HURRICANE IDALIA
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PRELIMINARY VIRTUAL RECONNAISSANCE REPORT (PVRR)

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PREFACE

The National Science Foundation (NSF) awarded an EAGER grant (CMMI 1841667) to a consortium of universities to form the Structural Extreme Events Reconnaissance (StEER) Network (see https://www.steer.network for more details). StEER was renewed through a second award (CMMI 2103550) to further enhance its operational model and develop new capabilities for more efficient and impactful post-event reconnaissance. StEER builds societal resilience by generating new knowledge on the performance of the built environment through impactful post-disaster reconnaissance disseminated to affected communities. StEER achieves this vision by: (1) deepening structural engineers' capacity for post-event reconnaissance by promoting community-driven standards, best practices, and training, as well as their understanding of the effect of natural hazards on society; (2) coordination leveraging its distributed network of members and partners for early, efficient and impactful responses to disasters; and (3) collaboration that broadly engages communities of research, practice and policy to accelerate learning from disasters.

Under the banner of the Natural Hazards Engineering Research Infrastructure (NHERI) CONVERGE node, StEER works closely with the wider Extreme Events Reconnaissance consortium to promote interdisciplinary disaster reconnaissance and research. The consortium includes the Geotechnical Extreme Events Reconnaissance (GEER) Association and the networks for Interdisciplinary Science and Engineering Extreme Events Research (ISEEER), Nearshore Extreme Event Reconnaissance (NEER), Operations and Systems Engineering Extreme Events Research (OSEEER), Social Science Extreme Events Research (SSEER), Sustainable Material Management Extreme Events Reconnaissance (SUMMEER), and Public Health Extreme Events Research (PHEER), as well as the NHERI RAPID equipment facility, the NHERI Network Coordination Office (NCO), and NHERI DesignSafe CI, curation site for all StEER products

While the StEER network currently consists of the three primary nodes located at the University of Notre Dame (Coordinating Node), University of Florida (Southeast Regional Node), and University of California, Berkeley (Pacific Regional Node), StEER is currently expanding its network of regional nodes worldwide to enable swift and high quality responses to major disasters globally.

StEER's founding organizational structure includes a governance layer comprised of core leadership with Associate Directors for each of the primary hazards as well as cross-cutting areas of Assessment Technologies and Data Standards, led by the following individuals:

- Tracy Kijewski-Correa (PI), University of Notre Dame, serves as StEER Director responsible for overseeing the design and operationalization of the network and representing StEER in the NHERI Converge Leadership Corps.
- Khalid Mosalam (co-PI), University of California, Berkeley, serves as StEER Associate Director for Seismic Hazards, serving as primary liaison to the Earthquake Engineering community.
- David O. Prevatt (co-PI), University of Florida, serves as StEER Associate Director for Wind Hazards, serving as primary liaison to the Wind Engineering community.
- Ian Robertson (co-PI), University of Hawai'i at Manoa, serves as StEER Associate Director for Coastal Hazards, serving as a primary liaison to the coastal engineering community and ensuring a robust capacity for multi-hazard assessments.
- David Roueche (co-PI), Auburn University, serves as StEER Associate Director for Data Standards, ensuring StEER processes deliver reliable and standardized reconnaissance data suitable for re-use by the community.

This core leadership team works closely with StEER Research Associates, Data Librarians and its Student Administrator in event responses, in consultation with its Advisory Boards for Coastal, Seismic and Wind Hazards.

ATTRIBUTION GUIDANCE

Reference to PVRR Analyses, Discussions or Recommendations

Reference to the analyses, discussions or recommendations within this report should be cited using the full citation information and DOI from DesignSafe (these are available at https://www.steer.network/responses).

Citing Images from this PVRR

Images in this report are taken from public sources. Each figure caption specifies the source; re-use of the image should cite that source directly. Note that public sources might still have copyright issues and depending on the use case, the user may need to secure additional permissions/rights from the original copyright owner.

ACKNOWLEDGMENTS

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We also acknowledge VAST member Huy Pham, Virginia Tech, who joined the authors listed on this report in building the corresponding Media Repository, published under a separate DOI. This photographic evidence and analysis was vital to the production of this report.

StEER is grateful to Site Tour 360 and our colleagues Mike Vorce and Dylan Faraone for their generous collaboration and access to the street-level panoramic imagery.

Special thanks also go to our Student Administrator, Ella Gerczak, and to Program Manager Gabor Holtzer for coordinating the writing effort. We also gratefully recognize the input of University of Florida Civil Engineering students, Giorgio Carmagnani, Jonathon Micali and Sean A. Robinson who participated in building performance assessments.

The sharing of videos, damage reports and briefings via Slack by the entire NHERI community was tremendously helpful and much appreciated. StEER recognizes the efforts of the DesignSafe CI team who continuously supported and responded to StEER's emerging needs.

To access StEER products (briefings, reports and datasets) please visit the StEER website: https://www.steer.network/responses

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Common Terms & Acronyms

Acronym	General Terms	Brief Description
--	DesignSafe	Data Repository
--	DesignSafe-CI	Academic Organization within NHERI
ASCE	American Society of Civil Engineers	Professional Organization
ASTM	American Society for Testing and Materials (now ASTM International)	Standards Body
ATC	Applied Technology Council	Professional Organization
BOCA	Building Officials and Code Administrators	Code Body
CC-BY	Creative Commons Attribution License	Code/Standard
CESMD	Center for Engineering Strong Motion Data	Governmental Agency
CI	Cyberinfrastructure	Research Asset
CLPE	Critical Load Path Elements	StEER Term
CMU	Concrete Masonry Unit	Building Material
DBE	Design Basis Earthquake	Design Terminology
DEQC	Data Enrichment and Quality Control	StEER Term
DOI	Digital Object Identifier	Common Term
EARR	Early Access Reconnaissance Report	StEER Term
EERI	Earthquake Engineering Research Institute	Professional Organization
EEFIT	Earthquake Engineering Field Investigation Team	Professional Organization
EF	Enhanced Fujita Scale	Hazard Intensity Scale
EF	Equipment Facility	Academic Organization within NHERI
EIFS	Exterior Insulation Finish System	Building Component
FAA	Federal Aviation Administration	Governmental Agency
FAQ	Frequently Asked Questions	Common Term
FAST	Field Assessment Structural Team	StEER Term
FEMA	Federal Emergency Management Agency	Governmental Agency
FIRM	Flood Insurance Rate Maps	Regulatory Product
GEER	Geotechnical Extreme Events Reconnaissance	Academic Organization within NHERI
GPS	Global Positioning System	Measurement Technology
GSA	Government Services Administration	Governmental Agency

HVAC	Heating, ventilation and air conditioning	Building System
HWM	High Water Mark	Intensity Measure
IBC	International Building Code	Code/Standard
ICC	International Code Council	Code Body
IRC	International Residential Code	Code/Standard
ISEEER	Interdisciplinary Science and Engineering Extreme Events Research	Academic Organization within NHERI
LiDAR	Light Detection and Ranging	Measurement Technology
MCE	Maximum Considered Earthquake	Design Terminology
ME&P	Mechanical, electrical and plumbing	Building System
MMI	Modified Mercalli Intensity	Hazard Intensity Scale
NBC	National Building Code	Code/Standard
NEER	Nearshore Extreme Event Reconnaissance	Academic Organization within NHERI
NFIP	National Flood Insurance Program	Government Program
NHERI	Natural Hazards Engineering Research Infrastructure	Academic Organization within NHERI
NIST	National Institute of Standards and Technology	Governmental Agency
NOAA	National Oceanic and Atmospheric Administration	Governmental Agency
NSF	National Science Foundation	Governmental Agency
NWS	National Weather Service	Governmental Agency
OSB	Oriented strand board	Construction Material
OSEEER	Operations and Systems Engineering Extreme Events Research	Academic Organization within NHERI
PEER	Pacific Earthquake Engineering Research center	Academic Organization (Earthquakes)
PGA	Peak Ground Acceleration	Intensity Measure
PHEER	Public Health Extreme Events Research	Academic Organization within NHERI
PVRR	Preliminary Virtual Reconnaissance Report	StEER Term
QC	Quality Control	Oversight process
RAPID	RAPID Grant	Funding Mechanism
RAPID-EF	RAPID Experimental Facility	Academic Organization within NHERI
RC	Reinforced Concrete	Building Material

EXECUTIVE SUMMARY

Hurricane Idalia made landfall along the coast of the Florida Big Bend as a Category 3 hurricane on August 30, 2023, near Keaton Beach, FL. Marked by one of the fastest rates of tropical cyclone intensification observed in the Atlantic basin, the hurricane made landfall with maximum sustained wind speeds near 125 mph. The associated wind field had a relatively small radius of 12 miles, which was approximately half of the radius associated with 2022's Hurricane Ian. The hurricane caused powerful winds and storm surge, with recorded water levels of approximately 8-9 ft above mean sea level in coastal communities such as Cedar Key and Keaton Beach, FL. The storm brought heavy rainfall across Florida, and portions of Georgia and South Carolina.

The hurricane impacted a sparsely populated region along the Florida Big Bend, and observations of building and infrastructure damage were generally limited. Wind-induced non-structural damage was observed in residential and commercial buildings and schools in communities across Taylor County, FL, with some evidence of wind-induced structural damage. Storm surge-induced damage was observed in older structures that lacked sufficient elevation above the ground, and there was some evidence of displacement of manufactured homes by storm surge. In addition to the temporary closure of some bridges and roadways due to the associated flooding, the storm surge also caused damage to some roadway and bridge infrastructure due to weakening of the supporting soils. Power outages caused by the storm affected approximately half a million customers in Florida, Georgia and the Carolinas.

As the storm primarily affected a lightly inhabited region, the damage patterns observed in the aftermath of Hurricane Idalia may have limited potential to generate new knowledge for natural hazards engineering. However, the event may still offer important lessons regarding: (1) human perceptions of risk and voluntary mitigation investments by individuals and communities to address vulnerable properties with little to no freeboard, (2) code-exempted agricultural buildings, and (3) older manufactured and mobile homes in highly exposed areas.

This **Preliminary Virtual Reconnaissance Report (PVRR)** explores these topics as the primary product of StEER's Level 1 response to hurricane Idalia, intended to:

1. provide an overview of the hurricane, particularly relating to the wind and storm surge hazards and their impacts on the built environment,
2. overview the regulatory environment and construction practices in the affected area,
3. synthesize preliminary reports of damage to buildings and other infrastructure,
4. provide recommendations for continued study of this event by StEER and the wider engineering reconnaissance community.

