(C) – The Art & Science of Field Studies: Past, Present, and Future

IN-CORE Validation and Real-time Forecasting for Building Damage due to Coastal Flood: Hurricanes Ian (2022) and Helene (2024)

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NIST SAM, Nov 7, 2024

NIST CENTER FOR RISK-BASED COMMUNITY RESILIENCE PLANNING

Recon

Sep 28, 2022
Hurricane Ian landfall (Cat 4)

Oct 2022
FEMA pre-MAT

Oct 2022
NSF StEER – San Carlos

Oct 2022
NSF StEER – FMB

Nov 2022
ASCE Recon – SI + FMB

Jan 2023
FEMA MAT

Mar 6-8, 2023
OSU Recon – FMB

Jun 3-4, 2023
OSU Recon – FMB

Sept 16-18, 2023
OSU Recon – FMB

Jan 13-14, 2024
OSU/URI Recon – FMB

May 4-5, 2024
OSU/URI Recon – FM

Aug 17-18, 2024
OSU/URI Recon – FMB

Nov 23-24, 2024

- Ian Recovery
- Milton

Oct-22 Nov-22 Dec-22 Feb-23 Mar-23 May-23 Jun-23 Aug-23 Sep-23 Nov-23 Dec-23 Feb-24 Mar-24 May-24 Jun-24 Aug-24

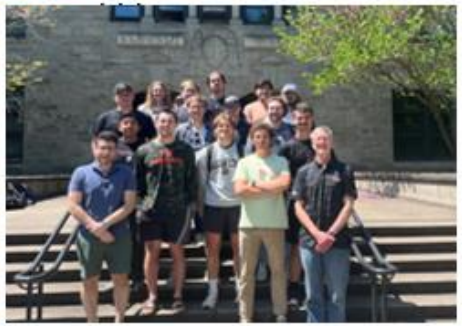
VDA

Nov 2022 - Jan 2023
Develop VDA method:

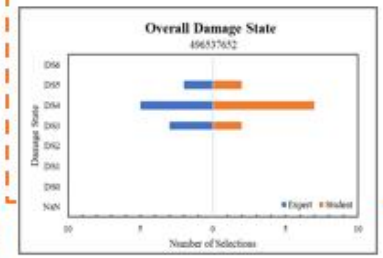
- Gather data sources
- Damage Rating
- Flow Chart
- Examples
- Data sharing
- Communication

Phase 1: Jan 24 - Mar 24, 2023 -> 10 students; 7 weeks

Phase 2: Apr 12 - Jun 16, 2023 -> 16 students; 9 weeks;



Phase 3: Jun 23 - July 31, 2023 -> Expert VDA
10 experts/5 weeks



Phase 4: Oct 23 - May 31, 2024 -> First-floor-elevation + QAQC **(OSU/URI)**

Oregon State University

VDA Results

Damage Scale:
Tomiczek et al. (2017)

Legend

Assessment Status:
- Full (3118)
- Partial (290)

Damage State:
- No Damage (DS0)
- Minor (DS1)
- Moderate (DS2 & DS3)
- Major (DS4)
- Complete (DS5 & DS6)

