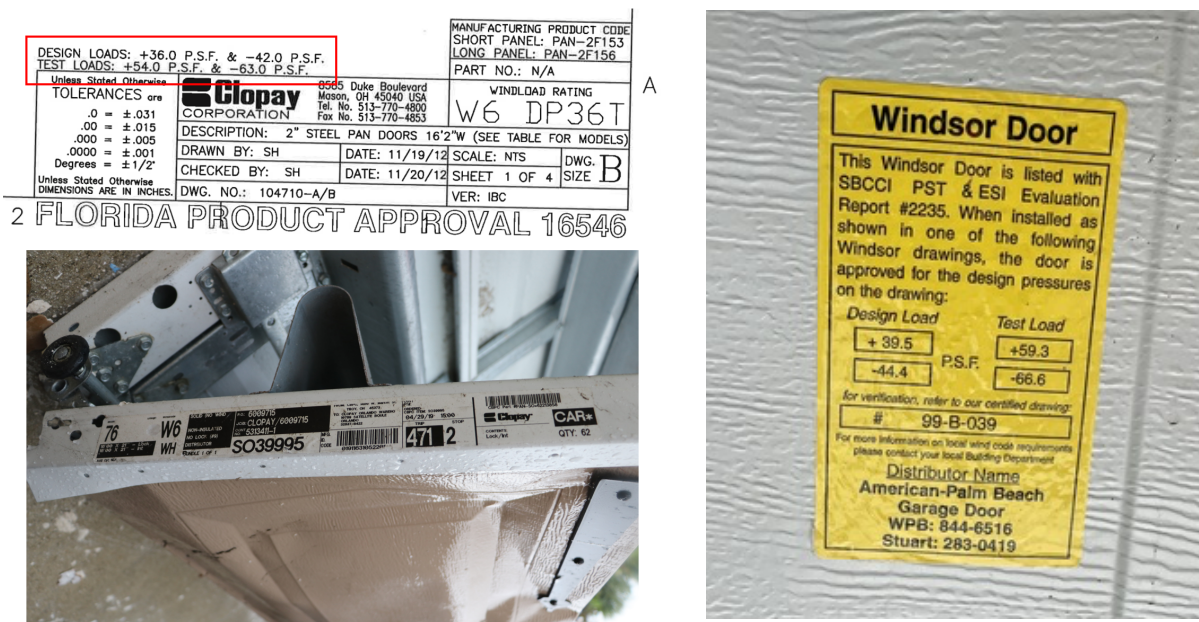


Figure 28. Garage door labels and design pressures observed in the field study. The left figure shows the label and associated Florida Product Approval for a failed garage door in the Cobblestone community. The right figure shows the label for a non-impact rated garage door installed in a 2007 home in the Spanish Lakes community that was not damaged.

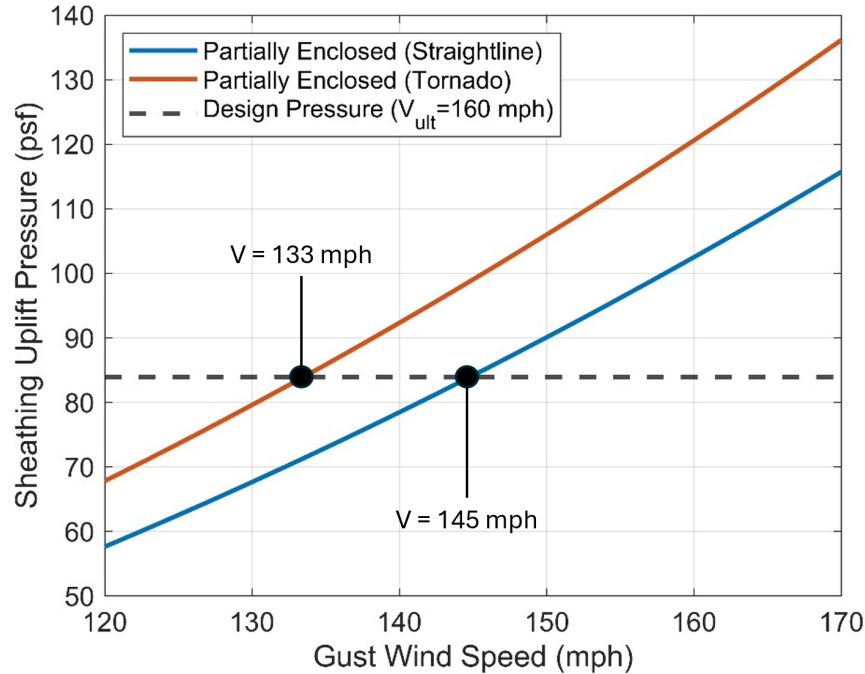


Figure 29. Illustrative sheathing uplift design pressures for various wind speeds, enclosure, and hazard scenarios, assuming a hipped roof in Exposure C with a roof pitch of 4:12. Tornado and straightline wind loads are calculated using the provisions of ASCE 7-22. With the garage door failure and subsequent change in internal pressure, the sheathing uplift pressure associated with the design wind speed of 160 mph is exceeded prematurely – at gust velocities of 133 mph and 145 mph respectively for tornado and straight-line winds.