1. Introduction

Hurricane Idalia made landfall near Keaton Beach, FL as a Category 3 hurricane on August 30, 2023. The hurricane impacted a sparsely populated region resulting in a significantly reduced quantity of buildings damaged as compared to 2022's Hurricane Ian. However, near-coast communities such as Perry and Cedar Key experienced significant damage from storm surge and wind. The hurricane weakened considerably by the time it crossed the state line near Valdosta, Georgia, tracking through Georgia and South Carolina before emerging into the Atlantic Ocean.

This hurricane was marked by one of the fastest rates of tropical cyclone intensifications observed in the Atlantic basin, with a wind speed increase of 55 mph during a 24-hour period prior to landfall. The hurricane intensified briefly to a Category 4 storm, before weakening to Category 3 at landfall. The storm's intensity was unprecedented for the Tallahassee region in the modern era (Burlew, 2023).

Verisk, an insurance rating bureau, issued their estimate of insured losses for Hurricane Idalia at \$2.5-\$4.0 billion, with the majority attributable to wind damage (Verisk, 2023). The hurricane also had significant impacts on road infrastructure and other lifelines. As the hurricane made landfall, several bridges and roadways were closed due to flooding around the Tampa Bay area (Marrero & Prator, 2023). Wind-downed power lines led to closure of a portion of Interstate 75 and loss of power to 278,000-500,000 customers in Florida and Georgia (Spencer, 2023; https://poweroutage.us).

1.1. Loss of Life and Injuries

As of September 11, 2023, the death toll associated with Hurricane Idalia in Florida and Georgia was five people, four of whom died due to storm-related traffic incidents and fallen trees (AP, 2023; Turbeville, 2023). The Pasco County Emergency Management director estimated that 150 people required rescuing during the storm (Axelbank, 2023). Rip currents produced by the storm across the Eastern US resulted in at least a dozen rescues and four additional deaths (Titlow, 2023; Calderon, 2023).

1.2. Official Response

The National Hurricane Center (NHC) issued tropical storm, storm surge and hurricane watches for parts of Florida on August 28 (2:00 AM EDT). By August 29 (2:00 AM EDT), a tropical storm warning was in effect for parts of Florida and Georgia. When the hurricane intensified to Category 4 on August 30 (at 6:00 am EDT), the NHC advisory update warned of catastrophic storm surge and destructive winds in the Big Bend region of Florida. An updated advisory at 7:45 am EDT described the storm as an extremely dangerous Category 3 hurricane as it made landfall in the Florida Big Bend. A later advisory at 10:00 am EDT warned of damaging winds spreading into southern Georgia, with subsequent advisories warning of heavy rain and flooding across southern Georgia and portions of the Carolinas. The September 1 advisory forecast Hurricane Idalia to slow down and affect Bermuda the following day. On September 2, the NHC advisory warned of dangerous rip currents from Hurricane Idalia along the US East coast.

Evacuation orders were issued for at least 30 counties in Florida (Yoon, 2023). At the state level, Governor Ron DeSantis declared a state of emergency in 33 of Florida's counties prior to landfall (State of Florida, 2023; Rodriguez, 2023). As of September 8, the State of Florida and the Federal Emergency Management Agency (FEMA) had opened six temporary Disaster Recovery Centers across six counties in Florida (Levy, Suwannee, Dixie, Hamilton, Lafayette and Madison) to provide help to those affected by the hurricane (FEMA, 2023).

1.3. Report Scope

This **Preliminary Virtual Reconnaissance Report (PVRR)** is the primary product of StEER's Level 1 response to Hurricane Idalia, intended to:

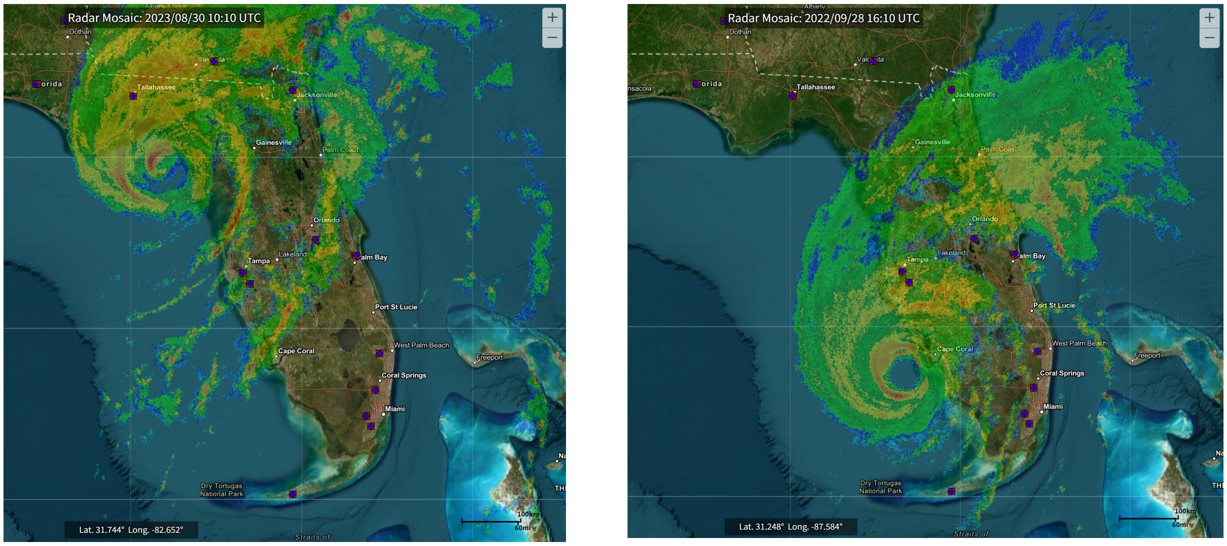
1. provide an overview of the hurricane, particularly relating to the wind and storm surge hazards and their impacts on the built environment,
2. overview the regulatory environment and construction practices in the affected area,
3. synthesize preliminary reports of damage to buildings and other infrastructure,
4. provide recommendations for continued study of this event by StEER and the wider engineering reconnaissance community.

2. Hazard Characteristics

2.1. Wind Field

Hurricane Idalia made landfall with maximum sustained winds near 125 mph according to the NHC (Public Advisory #15: Update 7:45 AM). This estimate was based on data from an Air Force Reserve Hurricane Hunter aircraft and nominally corresponds to the maximum 1-minute averaged wind speed at 10 m over open water. The wind field of Hurricane Idalia was relatively small, with an approximately 12 m radius of maximum winds and the radius of hurricane force winds extending outward up to 25 miles. In contrast, Hurricane Ian (2022) had a radius of maximum winds of nearly 25 miles at handfall, with hurricane force winds extending outward up to 45 miles from the center. Figure 2.1 shows the respective sizes of these two Florida storms based on composite reflectivity from nearby National Weather Service (NWS) radars.

Figure 2.1(a) illustrates that the majority of the convection associated with Hurricane Idalia was asymmetrically located to the west of the storm center, even in the eyewall. Previous studies have suggested that surface winds are strongest underneath regions of deep convection that aid in mixing strong gusts down to the surface (e.g., Henning, 2006). The NIST/ARA wind field (Fig. 2.2), which is based on a parametric wind field model of cyclostrophic winds, shows strongest gusts to the right of the track where the translational and rotational velocity vectors align. Near-surface wind observations of Hurricane Idalia were limited, particularly near the eyewall, due to its landfall in a relatively sparsely populated region in Florida. The Florida Coastal Monitoring Program (FCMP) deployed four towers in total, two in Alachua County and two in Taylor County near the landfall site. Figure 2.3 summarizes surface wind observations (wind speed and direction) for notable stations in the landfall region that recorded continuously during the storm's progression. Available metadata on the wind measurements (GPS, map of locations, view of terrain exposures, gust averaging time, height) are included in Appendix A. The peak surface gust wind speeds observed were just above 80 mph and were measured by four different stations within the eyewall on the right side of the track, including one (FAWN Mayo) that was nearly 30 miles inland.



(a)

(b)

Figure 2.1. Composite reflectivity images of (a) Hurricane Idalia and (b) Hurricane Ian near their respective landfalls.

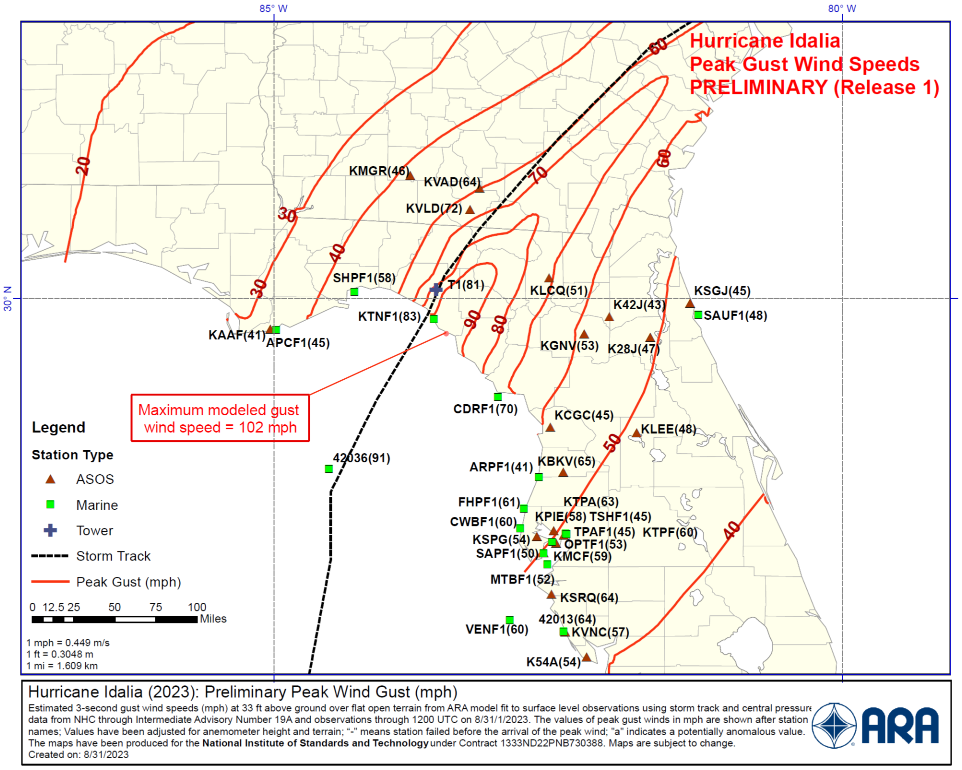


Figure 2.2. Peak gust wind speeds produced by Hurricane Idalia as estimated by Applied Research Associates (ARA).