Source: StEER

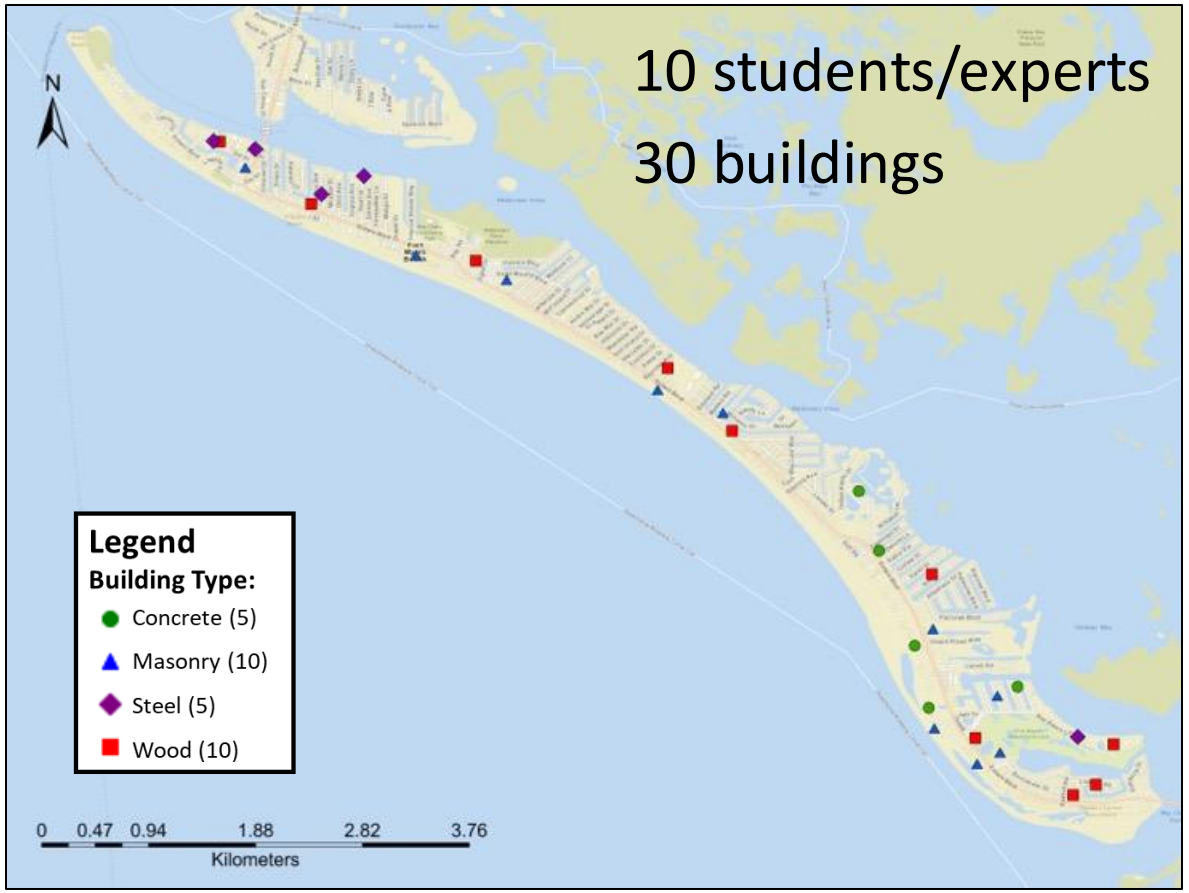
NSI fd_id: 497089214
NSI Occupancy: RES1-1SNB
NSI Building Type: Wood (W)
Act Year Built: 1951
Elevated: No
Damage State: DS5
- Roof: DS5
- Walls: DS5
- Foundation: DS0
- Attachments: DS1
- Openings: DS3

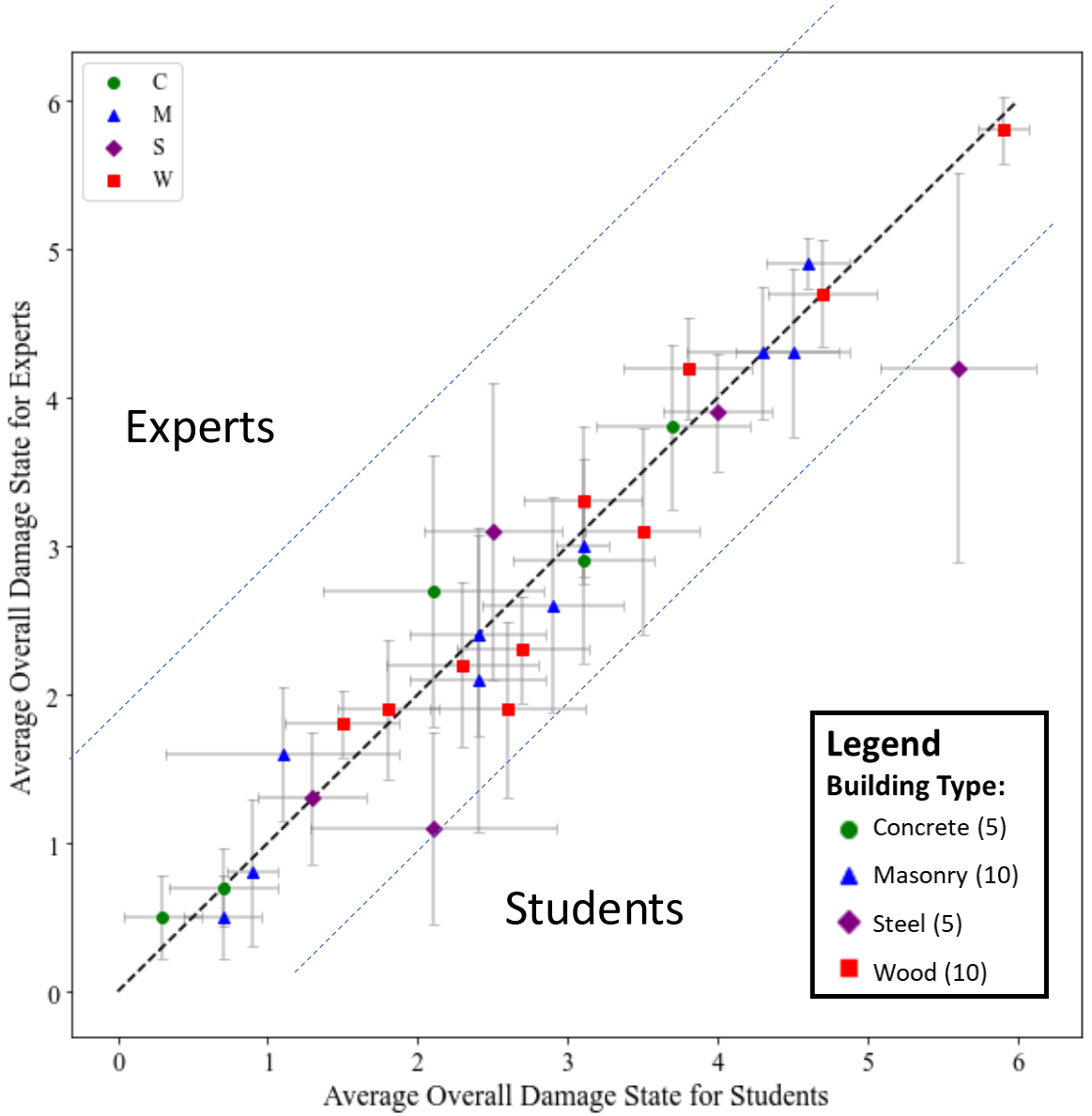
Damage Description: Roof has large holes and suffered heavy damage; Walls have been destroyed on front of house...
Confidence Level: High
Source of Data: StEER Aerial Imagery and Streetview