7.4 Sheathing Fastener Failure Mechanisms

Section 7.2 showed the failure of roof sheathing in post-FBC, or retrofitted construction was predominately due to fastener head pull-through. The roof sheathing wind uplift capacity is a function of the sheathing thickness, roof framing spacing, fastener field and edge spacing, and fastener length and diameter amongst other factors. Roof sheathing fastener requirements have changed over the various editions of the FBC and FBCR, as summarized in Table 7. Given all else being the same (e.g., framing spacing, sheathing thickness, etc), the fastener ultimate withdrawal capacity changes significantly over the fastener types required by the FBCR, with the ring shank nails now required by the code having a 50% greater ultimate withdrawal capacity than the 8d common nails required in the original 2001 FBC (Table 8). However, as the fastener requirements have changed, the ultimate sheathing pull-through capacity, as calculated using the NDS, has decreased, and becomes the dominant expected failure mode as the withdrawal capacity increases. Further, the fastener pull-through is more sensitive to construction defects such as overdriving the nails (often an issue when pneumatic nail guns are used with pressures set too high). With the sheathing fastener overdriven by 1/16-inch, the withdrawal capacity increases slightly (due to the increase in embedment length), but the pull-through capacity is reduced by 15%. This issue is potentially driving premature roof sheathing failures, with fastener pull-through the dominate failure mechanism as observed in the field data (e.g., Figure 32). Further study would be needed to confirm these capacities using laboratory data and to relate the fastener capacities to the resulting sheathing panel capacities relative to design pressures.

Table 7. Roof sheathing fastener requirements of the Florida Building Code: Residential

Code Edition	Roof Sheathing Fastener Requirements for Typical Roof ^[1]
2001	8d common (2.5”L by 0.131”D with 0.3125”D head) at 6/12 spacing
2007	8d RS nails (2”L by 0.113”D with 0.280”D head) at 6/6 spacing ^[2]
2010	8d RS nails (2”L by 0.113”D with 0.280”D head) at 6/6 spacing ^[2]
2014	8d RS nails (2”L by 0.113”D with 0.280”D head) at 6/6 spacing ^[3]
2017	RSRS-01 (2 3/8”L by 0.113”D with 0.281”D head) at 6/6 spacing ^[3]
2020	RSRS-01 (2 3/8”L by 0.113”D with 0.281”D head) at 6/6 spacing (Exposure B) RSRS-01 (2 3/8”L by 0.113”D with 0.281”D head) at 6/6 spacing (Exposure C) RSRS-01 (2 3/8”L by 0.113”D with 0.281”D head) at 4/4 spacing (Exposure D)
[1] Typical roof assumes roof framing is Southern Pine ($SG \geq 0.49$) and ultimate wind speed is between 130 mph and 160 mph.	
[2] Fastener field spacing is allowed to be 12” on center in roof wind zones 1 for any design wind speed and in roof wind zone 2 when the design wind speed is less than 120 mph ($V_{ult}=152$ mph)	
[3] Fastener field spacing is allowed to be 12” on center in roof wind zones 1 for any design wind speed and in roof wind zone 2 when the V_{ult} wind speed is less than 150 mph	
Other Notes: RS = ring shank, [#]/[#] = required edge and field spacing of fasteners, RSRS = roof sheathing ring shank nail meeting ASTM-F1667.	

Table 8. Expected failure modes and capacities for various roof sheathing fastener scenarios.

	8d Common		8d Ring-Shank		RSRS-01	
	w/o Overdrive	w/ Overdrive	w/o Overdrive	w/ Overdrive	w/o Overdrive	w/ Overdrive
Sheathing Thickness (in)	0.44	0.44	0.44	0.44	0.44	0.44
Sheathing Specific Gravity	0.50	0.50	0.50	0.50	0.50	0.50
Framing Specific Gravity	0.50	0.50	0.50	0.50	0.50	0.50
Nail Length (in)	2.5	2.5	2	2	2.375	2.375
Nail Diameter (in)	0.131	0.131	0.113	0.113	0.113	0.113
Nail Head Diameter (in)	0.313	0.313	0.280	0.280	0.281	0.281
Nail Overdrive Length (in)	0.00	0.0625	0.00	0.0625	0.00	0.0625
NDS Withdrawal Factor of Safety	6.00	6.00	6.00	6.00	6.00	6.00
NDS Pull-through Factor of Safety	5.00	5.00	5.00	5.00	5.00	5.00
Ultimate Withdrawal, W (lbf) ^[1]	395	407	477	477	591	591
Ultimate Pull-through, W_H (lbf) ^[2]	370	318	332	285	333	286
Limiting Failure Mode	Pull-through	Pull-through	Pull-through	Pull-through	Pull-through	Pull-through
Withdrawal to Pull-through Ratio	0.94	0.78	0.70	0.60	0.56	0.48

Notes: [1] $W = 1800 G^2 D$, where G = specific gravity and D = nail diameter. [2] $W_H = 690 \pi D_H G^2 t_{ns}$, where D_H = fastener head diameter and t_{ns} = sheathing thickness.

7.5 Wind Performance of Retrofitted Homes

One of the tornadoes surveyed by the authors was an EF2 tornado that struck Stuart, FL in Martin County. The tornado destroyed several homes in Mariner Sands country club and adjacent neighborhoods just north, and the survey team evaluated the performance of 66 homes in this community. Martin County makes all permit data publicly available, which provides an opportunity to gauge the frequency and effectiveness of wind retrofit measures. For homes in the study dataset, permits were reviewed to capture when the permit was pulled and whether it was related to wind mitigation measures. The four classes of permits that were observed were the following: 1) re-roofing, 2) re-nailing the roof decking (associated with a re-roofing permit, though not all re-roofing permits also had a re-nailing permit), 3) installation of a new garage door, and 4) installation of impact resistant doors, windows, or shutters. Figure 30 provides a summary of the frequency of retrofits observed. All the permits related to re-nailing the roof deck occurred in 2015 or later.