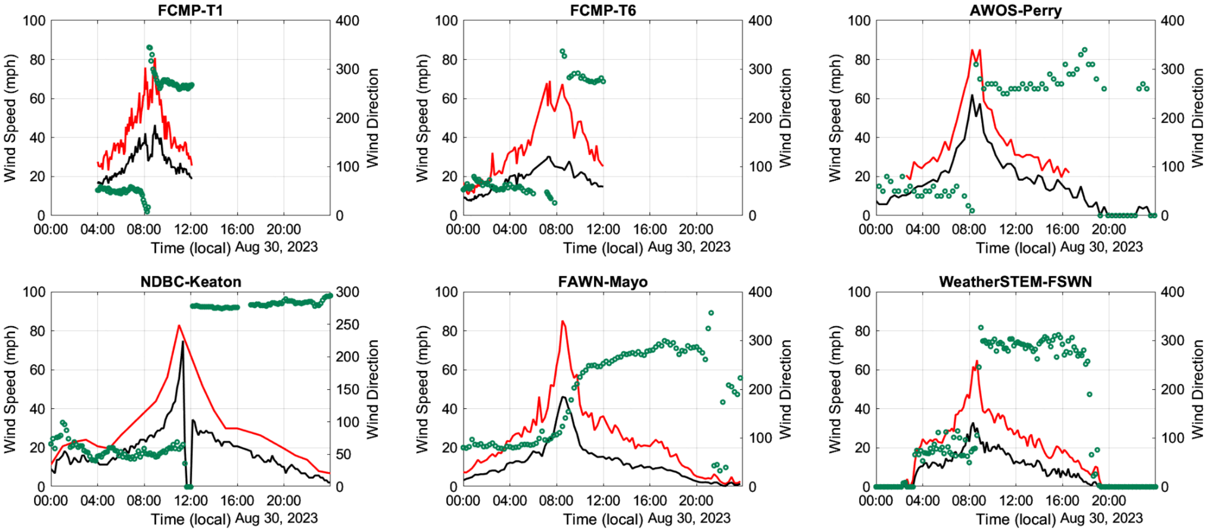


Figure 2.3. Selected surface wind observations in the landfall region, including wind gusts (red), average wind speeds (black), and wind directions (green). See Appendix A for additional metadata.

2.2. Storm Surge and Coastal Flooding

Hurricane Idalia was expected to produce a sizable storm surge along the western coastline of Florida from Tampa to Keaton Beach (Fig. 2.4). Storm surge was dictated by the combined effects of the strong onshore wind field associated with the hurricane, tidal effects, the coastal geography consisting of the wide, gently-sloping continental shelf, and the concavity and low-lying coastal features of the Big Bend. Only a few gauges from USGS or NOAA were located in coastal areas of Florida's Big Bend in the landfall region, and these recorded water levels approximately 8-9 ft above mean sea level in communities between Cedar Key, FL and Keaton Beach, FL (Figs. 2.5-2.7). These reasonably match the predictions by the Coastal Emergency Risk Assessment (CERA) (Fig. 2.4). A live streaming camera (WJXT News4Jax) showed water levels reaching approximately 5 ft above grade (~9 ft above mean sea level) in coastal areas of Steinhatchee.

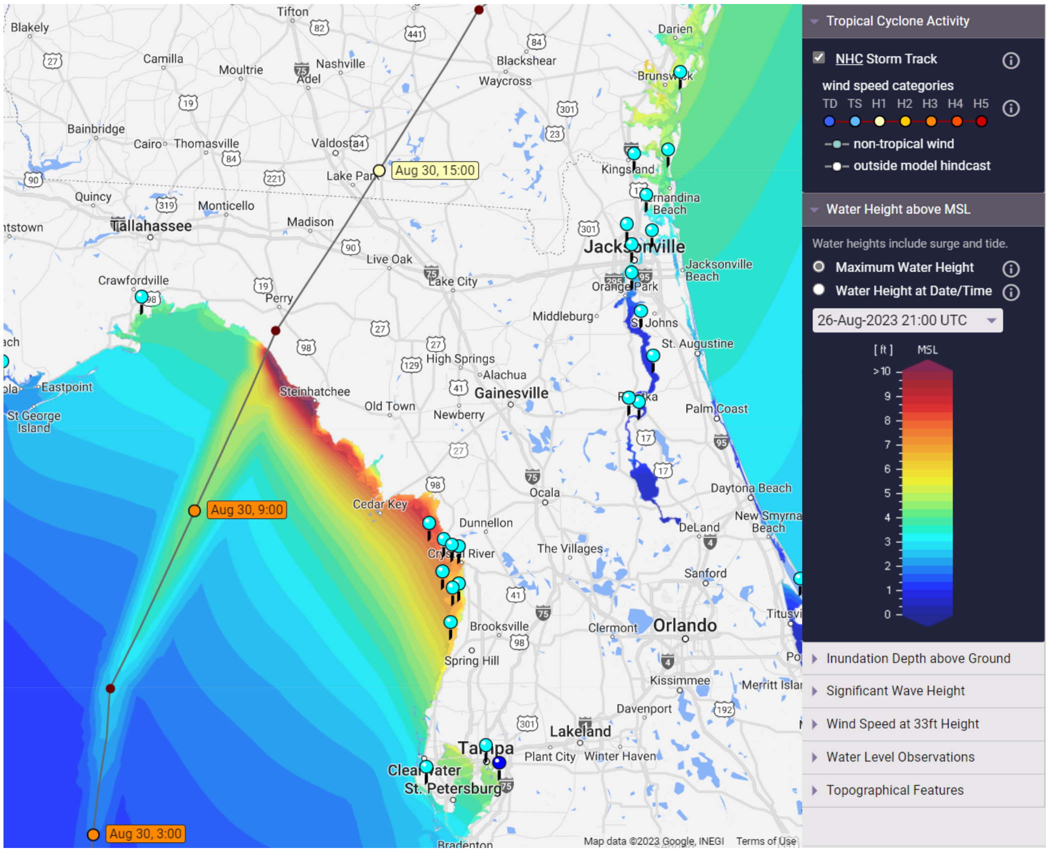


Figure 2.4. Predicted storm surge relative to mean sea level as estimated by the ADCIRC Surge Guidance System and the Coastal Emergency Risk Assessment platform (Source: CERA).

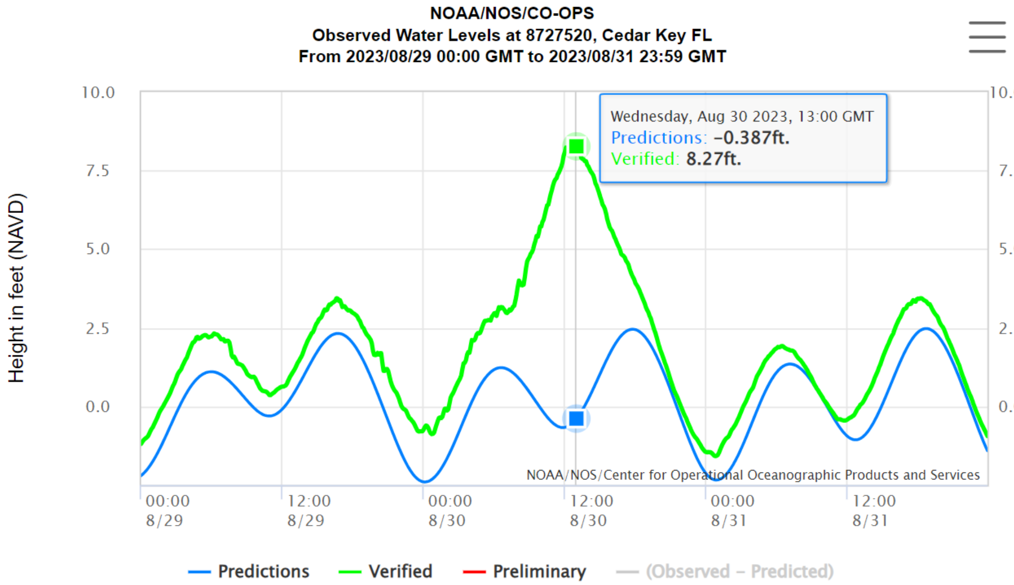


Figure 2.5. Observed water levels near Cedar Key, FL during the passage of Hurricane Idalia (2023). Water levels are relative to the NAVD88 vertical datum, which is +0.22 ft relative to Mean Sea Level for this location (Source: [NOAA](#)).

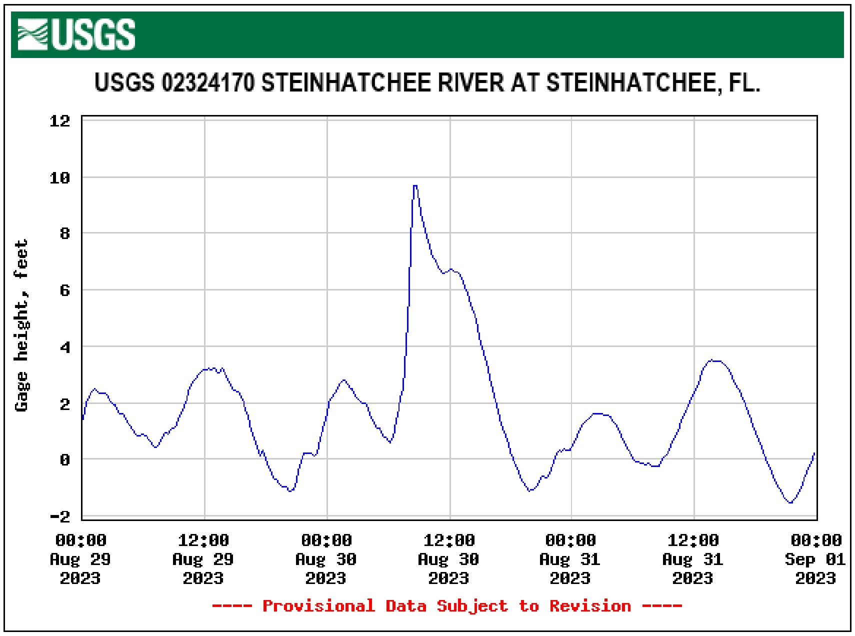


Figure 2.6. Observed water levels near Steinhatchee, FL (GPS: 29.66828, -83.37736) as measured by a USGS stream gauge. Gauge level is 1.64 ft relative to NAVD88 (Source: [USGS](#)).

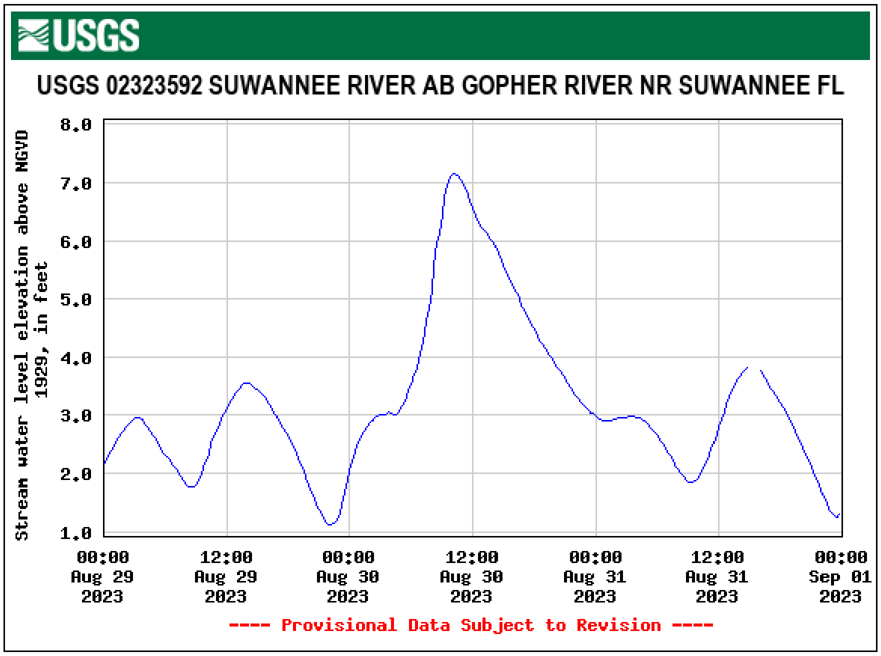


Figure 2.7. Observed water levels near Suwannee, FL (GPS: 29.3394, -83.0865) as measured by a USGS stream gauge. Observations are relative to NGVD 1929, which is approximately 0.5 ft above the NAVD88 at this location (Source: USGS).

2.3. Rainfall and Inland Flooding

Hurricane Idalia brought heavy rainfall intensities across Florida and along the eastern seaboard (Fig. 2.8). Maximum total rainfall across a 48-hr period during Idalia's passage was estimated at almost 10 inches in swaths near St. Petersburg, FL and along the storm's track from the Florida panhandle and into portions of Georgia and South Carolina.

2.4. Tornadoes

The convective bands associated with Hurricane Idalia produced multiple tornadoes and tornado-warned storms. Between August 30-31, 2023 (UTC time), the NWS issued 40 tornado warnings and 9 tornadoes were reported (Fig. 2.9). The NWS confirmed 13 tornadoes, all rated EF0 or EF1 using the Enhanced Fujita Scale (NWS). Appendix B includes a summary of the observed tornadoes.

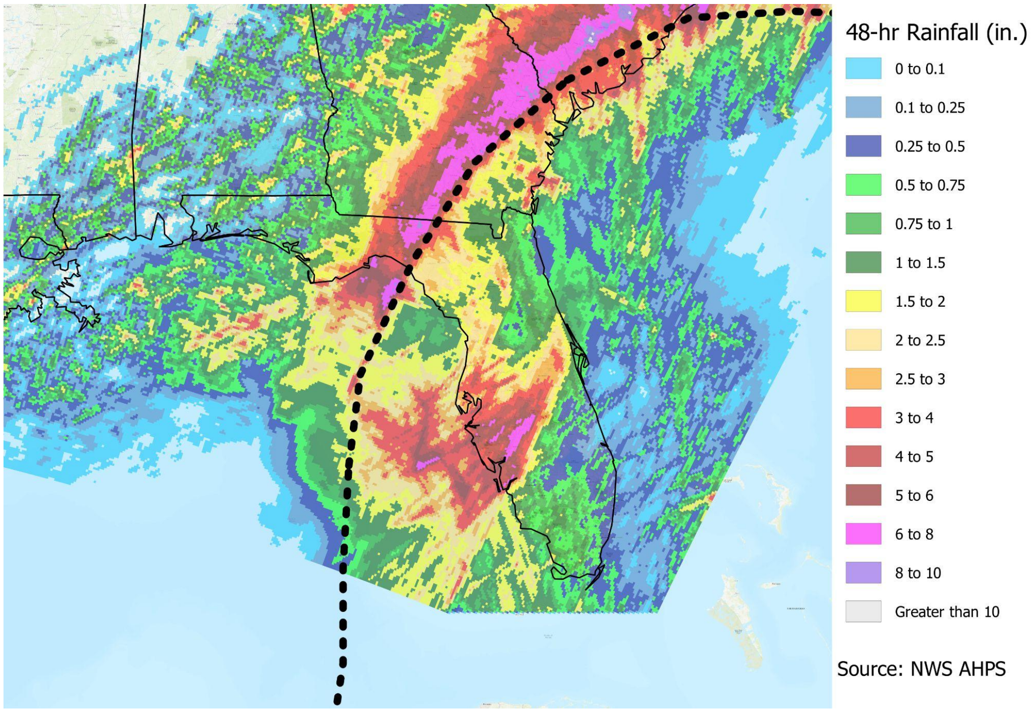


Figure 2.8. Total estimated rainfall over a 48-hr period between 7:00 AM CDT August 30, 2023 and 7:00 AM September 1, 2023. Data is sourced from the NWS Advanced Hydrologic Precipitation Service. The NHC best track is indicated by the dashed black line.

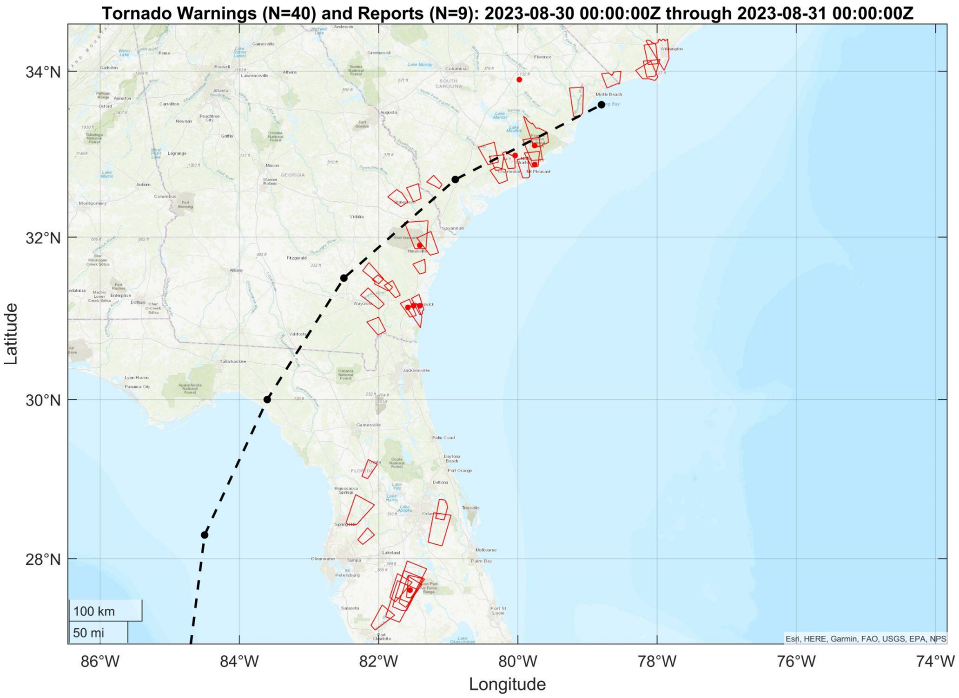


Figure 2.9. Tornado warnings (red polygons) and reports (red circles) issued by the NWS. The black line indicates the NHC best track for Idalia.

3. Local Codes and Construction Practices

Florida relies on two codes to regulate most building construction: (1) the Florida Residential Code and (2) the Florida Building Code. While the Florida Residential Code provides regulations and guidance for the construction of one and two-family dwellings, the Florida Building Code addresses all other permanent buildings and structures. The Florida Building Code, released in 2010, was primarily based on the 2009 International Building Code, which did not incorporate the specifications of ASCE 7-10 at that time. From 2012, the ASCE 7-10 served as the foundation of the minimum structural design provisions of the Florida Building Code. See Table 3.1 for the history of code adoption in the landfall region and how the design pressure has changed with time.

According to the 7th edition of the Florida Building Code, wind loads on buildings must be calculated using Chapters 26-30 of ASCE 7-16, with design wind speeds determined from the maps given in Figures 1609.3(1), 1609.3(2), and 1609.3(3) of the 2017 Florida Building Code, Sixth Edition. Figure 3.1 illustrates the design wind speeds from ASCE 7-16 Risk Category 2 structures (700-yr mean recurrence interval) in Florida. In the landfall region, design wind speeds are 120 mph or less, the lowest in all of the state. For comparison, the allowable stress design level lateral wind pressure has dropped from the 34 psf established in the ASCE 7-98 to 22 psf in ASCE 7-10 and subsequent editions.

Note that Hurricane Charley's impacts in 2004 spurred several changes to the Florida Building Code, summarized as follows:

- Improved requirements for wood to masonry wall interfaces
- Improved requirements for roof tile attachment
- Adoption of standards that rated asphalt shingles based on wind speed resistance
- Requirement to improve roof deck nailing when reroofing existing buildings
- Adoption of wind pressure criteria for soffits
- Adoption of requirements for labeling of windows, garage doors, and shutters for wind pressure.

Mobile and manufactured home regulations in Florida are managed by the Florida Department of Highway Safety and Motor Vehicles and provided in Rule 15C-1.0102 of the Florida Administrative Code. Individual counties may have more stringent standards. The regulations require compliance with manufacturer installation standards unless otherwise noted in Rule 15C and reference the federal Housing and Urban Development (HUD) Wind Zone regions for mobile and manufactured homes. Hurricane Idalia mostly affected HUD Zone 1 and HUD Zone 2 manufactured homes. Storm surge loads are not included in the anchorage requirements or superstructure design based on the HUD manufactured home installation standard (HUD, 2022), but the State of Florida does have tie-down requirements for all such structures.