Performance of the homes with retrofits was mixed, as illustrated in Figure 31, which shows the overall damage state of buildings assessed in the tornado path. Homes that were retrofitted (including upgrading the garage door, re-nailing the roof deck, or adding impact resistant windows or doors) are marked with an open black rectangle. In site 1 of Figure 31, a home installed shutters in 2006, and installed a new garage door in 2017, but suffered major damage to the roof, including partial loss of roof structure, sheathing, and cover (metal roof). In site 2, a wood-frame home that was not retrofitted suffered almost complete loss of the roof structure, while the two homes adjacent to it did not suffer any evident structural damage. Both surviving structures were partially retrofitted, with one installing a new garage door in 2006, and the other replacing existing windows with impact resistant ones in 2021. All three homes were wood-framed and constructed between 1980 and 1982. In site 3 of Figure 31, multiple homes with retrofits suffered major damage, including a home constructed in 1970 that was retrofitted in 2017 and 2020 to install impact-rated windows, re-nail plywood roof deck, and install a metal roof. During the tornado, the home suffered damage to almost half the roof structure, including extensive loss of roof sheathing panels (Figure 32). Each of these examples are anecdotal, particularly since the damage occurred in a tornado, which can produce sharp wind speed gradients and rapid wind speed and direction changes that make interpreting damage much more complex than that from hurricanes. A broader study of the performance of wind-retrofitted structures under hurricane conditions would be needed to make conclusions about the actualized benefits of wind retrofits.

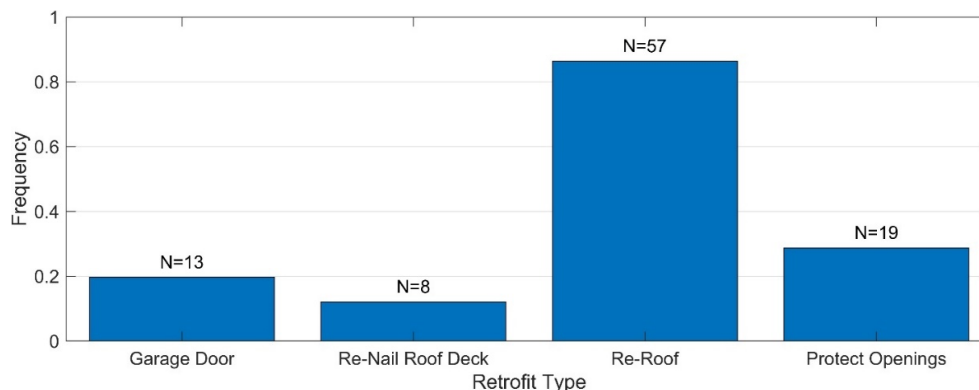


Figure 30. Frequency of wind mitigation retrofits observed in homes in Martin County affected by the EF2 tornado.

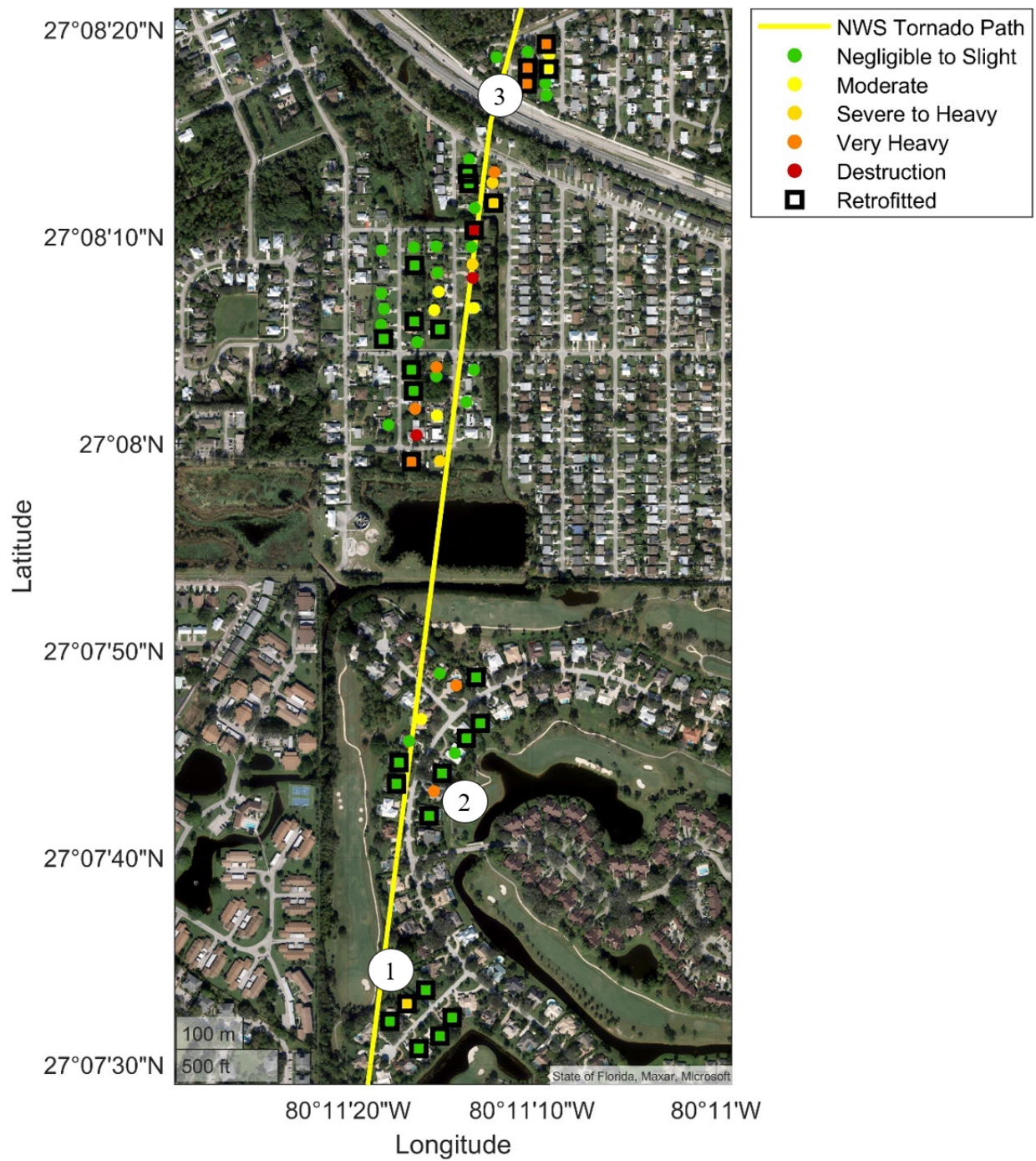


Figure 31. Locations of retrofitted homes (excluding roof cover replacement) with respect to the EF2 tornado in Stuart, FL.



Figure 32. Severe structural roof damage to a wood-frame home constructed in 1977 that was retrofitted in 2017 and 2020 to install impact-rated windows, re-nail plywood roof deck, and install a metal roof. The inset shows a typical roof truss top chord with fasteners all remaining embedded in the truss, with failure of the roof deck due to fastener pull-through.

8 SUMMARY / CONCLUSIONS

Hurricanes Helene and Milton produced significant winds and coastal hazards along the east and west coasts of Florida. Hurricane Helene's impacts in Florida were primarily concentrated in the Big Bend region, where storm surge inundation was estimated as high as 17 ft above ground near Keaton Beach, FL, and peak wind gusts over land were estimated as high as 114 mph, also near Keaton Beach, FL, nearly equaling the ASCE 7-16 basic wind speeds for the same area. Hurricane Milton's direct impacts on the west coast were much less severe than Helene's, but it did produce over 40 tornadoes, including several long-track EF3 tornadoes along the east coast of Florida that caused substantial damage.

In response to the impacts, researchers conducted 358 performance assessments, both on-site and virtual using aerial and ground-level imagery, to assess the performance of residential structures with respect to the Florida Building Code Residential. Performance assessments were conducted using non-biased sampling methods to ensure representative samples were obtained. The following are the primary conclusions that result from this study.

1. Residential structures built to the provisions of the FBCR performed substantially better than those built prior to the FBCR. In coastal regions, 46% of pre-FBC structures were classified as destroyed, indicating they experienced significant structural damage that could compromise life safety. In contrast, none of the post-FBC structures were classified as destroyed. In the tornado-impacted regions, 16% of pre-FBC structures were classified as destroyed, while none of the post-FBC structures were classified as destroyed.
2. Building performance of coastal structures was primarily conditioned on the amount of freeboard (i.e., elevation of the lowest horizontal structural member above maximum water levels). Many of the pre-FBC structures were elevated, but the elevation levels were often below the storm surge hazard levels experienced. Post-FBC homes on average had an

elevation to the Lowest Horizontal Structural Member (LHSM) that was 4 ft higher than that for pre-FBC structures.

3. Despite wind speeds being estimated at near design levels in portions of the Big Bend of Florida, wind damage in this region (where it could be discerned to surviving structures) was almost exclusively limited to isolated instances of roof cover, wall cladding, and soffit loss in the sample of structures that formed this study. However, one instance of a structural failure in a post-FBC multi-family structure was observed. Economic impacts of the building envelope damage and potential water ingress are unknown.
4. Wind damage due to the tornadoes spawned by Hurricane Milton was more severe than expected, even to post-FBC residential structures, given that maximum wind speeds were estimated to be below design wind speeds for the locations. However, the true maximum wind speeds in the tornadoes are not known, as the NWS-provided tornado speeds are estimated by hindcasting them from most severe degrees of damage (DOD) to damage indicators (residential buildings) observed. There is great uncertainty in these estimates.
5. Garage door failures prematurely initiated structural failures in a few post-FBC structures and remain a weak point in the wind resistance of modern FBCR homes.
6. Roof sheathing in several homes impacted by tornadoes experienced premature failures due to the susceptibility of fastener pull-through failures. Recent updates to the FBCR related to sheathing fastener requirements are ineffective due to the propensity for the pull-through failure mode.