The Florida Coastal Construction Control Line (CCCL) is another important part of Florida's regulatory environment and was first implemented in the late 1970s, with the most recent updates in Lee County implemented in 1991. The CCCL delineates that area of the beach-dune system vulnerable to erosion, dune destabilization, upland property damage, or interference with public access. Siting and design criteria for structures seaward of the CCCL may be more stringent than those already applied in the rest of the coastal building zone because of the greater forces expected to occur in this zone during a 100-year storm event. Specifically, the 100-year storm elevation requirements for habitable structures located seaward of the coastal construction control line ensure that the lowest horizontal structural member of the building is placed at an elevation above the predicted breaking wave crest, termed the 100-year storm elevation. All major structures are required to be designed to resist the predicted forces associated with a 100-year storm event. Notably, there is no CCCL in Big Bend, as it governs only sandy beaches.

Table 3.1. History of building codes and wind design standards for Keaton Beach, FL

Code Edition	Effective Date	ASCE Reference	Design Wind Speed (mph)[a]	ASD Wind Load Factor	Lateral Design Pressure (psf)[b]
1997 SBC	Pre-2002	ASCE 7-98	120	1	36.8
2001 FBC	Mar-02	ASCE 7-98	120	1	36.8
2004 FBC	Oct-05	ASCE 7-02	120	1	36.8
2007 FBC	Mar-09	ASCE 7-05	120	1	36.8
2010 FBC	Mar-12	ASCE 7-10	122	0.6	22.9
2014 FBC	Jun-15	ASCE 7-10	122	0.6	22.9
2017 FBC	Dec-2017	ASCE 7-10	122	0.6	22.9
2020 FBC	Jan-2021	ASCE 7-16	117	0.6	21
2023 FBC	July-2023	ASCE 7-22	122	0.6	22

[a] Design wind speeds are 3-second gusts in open terrain at 10 m height above ground level, but correspond to a 50 yr MRI in ASCE 7-98/02/05 and a 700 year MRI in ASCE 7-10.

[b] Lateral design pressure is defined as $P = 0.00256*(V_{design})^2*LF$, where V_{design} is the design wind speed, and LF is the ASD wind load factor.

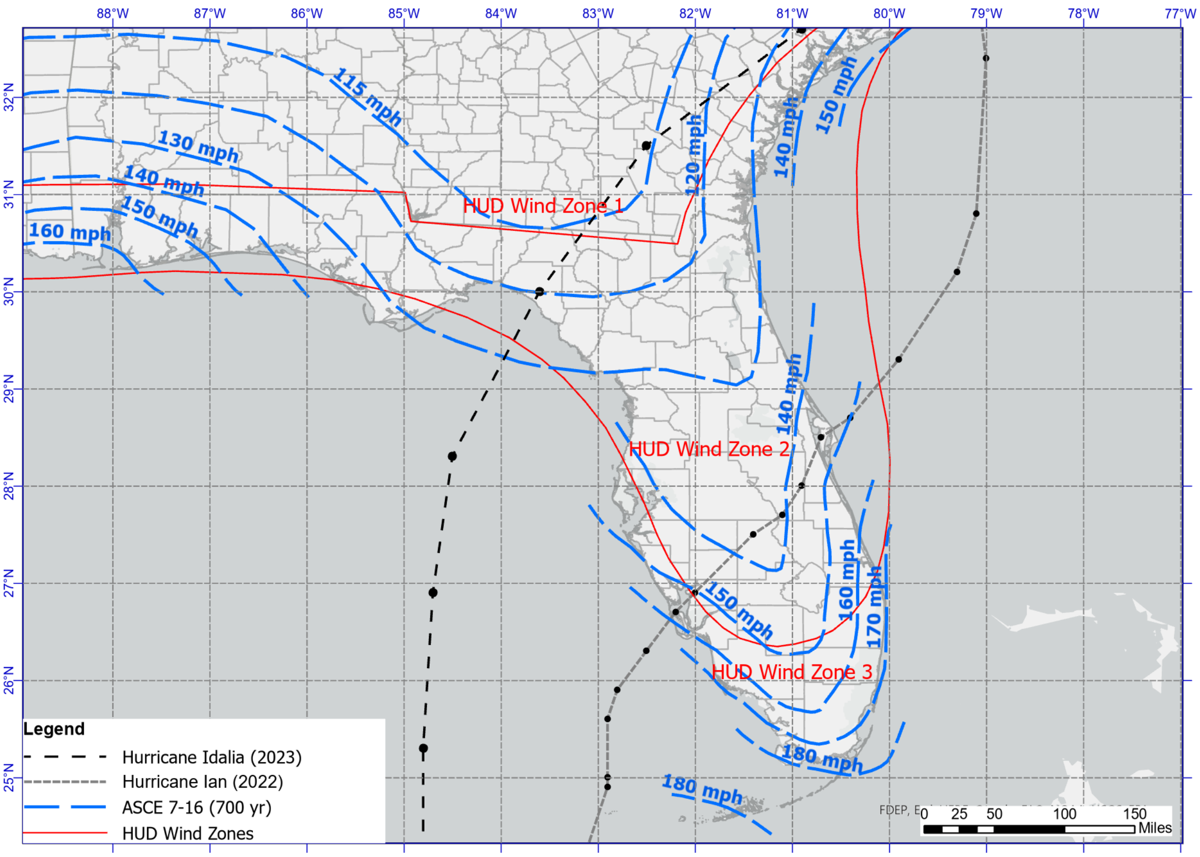


Figure 3.1. Design wind speeds in Florida for ASCE 7-16 Risk Category II buildings (blue) and HUD-regulated buildings (red).

4. Building Performance

Damage to residential and commercial buildings was heaviest near the landfall location in the Big Bend region of Florida from Cedar Key to Keaton Beach, FL. Damage ranged from failures of building envelope systems, roofing, and wall sidings to complete structural collapse. There were several reports of damage to manufactured homes due to wind and storm surge. Many fallen trees within the hurricane path caused additional building damage, downed power lines, and blocked roads.

Tables 4.1 and 4.2 provide a synthesis of the typical performance of buildings in this event, respectively organized by occupancy and geography. The subsections that follow present notable case studies. Readers may consult the imagery compiled in the accompanying Media Repository, curated with this report in DesignSafe, to access a richer collection of georeferenced visual evidence cataloged by occupancy.

Table 4.1. Summary of Building Performance by Occupancy	
Single-Family Residential Buildings	In regions subjected to the highest wind and/or storm surge hazards, damage was observed to older (pre-1994) homes, particularly those constructed at or near grade level. Observed wind damage primarily consisted of roof cover and wall cladding loss, but a few instances of structural damage due to wind were also observed in older homes, such as roof decking failure.
Multi-Family Residential Buildings	Instances of wind damage to multi-family residential buildings were observed, including collapse of the brick facade on gable end walls and roof cover loss. However, based on early reports, wind damage was not widespread.
Commercial Buildings	A few examples of significant wind damage to commercial structures were observed, including toppling of gas service station canopies, complete failure of a metal building system, damage to architectural elements on several retail stores and a few industrial buildings, and roof cover loss. Wind damage was not widespread based on early reports, but several of the structures with observed damage were constructed post-2002. A few older commercial structures along the coast were damaged by storm surge.
Farm Buildings[1]	There were several reported failures of warehouses and industrial sheds located on farms. Observations of complete collapse of open sheds and enclosed warehouses were observed. Collapsed structures were constructed of both wood framing and structural steel framing systems. In one case, a steel open canopy was uplifted pulling the concrete tube foundations out of the ground.
Healthcare/Medical Facilities	No reports of damage to healthcare or medical facilities were documented. A cyclone-induced EF0 tornado that struck Southport, NC damaged the roof cover and interior of a veterinary hospital.
Schools	Building damage caused by wind was observed at some schools. The damage included extensive peeling of a metal roof, shingle loss, likely structural roof damage due to fallen trees, and damage to athletic field structures, e.g., a leaning scoreboard likely due to post withdrawal and the loss of walls and roof of an announcer box.
Government Facilities	No observations available for this class at time of this report.

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[1] In Florida, any nonresidential farm building, farm fence, or farm sign that is located on lands used for bona fide agricultural purposes, not including those lands used for urban agriculture, is exempt from the Florida Building Code and any county or municipal code or fee, except for code provisions implementing local, state, or federal floodplain management regulations.

Mobile/Manufactured Homes	Despite numerous mobile and manufactured homes in the regions impacted by Hurricane Idalia, specific damage reports are lacking. A mobile home park in St. Petersburg experienced severe flooding that required persons to be rescued. Several reports of storm surge carrying mobile/manufactured homes off their foundation were also found.
Critical Facilities	Building damage was observed at a fire station in Cedar Key, FL. Damage was sustained to an accessory structure and included the peeling away of a metal roof, complete loss of an endwall, and separation of the bottom portion of a rollup door.
Historical Buildings	No observations available for this class at the time of this report.
Religious Institutions	Flood damage was observed in a church in Horseshoe Bend, FL, and minor wind damage (roof shingle blowoff) was reported for a church in Perry, FL. No other damage reports to religious facilities have been obtained, so it is anticipated that only isolated exterior damage occurred, with potential for more widespread interior damage from flooding or rainwater ingress.

Table 4.2. Summary of Building Performance by Geography

Dekle Beach, Keaton Beach, Dark Island (Taylor County, FL)	Significant flooding was observed but there was no evidence of any structures collapsed by storm surge impacts. Some structures may have been sheltered from wave action by the relatively high density of trees and other vegetation. Wind-induced building damage was common but mostly limited to roof cover and wall cladding loss. Isolated structural damage was observed in Keaton Beach. Roof cover loss was most common on older asphalt shingle roofing systems, and also to metal roofing. Roof decking loss was observed but infrequent and confined to older residential structures. More inland portions of these communities were heavily forested and wind damage was not discernible from available sources at this time.
Steinhatchee and Jena (Taylor County, FL)	A few isolated instances of roof cover damage were observed in the NOAA aerial imagery. No evidence of significant, surge-related exterior damage (e.g., buildings shifted off the foundation) despite the extensive storm surge along the coastal areas.
Horseshoe Beach and Suwannee (Dixie County, FL)	Storm surge damage was observed in at-grade structures and structures below the storm surge level in Horseshoe Beach. Many instances of older homes built at grade-level or with minimal elevation were dislodged from their foundations, while several structures on the coast were completely destroyed. There was some

	wind damage to isolated roofs but this damage pattern was not extensive. Minor wind damage to sheds, boat houses, and a few homes were observed in Suwannee, but surge-induced damage was generally not discernible from early reports, videos, and images, in contrast to the frequent damage observed in Horseshoe Beach.
Perry, FL and Surrounding Communities (Taylor County)	Isolated instances of wind damage to roofs, wall cladding, and wind susceptible structures such as signs and gas station canopies were documented. Significant swaths of downed trees were observed in Madison County, FL along I-10, approximately between mile markers 252 and 257.
Cedar Key, FL (Levy County)	Isolated wind damage (minor roof cover loss, gas station canopy collapse) was reported. Surge impacts were more extensive, flooding numerous residences and other structures, and damaging breakaway walls.