Recommended Further Study

Based on the observations and conclusions of this study, the following recommendations for follow-up studies on building performance relevant to the Florida Building Code Residential are made:

1. Follow-up studies should investigate the performance of structures with respect to wind-driven rain, rainwater ingress, and interior damage due to wind-driven rain and storm surge. Such effects are potentially severe even in many of the structures identified in this study as having no or negligible damage. Previous studies have used follow-up interviews with residents, which currently likely remains as the best method for quantifying these effects.
2. Laboratory testing should be conducted to evaluate the sheathing uplift capacity of panels under recent code provisions. Analytical modeling suggests that sheathing panels may be significantly lower than expected and may not be able to resist design pressures due to the propensity for fastener pull-through failures. The rapid load onset occurring in tornadoes may further exacerbate the issue. Laboratory testing using a Pressure Loading Actuator device (i.e. the [High Airflow Pressure Loading Actuator \(HAPLA\)](#) at the University of Florida) should be used to evaluate building components behavior when subjected to time-varying wind pressures that replicate hurricane and tornado pressure time series and evaluate the effects on uplift capacity.
3. Sufficient freeboard ensured good performance of the main living area of the structure, but functionality was often lost due to the loss of the exterior access stairs. A formal study should investigate the post-storm functionality of surviving structures and propose guidelines for ensuring functionality is maintained after design-level and below coastal events. The study could be used to comprehensively model the economic impacts of specific storm surge elevations on one or more of Florida's coastal towns and villages where all LHSM elevations are known, and the value of the properties can be calculated.

Municipal planning decisions benefit from this by enabling realistic comparisons of the benefits of mitigation options to the long-term and sustainable life of the community.

4. Garage door failures prematurely compromised the structural performance of multiple post-FBC homes impacted by tornadoes. Garage door design pressures are allowed to be taken as 60% of the ASCE 7 values, and the debris impact requirements in the FBCR are unclear. Further study should investigate the adequacy of these provisions and the proper selection and installation of garage doors.

9 REFERENCES

- Alam, M., J. Paul, T. Do, K. Wolohan, T. Kijewski-Correa, D. Prevatt, D. Roueche (2025). “StEER: 2024 Hurricane Helene Early Access Reconnaissance Report (EARR),” *StEER - Hurricane Helene* [Version 2]. DesignSafe-CI. <https://doi.org/10.17603/ds2-nqev-2171>
- BMS. 2019. “Evaluating Garage Doors as a Damage Amplifier.” *BMS*. Accessed June 4, 2025. <https://www.bmsgroup.com/news/summary-of-ibhs-disaster-dynamics-academy-evaluating-garage-doors-as-a-damage-amplifier>.
- CERA. 2025. “Coastal Emergency Risks Assessment.”
- Do, T., W. Wang, M. Amini, A. Abdelhady, S. Xu, R. NEGRI, S. Kameshwar, C. Wang, H. Dang, A. Jana, E. Carter, M. Alam, T. Kijewski-Correa, D. Prevatt, D. Roueche, and K. Wolohan. 2025. *StEER: Hurricane Milton Preliminary Virtual Reconnaissance Report (PVRR): in StEER - Hurricane Milton*. Designsafe-CI.
- FLOIR. 2025a. “Hurricane Helene.” *Fla. Off. Insur. Regul.* Accessed April 11, 2025. <http://floir.com/home/hurricane-helene>.
- FLOIR. 2025b. “Hurricane Milton.” *Fla. Off. Insur. Regul.* Accessed April 11, 2025. <http://floir.com/tools-and-data/catastrophe-reporting>.
- Kovar, R. N., T. M. Brown-Giammanco, and F. T. Lombardo. 2018. “Leveraging Remote-Sensing Data to Assess Garage Door Damage and Associated Roof Damage.” *Front. Built Environ.*, 4. Frontiers. <https://doi.org/10.3389/fbuil.2018.00061>.
- Kyprioti, A. K. P., J. Yuzbasi, H. Dang, A. Jana, S. Kameshwar, A. Diekmann, S. Garcia, P. Mohammadi, M. Gutierrez Soto, B. Webb, S. Pilkington, M. Amini, P. Alagusundaramoorthy, D. Kalliontzis, S. Parajuli, P. Pokhrel, S. Ray, T. Tomiczek, S. Xu, C. Wang, A. Gasha, M. Perotin, K. Mostafa, D. Roueche, T. Lin, T. Do, K. Ancona, and K. Wolohan. 2024. *StEER: Hurricane Helene Annotated Media Repository: in StEER - Hurricane Helene*. Austin, TX: Designsafe-CI.
- Roueche, D., and D. O. Prevatt. 2013. “Residential Damage Patterns Following the 2011 Tuscaloosa, AL and Joplin, MO Tornadoes.” *J. Disaster Res.*, 8: 1061.
- Webb, B., D. Prevatt, T. Kijewski-Correa, M. Amini, R. Ramponi, T. Tomiczek, S. Pilkington, H. Pham, K. Mostafa, D. Kalliontzis, S. Kameshwar, H. Dang, A. K. P. Kyprioti, J. Capa Salinas, S. Xu, T. Do, M. Gutierrez Soto, A. Diekmann, A. Jana, T. Lin, T. Lahna, S. Ray, M. Alam, D. Roueche, and K. Wolohan. 2024. *StEER: Hurricane Helene Preliminary Virtual Reconnaissance Report (PVRR): in StEER - Hurricane Helene*. Designsafe-CI.