4.1. Case Study: Surge-Induced Failures of Masonry Structures

Multiple instances of failure of masonry or masonry-supported structures due to storm surge were observed and are summarized in Figures 4.1-4.3. Figure 4.1 shows a surge-induced out-of-plane collapse of a front masonry wall of a commercial building located in Horseshoe, FL.

Figure 4.2 demonstrates the complete destruction of a nearshore single-story concrete masonry home constructed in 1970 at Horseshoe, FL. The photograph in the right panel of the figure shows that the home employed an ungrouted concrete masonry wall system with no evidence of positive anchorage to the concrete slab, which subsequently collapsed during the storm.

(before) (after)

Figure 4.1. Collapse of concrete masonry wall of commercial building in Horseshoe Beach, FL (Source: Vic Micolucci via Facebook).

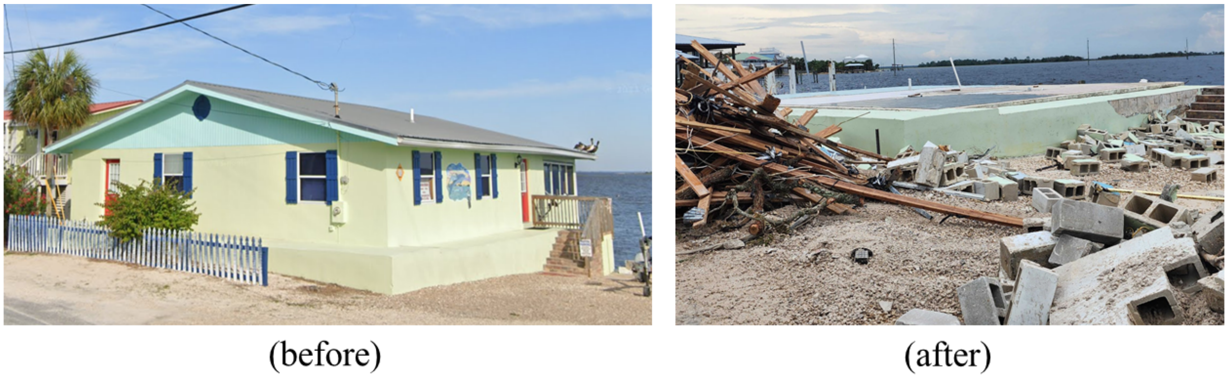

(before) (after)

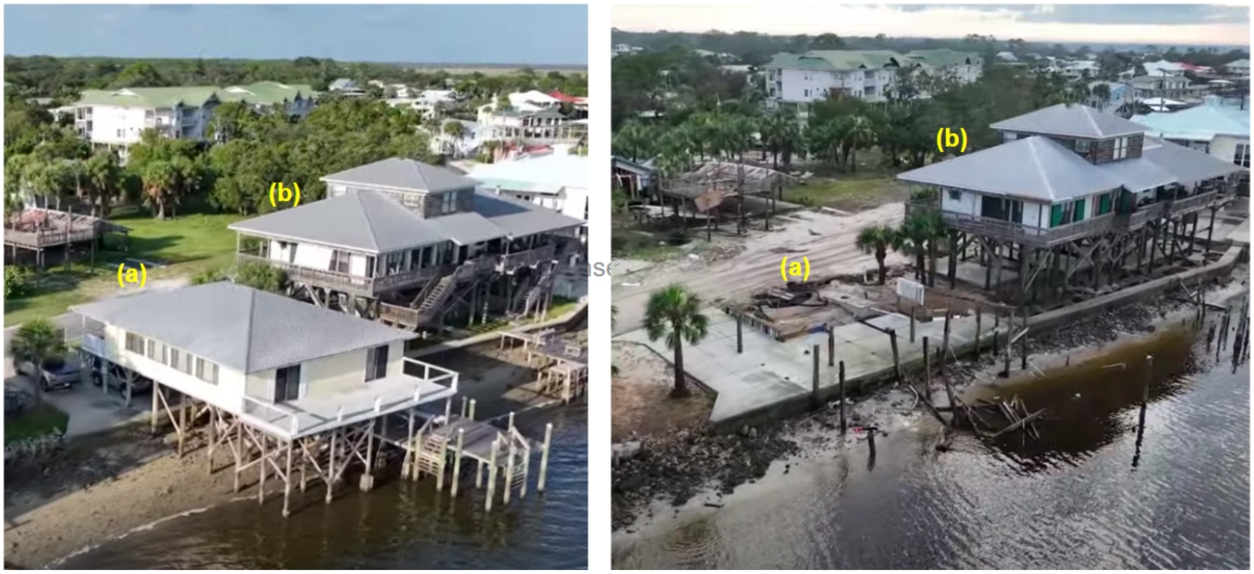
Figure 4.2. Complete loss of single-story unreinforced concrete masonry house in Horseshoe Beach, FL (Source: Nina Stark, Rutgers University via DesignSafe-CI Slack).


(before) (after)

Figure 4.3. Complete loss of home elevated on masonry piers in Horseshoe Beach, FL (Sources: Site Tour 360 (left) and Civil Air Patrol (right)).

4.2. Case Study: Complete Loss of Elevated Wood Structure

Figure 4.4 shows an elevated wood structure (labeled (a) in Fig. 4.4) that was washed away during Hurricane Idalia in Horseshoe Beach, FL. The structure was built in 1937 and elevated nearly 6 ft above grade. The structure was supported on wooden piles, many of which failed and lost connection to the superstructure during the storm. The pile system was supported by diagonal bracing in the direction of the surge flow. Failure may be attributed to insufficient elevation of the lowest horizontal structural member above grade and inadequate pile-to-superstructure connection detailing. An adjacent home constructed in 1994 (labeled (b) in Fig. 4.4) survived but lost some ground floor enclosures.



(before) **(after)**

Figure 4.4. Before and after views showing disparate surge performance in Horseshoe Beach, FL. The elevated wood-frame home that was washed away (a), was constructed in 1937 and elevated approximately 6 ft above grade. The elevated home that is still standing was constructed in 1994 and was elevated approximately 10 ft above grade (Source: WXChasing YouTube).

5. Other Infrastructure Performance

Table 5.1 provides a synthesis of the typical performance of other infrastructure classes in this event, organized by class. Readers may consult the imagery compiled in the accompanying Media Repository, curated with this report in DesignSafe, to access a richer collection of georeferenced visual evidence cataloged by infrastructure class. Interested readers may also consult the Outage/Restoration Database, curated with this report in DesignSafe, for a chronology of disruption/outage/restoration data for power, telecommunications, and transportation networks.

5.1. Power Outages & Restoration

Figure 5.1 shows the peak outages per Florida county on August 30th, after landfall. The four counties of Madison, Suwannee, Taylor, and Jefferson experienced about 100% outages on August 30th. Figure 5.2 illustrates the restoration in Florida from August 30th to September 8th. Most power lines had been restored in Florida by September 8th and a day later in Georgia and the Carolinas. Note that in many cases, buildings were not ready to “receive” power or connect to the distribution system after sustaining internal hurricane damage. Restoration rates by geography are presented in Table 5.2.

Table 5.1. Summary of Performance by Infrastructure Class	
Power Infrastructure	As of August 30th 7:30 EDT, there were 126,000 customer outages in Florida (DOE, 2023)[2]. The combined total was approximately 295,000 customers for the Big Bend region, which is approximately 2.7% of the 11 million customers in the State of Florida.
Telecommunications Infrastructure	16% of cell sites that were out of service in the State of Florida between August 30 and September 4. Hamilton County was the hardest hit with 27.3% cell sites out of service as of September 2, with Lafayette County having 20% cell sites out of service at that time (FCC, 2023). The FCC did not provide cell outage data for Georgia and the Carolinas.
Roads & Bridges	No widespread damage observed. A section of the coastal roadway along Englewood Beach collapsed when supporting soils were washed away. Non-structural concrete panels on a bridge abutment failed on Highway 31 in North Myrtle Beach, SC.

Table 5.2. Extent of Power Outage and Restoration

	Peak Outage	Restoration Status
Florida (Northern “Big Bend”)	295,000 on August 30th Wednesday (DOE, 2023) 147,293 outages on the morning of August 31 (Norman, 2023).	Power had been restored for almost all customers (over 90%) in Florida by September 8th (FPSC, 2023).
Georgia	209,000 on August 30th (DOE, 2023); affected areas: Savannah, Brunswick, Tifton Valdosta and Waycross (Georgia Power, 2023)	Restoration complete by time of report.

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[2] A customer represents an “account”, not a person; therefore, one customer may represent multiple buildings.

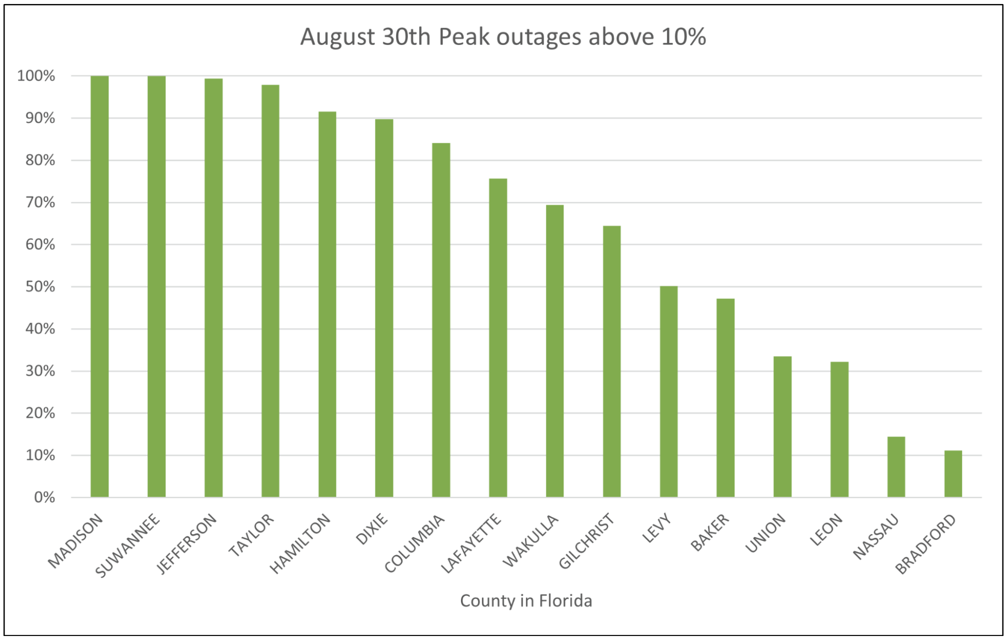

Figure 5.1. Peak power outages by county in Florida on the evening of August 30th. Data source: Florida Public Service Commission (FPSC, 2023).