APPENDIX A. FCMP TOWER DEPLOYMENTS BEFORE HURRICANES HELENE AND MILTON (2024)

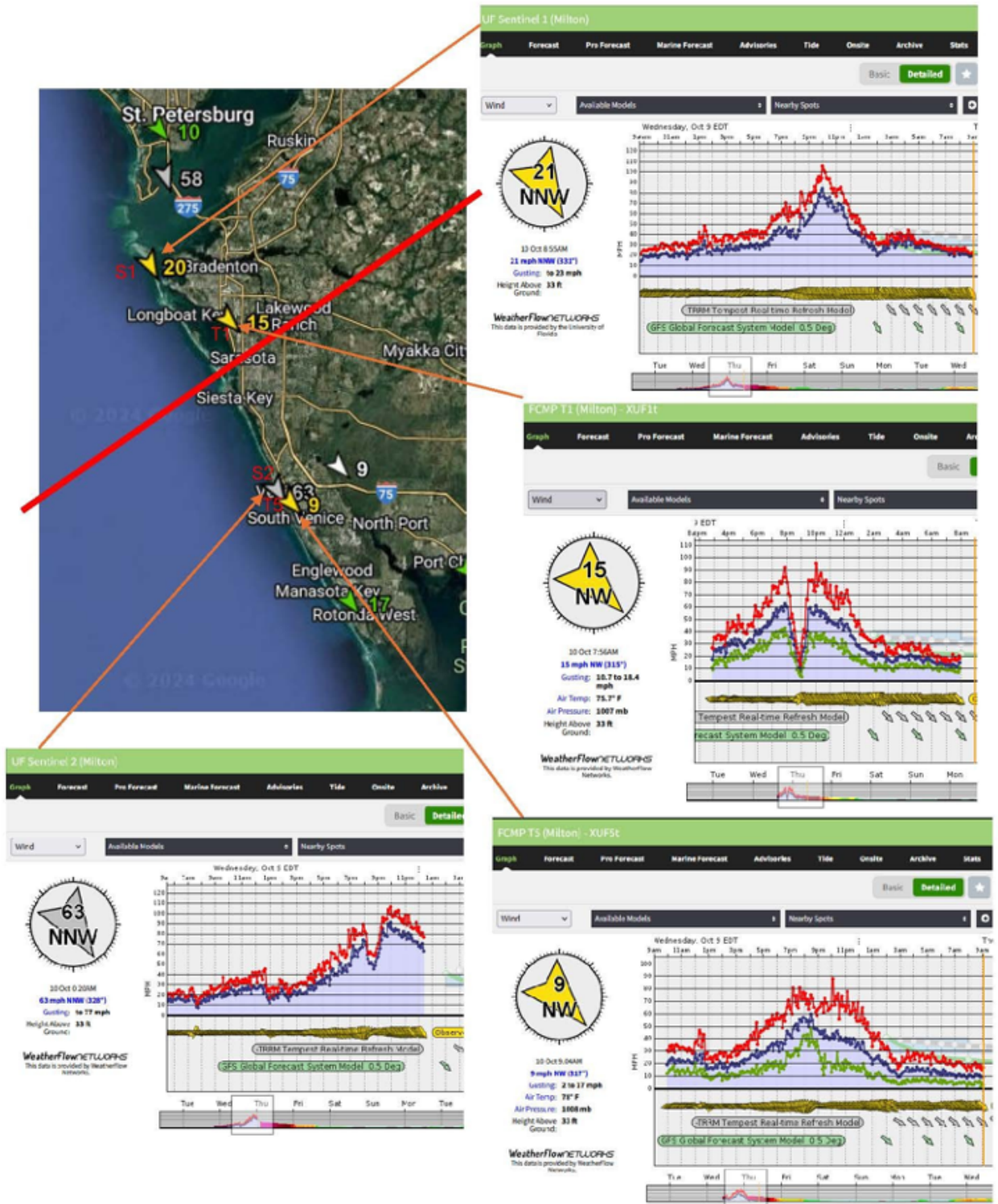
University of Florida meteorological assets collected wind speed data at four locations. The Stations designated by “T” are traditional structural steel meteorological towers, and the station designated by an “S” is the Sentinel station deployed within a sandy beach location.

Courtesy: Prof. Brian A. Phillips, University of Florida.

Hurricane Helene Deployed Assets

Station	Type	Latitude	Longitude	Height (ft)	Max 3-sec Gust (mph)	Max 1-min Avg (mph)
T1	FCMP	30.0407	-83.7182	33	76.03	51.52
T5	FCMP	30.1912	-84.2126	33	50.78	39.39
T6	FCMP	29.7576	-83.493	16.5	89.88	65.14
S2	Sentinel	29.137	-83.0295	33	85.03	70.78

Hurricane Milton Deployed Assets



APPENDIX B. CONFIRMED TORNADOES SPAWNED BY HURRICANE MILTON (NWS)

No.	Event Name	Date	Time	Rating	Max Wind (mph)	Length (miles)	Width (yards)	Injuries	Fatalities	County
1	KEY-MILTON1	8-Oct	22:10	EF1	95	0.3	50	0	0	Monroe, FL
2	FLCity	9-Oct	3:10	EF1	90	2.9	100	0	0	Miami-Dade, FL
3	SR41	9-Oct	7:10	EF0	80	9	0	0	0	Miami-Dade, FL
4	Miccosukee	9-Oct	8:10	EFU	0	13.5	0	0	0	Collier, FL
5	I75East	9-Oct	9:10	EFU	0	4.7	0	0	0	Broward, FL
6	Clewiston	9-Oct	9:10	EF1	95	17	0	0	0	Hendry, FL
7	Ortona	9-Oct	10:10	EF1	110	29.9	0	0	0	Hendry, FL
8	BelleGlade	9-Oct	10:10	EF0	74	15.4	0	0	0	Palm Beach, FL
9	LakeportWest	9-Oct	10:10	EF1	110	6.2	0	0	0	Glades, FL
10	Jonathan Harbour Tornado	9-Oct	10:10	EF0	80	0.2	33	0	0	Lee, FL
11	Matlacha Tornado	9-Oct	10:10	EF1	105	0.9	100	0	0	Lee, FL
12	Fort Myers Tornado	9-Oct	11:10	EF2	132	16.6	500	0	0	Lee, FL
13	Wild Island - Lorida Tornado	9-Oct	11:10	EF1	105	6.8	500	0	0	Highlands, FL
14	El Jobean Tornado	9-Oct	11:10	EF1	94	2.6	450	0	0	Charlotte, FL
15	Babcock Area Tornado	9-Oct	11:10	EF0	85	0.5	25	0	0	Charlotte, FL
16	Dixie Acres	9-Oct	13:10	EF2	115	8.5	250	2	0	Okeechobee, FL
17	Port St. Lucie West	9-Oct	13:10	EF0	0	18.1	0	0	0	Martin, FL
18	Pine Creek	9-Oct	13:10	EF1	110	17.1	300	0	0	Okeechobee, FL
19	Lake Placid Tornado	9-Oct	13:10	EF2	130	2.9	300	1	0	Highlands, FL
20	CR833N	9-Oct	13:10	EF0	60	1.3	0	0	0	Hendry, FL
21	TripsMid	9-Oct	13:10	EF1	102	1.3	0	0	0	Hendry, FL
22	CR833S	9-Oct	13:10	EF1	107	1.7	0	0	0	Hendry, FL
23	LakeportEast	9-Oct	13:10	EF3	140	15.2	250	3	0	Glades, FL
24	Rucks Dairy	9-Oct	13:10	EF2	115	2.6	100	0	0	Okeechobee, FL
25	Venus Tornado	9-Oct	13:10	EF1	105	0.6	100	0	0	Highlands, FL
26	Archbold Tornado	9-Oct	13:10	EF1	105	0.5	0	0	0	Highlands, FL

27	Avon Park Tornado	9-Oct	13:10	EF0	85	0.6	75	0	0	Highlands, FL
28	Fort Drum	9-Oct	13:10	EF1	90	7.9	100	0	0	Okeechobee, FL
29	SR80W	9-Oct	13:10	EFU	0	16.3	0	0	0	Palm Beach, FL
30	Bereah Tornado	9-Oct	13:10	EF1	104	1	40	0	0	Hardee, FL
31	Blue Cypress	9-Oct	13:10	EFU	-99	9.9	0	0	0	Indian River, FL
32	Port St. Lucie Central	9-Oct	13:10	EF1	90	11.7	200	0	0	Saint Lucie, FL
33	St. Lucie Indrio	9-Oct	14:10	EF1	90	8.5	100	0	0	Saint Lucie, FL
34	Escape Ranch	9-Oct	14:10	EF1	95	8.1	150	0	0	Indian River, FL
35	S Holopaw	9-Oct	14:10	EF1	100	21.1	100	0	0	Osceola, FL
36	Vero Beach #1	9-Oct	14:10	EF1	95	4.1	0	0	0	Indian River, FL
37	Stuart #1	9-Oct	15:10	EF1	105	2.7	250	1	0	Martin, FL
38	Vero Beach #2	9-Oct	15:10	EF1	100	3.4	100	0	0	Indian River, FL
39	Fort Pierce	9-Oct	15:10	EF1	95	6.9	150	0	0	Saint Lucie, FL
40	SR80E	9-Oct	15:10	EFU	0	19.6	0	0	0	Palm Beach, FL
41	PalmBeachGardens	9-Oct	15:10	EF3	140	29.1	457	7	0	Palm Beach, FL
42	Spanish Lakes	9-Oct	15:10	EF3	155	21.2	500	Unk	6	Saint Lucie, FL
43	Palm City and Port St. Lucie	9-Oct	16:10	EF2	125	31.6	-99	0	0	Martin, FL
44	South Martin	9-Oct	16:10	EF0	80	3.9	150	0	0	Martin, FL
45	Stuart #2	9-Oct	16:10	EF2	120	5.7	400	1	0	Martin, FL
46	Cocoa Beach	9-Oct	16:10	EF1	95	5.2	250	0	0	Brevard, FL