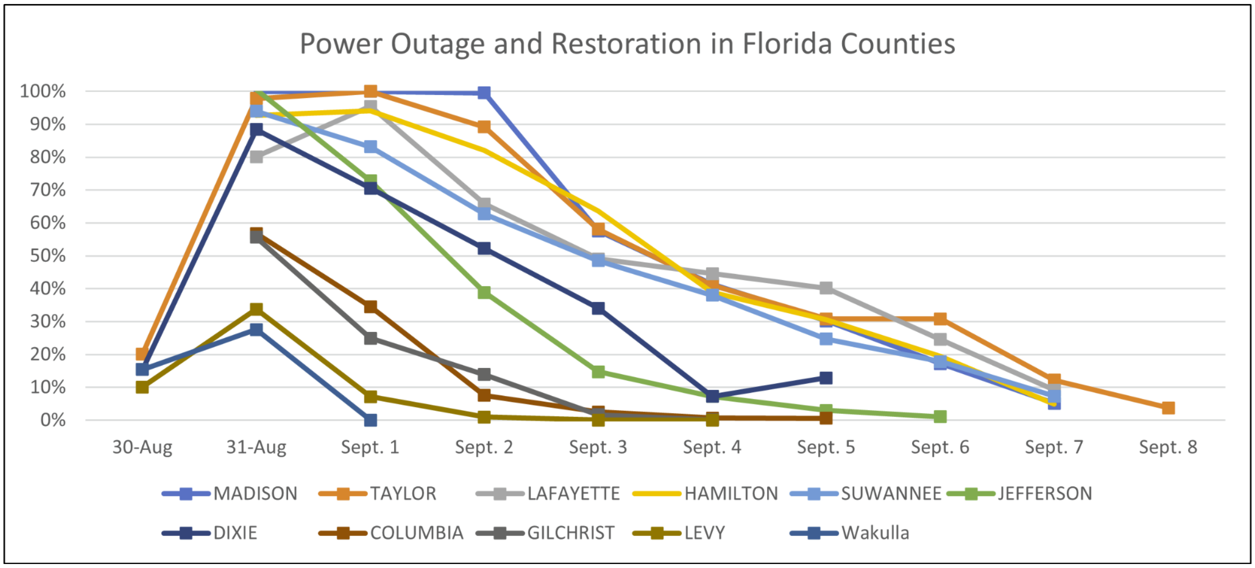

Figure 5.2. Power outage and restoration in Florida by county (FPSC, 2023).

5.2. Telecommunication Outages & Restoration

Figure 5.3 shows a peak percentage of 16% of cell sites that were out of service in the State of Florida between August 30 and September 4[3]. By September 4th, 1% of all cell sites in the State of Florida were restored (FCC, 2023).

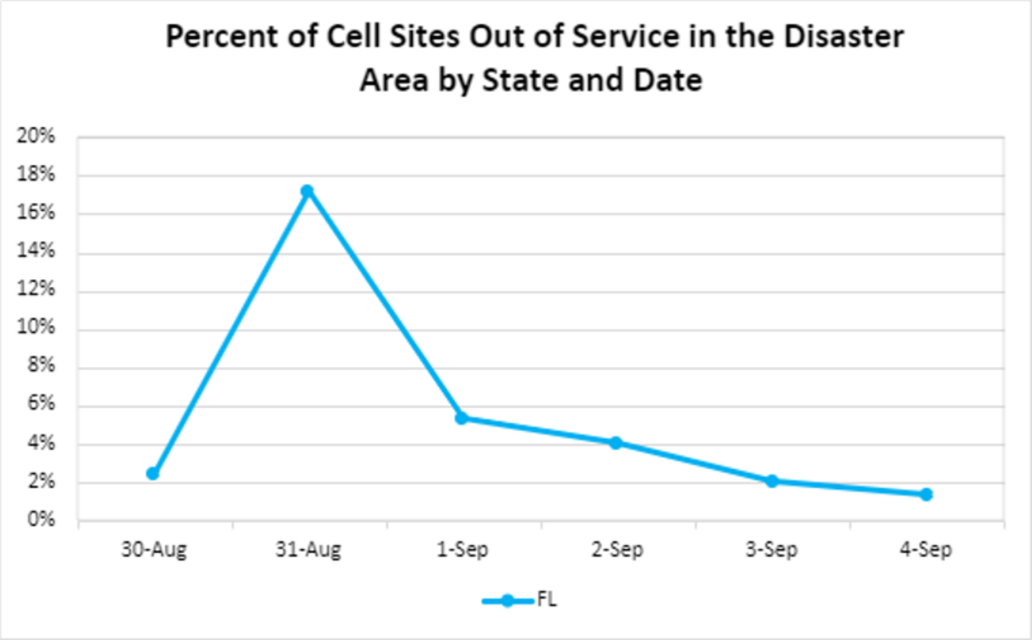

Figure 5.3. Percentage of out-of-service cell sites in Florida (FCC, 2023).

5.3. Transportation Infrastructure Damage

Hurricane Idalia-induced storm surge inundation around Englewood Beach caused a portion of the road to fail (Fig. 5.4). In South Carolina, the storm surge induced damage to nonstructural concrete slope protection panels installed on the sloping abutment below an overpass bridge on Highway 31. According to the South Carolina Department of Transportation, a portion of the bridge was closed to repair the damage (Benson, 2023) (Fig. 5.5).

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[3] Note that “cell sites out” does not mean there is no cell service due to overlapping of coverage.


(Before) (After)

Figure 5.4. Englewood Beachside Road, FL 34223, (26.96659, -82.38780) (Source: Sun News)

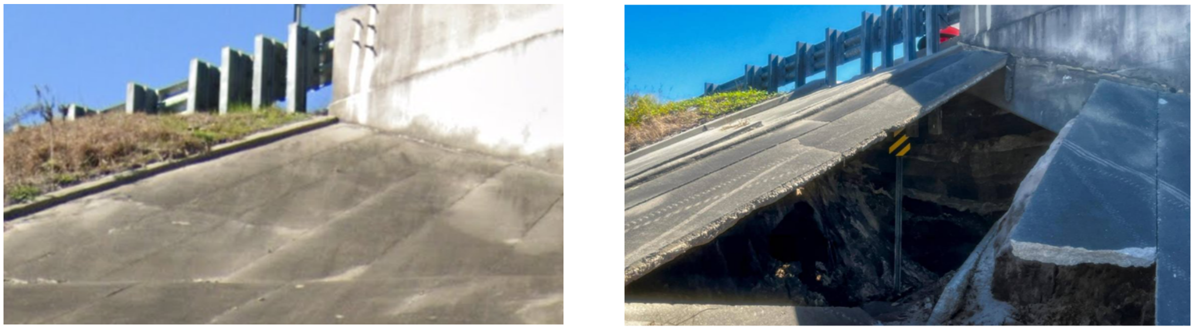
(Before) (After)

Figure 5.5. Highway 31, North Myrtle Beach, SC (33.844063, -78.701240) (Source: Sarasota County Government via X (formerly Twitter))

6. Geotechnical Performance

Geotechnical damage from Hurricane Idalia occurred throughout the area, including reports of scour-induced settlement and failure of column-to-footing connections at several locations (see News report, CBS News (CBS News, 2023); Fig. 6.1). A notable failure of an open shed structure on a peanut processing facility results from the pull out of 3-foot deep concrete foundations due to high wind uplift forces (Fig. 6.2). Many utility pole failures were also observed throughout the affected region.

Figure 6.1. View of Shallow foundation (slab footing) damage of residential structure showing severe washout (Source: Chase Allbritton via Storyful).

Figure 6.2. Column-foundation pull-out capacity failure.(Source: UF Building Performance Observation Survey on 2023-hurricane-idalia-vast design safe slack channel)

7. Recommended Response Strategy

Hurricane Idalia was one of the lowest-impact major hurricanes to landfall in the state of Florida in recent years, due to its landfall in a rural region dominated by farming and other agricultural activities. Nonetheless, and despite the moderate peak wind speeds (70 to 90 mph), wind damage to structures occurred well inland, extending as far as Jasper, FL near to the Georgia border. The observed level of damage to buildings and infrastructure caused by Hurricane Idalia represents the damage expected by this moderately strong event. Given the small number of damaged buildings, there are limited opportunities to generate new knowledge, from a hazard engineering perspective. However, there are opportunities to use this event to bolster the resilience of these communities through research on risk perception and behavioral responses to risk information, as well as policy advocacy, in the following areas:

Coastal Building Elevations/ Blue Sky Study -- Idalia highlighted the well-documented vulnerability of structures built on grade or with minimal freeboard to catastrophic failure, especially those that were built prior to the adoption of the Florida Building Code. The “near miss” of this hurricane can serve as a powerful motivator to examine current Flood Insurance Rate Maps (FIRMs) against elevation certificates to examine risks under a future design-level event. Such a study can initiate important dialog around programs and policy incentives to encourage voluntary mitigation investments during blue-sky conditions.

Code Exemptions for Buildings on Agricultural Property -- Several warehouses and open shed buildings on agricultural property suffered more than expected wind damage, including those located well inland, in areas where there was little evidence of wind damage to nearby trees. Buildings on agricultural property in Florida typically are exempted from the provisions of the Florida Building Code, but their damage creates both property losses and potentially lost revenue. This reiterates the importance of communicating the potential consequences of code exemptions and the benefits of adopting a more rigorous code-compliant approach to maintain continuity of operations for agricultural facilities.

Vulnerability of Manufactured and Mobile Homes – Hurricane Idalia renewed the discussion around the performance of manufactured and mobile homes (Levin, 2023). While performance of these structures was on par with site-built homes based on the information in this report, with the exception of anchorage issues unique to this class of building, the location of these properties may increase their exposure to risks for what are often more socially vulnerable households. This creates opportunities to promote cost-effective retrofit and replacement programs especially targeting older manufactured and mobile homes in areas with high exposure to wind and coastal hazards.

Those choosing to study this event further are encouraged to take advantage of the street-level panoramas collected by Site Tour 360 across the affected area. These partners have made this data available to StEER members (Access Viewer). The vehicle-mounted camera system collected images in three coastal residential communities (Steinhatchee, Horseshoe Beach and Cedar Key) and in five inland Florida towns (Mayo, Perry, Lake City, Live Oak and Madison). The data was captured within a week of Hurricane Idalia's landfall. This dataset of approximately 450 unique miles of data can be a valuable resource for ongoing study of this event.

Based on the observations of damage herein and evaluation against StEER's Response Activation Criteria (Table 7.1), **StEER's response to this event will remain at Level 1 with no activation of a Field Assessment Structural Team (FAST).** As a result, this PVRR represents the extent of StEER's official response. However, StEER will continue to coordinate with other organizations responding to this event to encourage consideration of the above recommendations and will monitor their assessments. Should these ongoing efforts reveal new information that would satisfy one or more of StEER's escalation criteria, StEER may re-evaluate its decision and deploy a FAST.

Table 7.1. Summary of Level 2 Response Escalation Criteria

Hazard	**Exposure**	**Feasibility**
☐ *Design-Level Event* • Hazard intensity meets or exceeds code-mandated or PBE-adopted levels	☐ *Infrastructure of interest* • Highly vulnerable structures with severe damage or collapse • Highly engineered structures with lower damage states • International: practices consistent with or analogous to US practice	☐ *Resources* • Availability/interest of members in the impacted region • Availability of sufficient support from regional nodes • Availability of imaging hardware
☐ *Unique Hazard characteristics* • Verified upon inspection of field observations/records	☐ *Community Impacts* • Significant fatalities • Potential for prolonged downtime and recovery	☑ *Access and safety* • Driving access to affected areas • Safe to access (security, public health - e.g., COVID)
	☐ *Downtime or Recovery Issues* • Potential for prolonged downtime and recovery	☐ *Collaboration Potential* • Other EER's deployment
1/8 (12.5%) of Level 2 Criteria Satisfied		

Appendix A: Surface Wind Observations

Metadata for the wind surface observations described in Section 2.1 are summarized below. Figure A.1 shows the locations of surface observation stations with respect to the hurricane track, while Figure A.2 provides polar plots of the mean wind speed and direction (averaging period varies by station) overlaid on satellite imagery centered on the station location. Table A.1 summarizes key metadata on the stations, including (if known) height, gust averaging time, and the precise location.

Table A.1. Summary metadata for select surface wind observation stations in the landfall region.

ID	Latitude	Longitude	Height (ft)	Gust Avg. Time (sec)	Mean Avg. Time (min)[1]
AWOS-Perry	30.0708	-83.5815	33	3	2
FCMP-T1	30.0768	-83.575	33	3	5
FCMP-T6	30.0421	-83.7133	33	3	5
NDBC-Keaton	29.8188	-83.5935	33	5	10
FAWN-Mayo	30.07974	-83.23457	33	3	15
WeatherSTEM-FSWN	30.4475	-83.4204	unk	unk	10

[1] Mean Averaging Time represents the period of time over which instantaneous wind samples are averaged. The precise details of the averaging algorithm (e.g., block vs moving) are not available at this time.

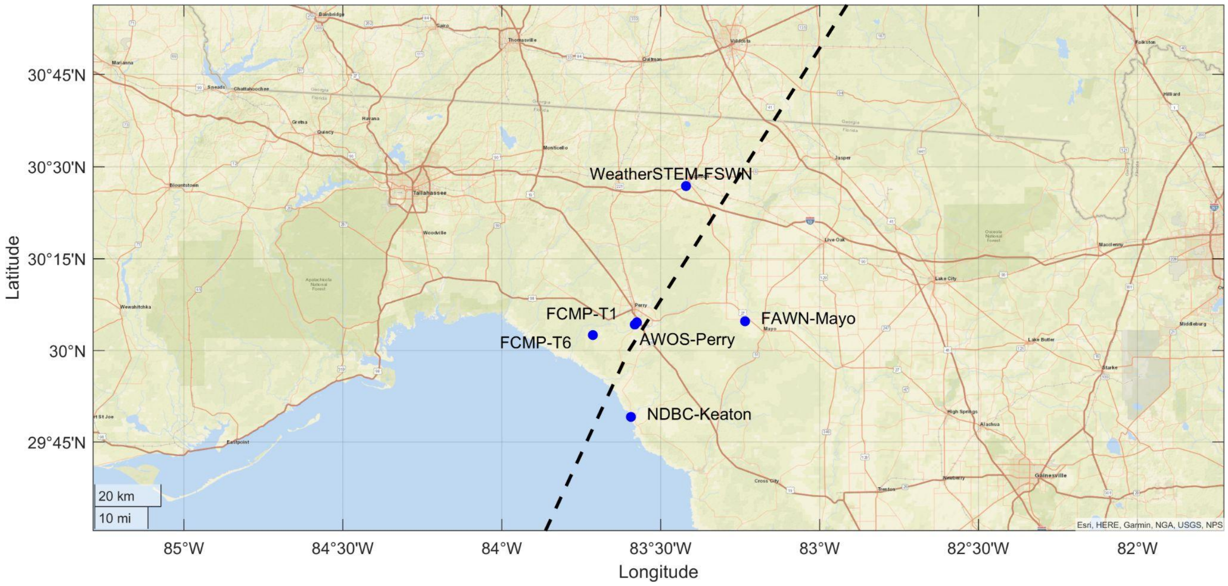

Figure A.1. Locations of select surface wind observation stations shown in Figure 2.3.

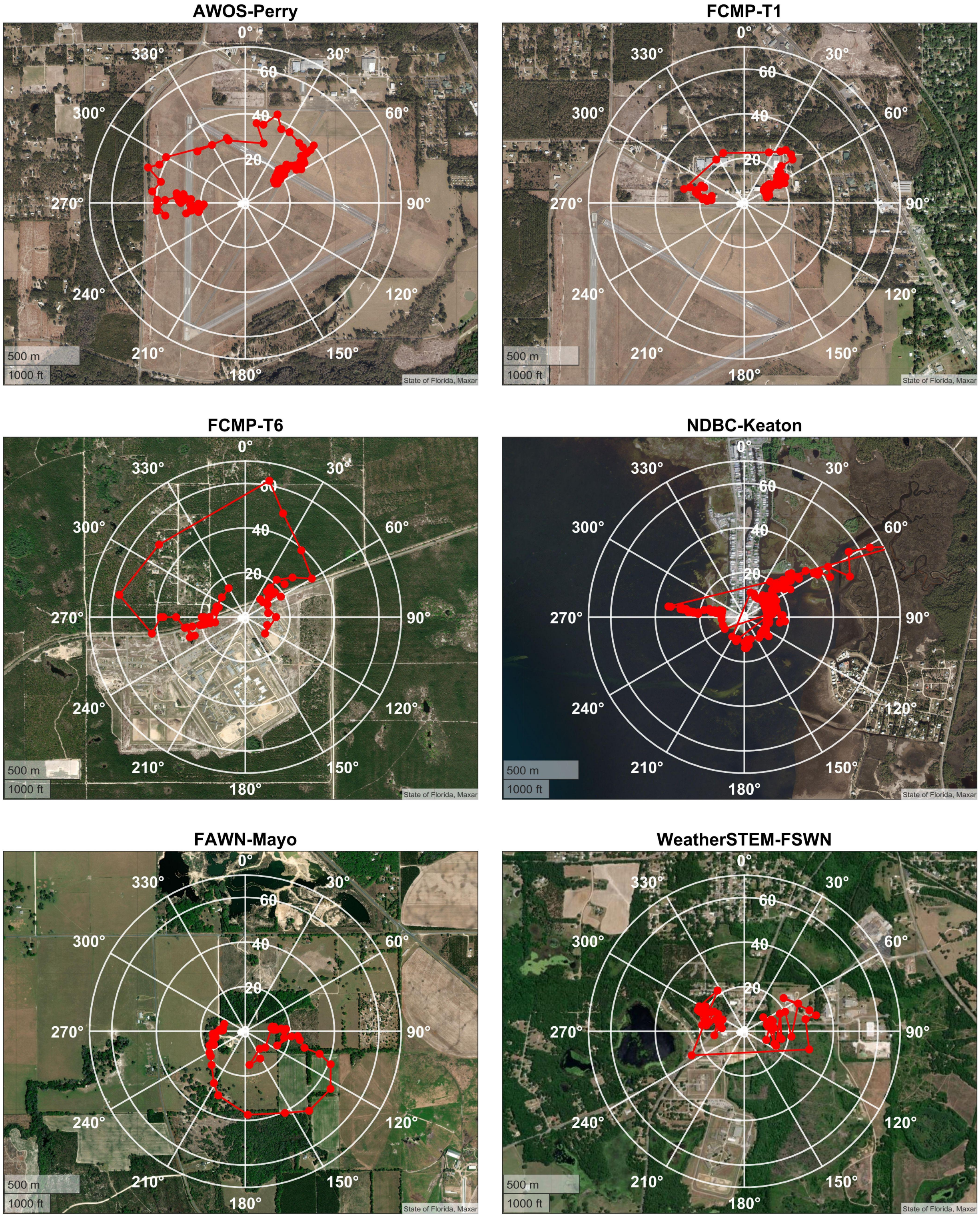

Figure A.2. Average wind speed (mph) and direction for select surface observation stations in the landfall region. Averaging periods are not the same between all stations. See Table A.1.

Appendix B: Confirmed Tornadoes

The tornadoes confirmed by the National Weather Service associated with Hurricane Idalia are summarized in Table B.1.

Table B.1. Tornadoes confirmed by the NWS as associated with Hurricane Idalia.

ID	Date	Length (miles)	Width (yards)	Injuries	Fatalities	EF Rating	Max Wind Speed (mph)
Idalia Tornado	8/30/2023	0.0293	50	2	0	EF0	75
Colonels Island Road Tornado	8/30/2023	9.7823	50	0	0	EF0	70
Fleming GA	8/30/2023	0.5321	100	0	0	EF0	85
New Jesup Highway Tornado	8/30/2023	7.9095	300	0	0	EF1	94
St. James Tornado	8/30/2023	0.3189	20	0	0	EF0	80
Cherry Grove Tornado	8/31/2023	1.6347	30	0	0	EF0	85
n/a	8/30/2023	2.7375	100	0	0	EF0	85
Silver Lake	8/30/2023	1.5657	30	0	0	EF1	100
Kings Way Tornado	8/30/2023	0.3225	50	0	0	EF1	90
n/a	8/30/2023	0.7284	125	0	0	EF1	90
River Road	8/30/2023	0.2446	40	0	0	EF1	110
n/a	8/30/2023	1.8944	100	0	0	EF1	95
Saint James	8/30/2023	0.4407	20	0	0	EF0	65

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