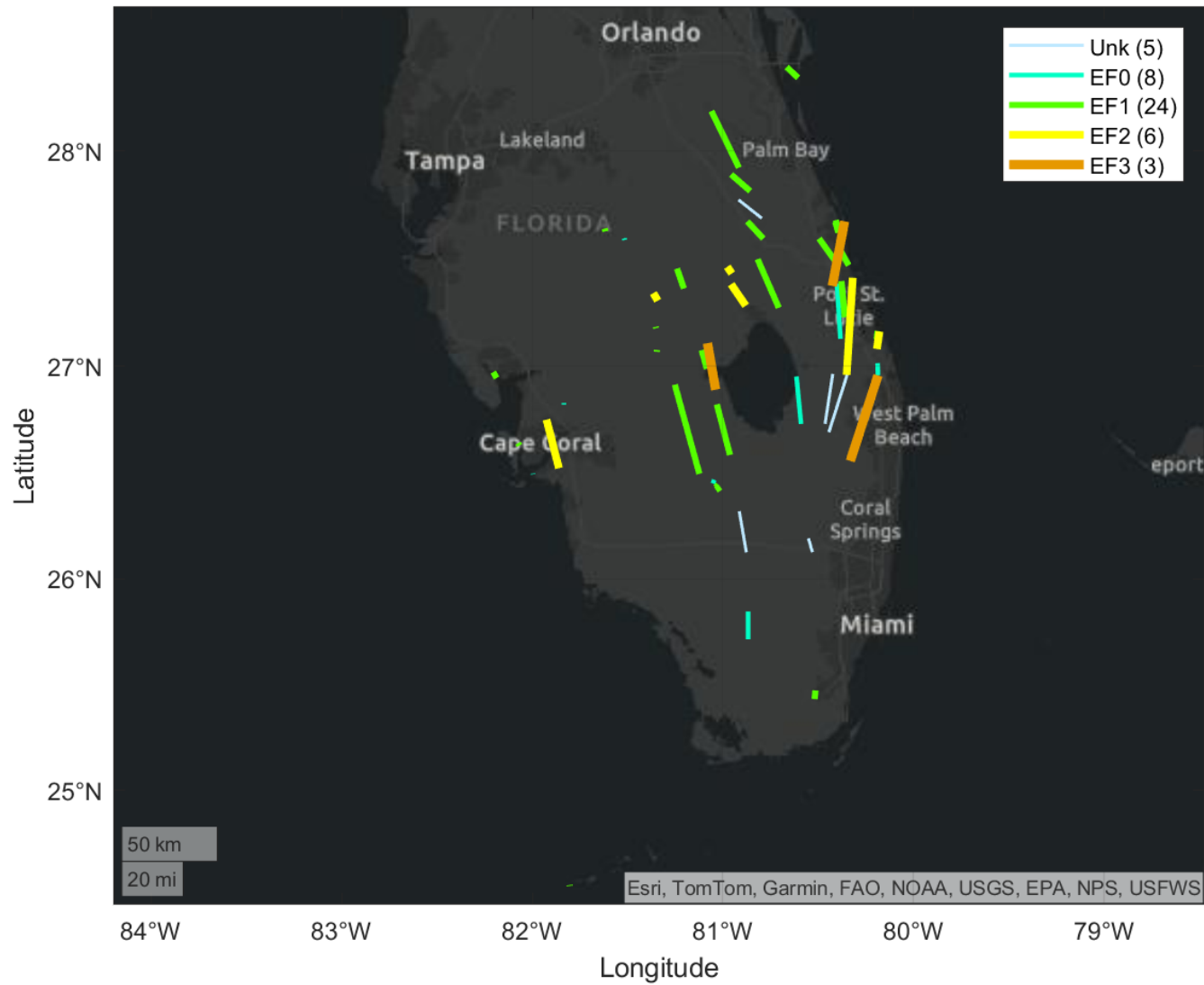


Figure B1. Confirmed tornado tracks spawned by Hurricane Milton. A total of 46 tornadoes were confirmed by the National Weather Service.

APPENDIX C. ATTRIBUTES COLLECTED DURING DATA ENRICHMENT EFFORT.

The following provides a list and brief description of the building attributes and features being collected as part of the data enrichment effort of Task 5.1.

Features	Descriptions
ID	Unique identifier for each building
Latitude	GPS Latitude
Longitude	GPS Longitude
Occupancy	Occupancy class of building
Address Sub Thoroughfare	Street number
Address Thoroughfare	Street name
Address Locality	City
Address Sub Admin Area	County
Address Admin Area	State
Address Postal Code	Zip Code
Year Built	Original year of construction
Number of Stories	Number of stories above ground
Elevation to LHSM	Elevation to lowest horizontal structural member in feet (Coastal Structures only)
Base Flood Elevation	Base flood elevation as determined by the current FEMA FIRM
Wall Cladding	Wall cladding type(s)
Roof Cover	Roof cover type
Roof Shape	Shape of roof
Mean Roof Height	Average height of roof
Building Length	Maximum horizontal footprint dimension
Building Width	Minimum horizontal footprint dimension
Foundation Type	Type of foundation system
Breakaway Wall Performance	Whether breakaway walls are present and if so, whether they failed or not
Building Collapsed, Partially Collapsed, or Shifted Off Foundation	Whether building is partially or fully collapsed or has been displaced from its original foundation by wind or surge
Garage Door Performance	Whether garage door is present, and performance if so
Roof Structure Damage	Percentage of roof structure damaged or missing
Roof Substrate Damage	Percentage of roof decking damaged or missing
Roof Cover Damage	Percentage of roof cover damaged or missing
Wall Structure Damage	Percentage of wall structure damaged or missing
Wall Substrate Damage	Percentage of wall sheathing damaged or missing
Wall Cladding Damage	Percentage of wall cover damaged or missing
Soffit Damage	Whether soffit damage is observed
Fascia Damage	Whether fascia damage is observed
Overall Performance Rating	Overall performance rating on a 0 to 5 scale
Permit 1 Number	Permit number for wind mitigation related permit

Permit 1 Type	Type of wind or surge mitigation related permit
Permit 1 Year	Year permit was closed
Permit 2 Number	Permit number for second wind or surge mitigation related permit
Permit 2 Type	Type of wind or surge mitigation related permit
Permit 2 Year	Year permit was closed
Peak Gust Wind Speed	Peak estimated 3-second gust wind speed in mph from the ARA wind maps
Peak Sustained Wind Speed	Peak estimated 1-minute sustained wind speed in mph from the ARA wind maps
Storm Surge Inundation	Peak storm surge inundation in ft relative to NAVD88 from high water marks