An example of VDA details

Figueira, S.A., Amini, M., Cox, D. T. & Barbosa, A. R. (**Forthcoming**). Virtual Structural Damage Assessment of Buildings in Fort Myers Beach, FL Subject to Impact from Hurricane Ian (2022)". Natural Hazards Review. 10.1061/NHREFO/NHENG-2310.

Data Validation (Damage States)





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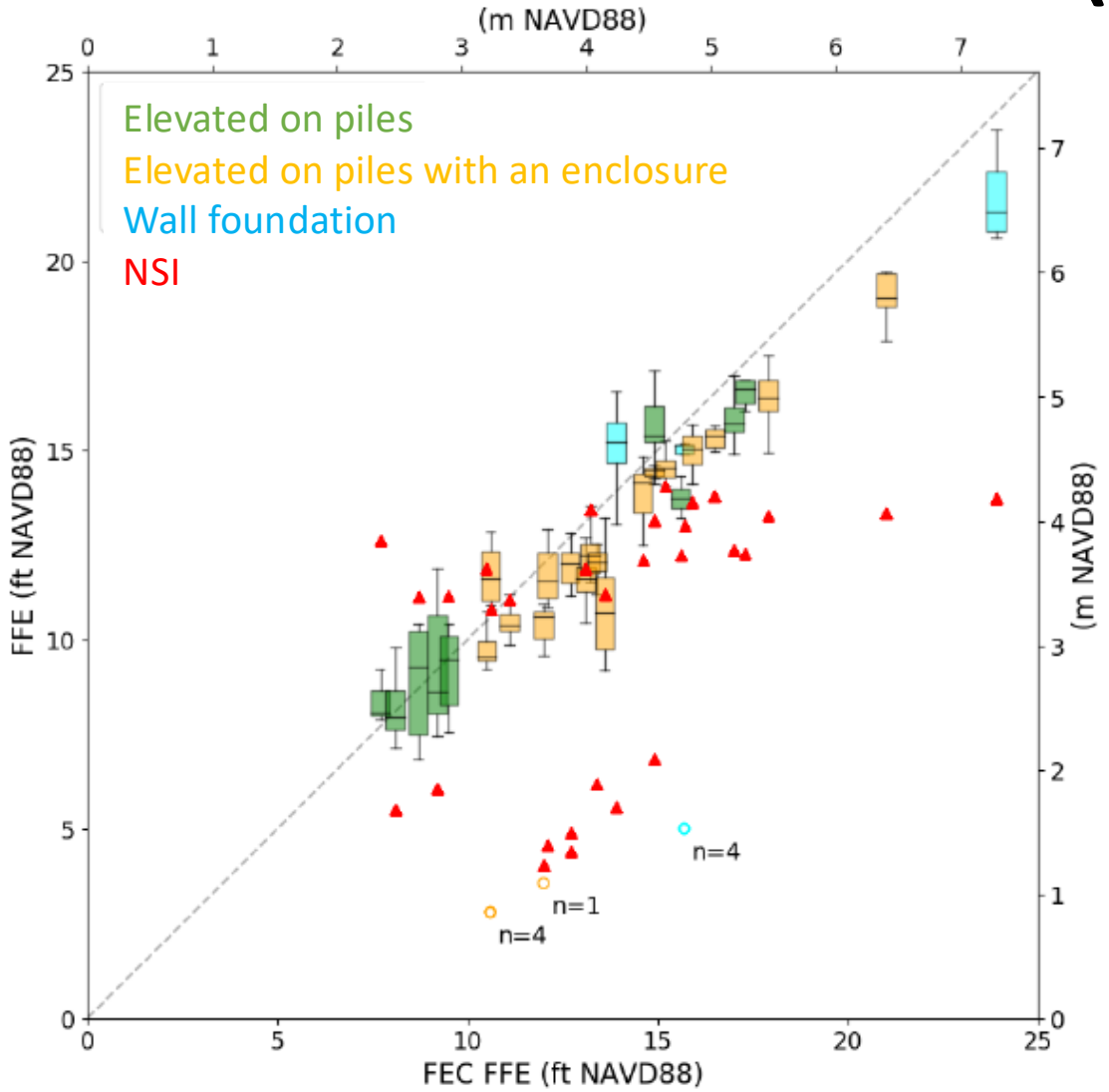
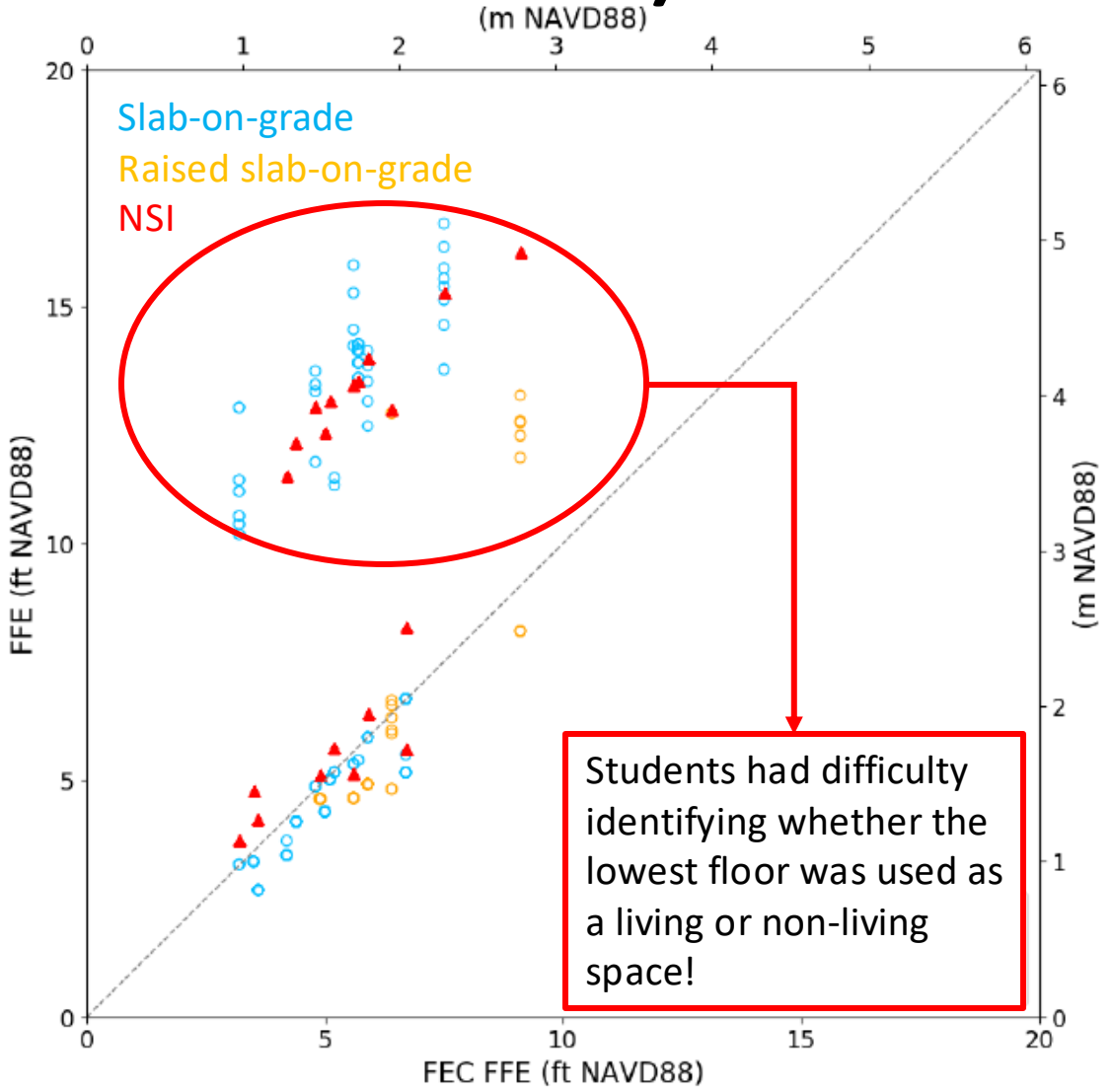
VDA vs NSI Data Validations (First Floor Elevation)





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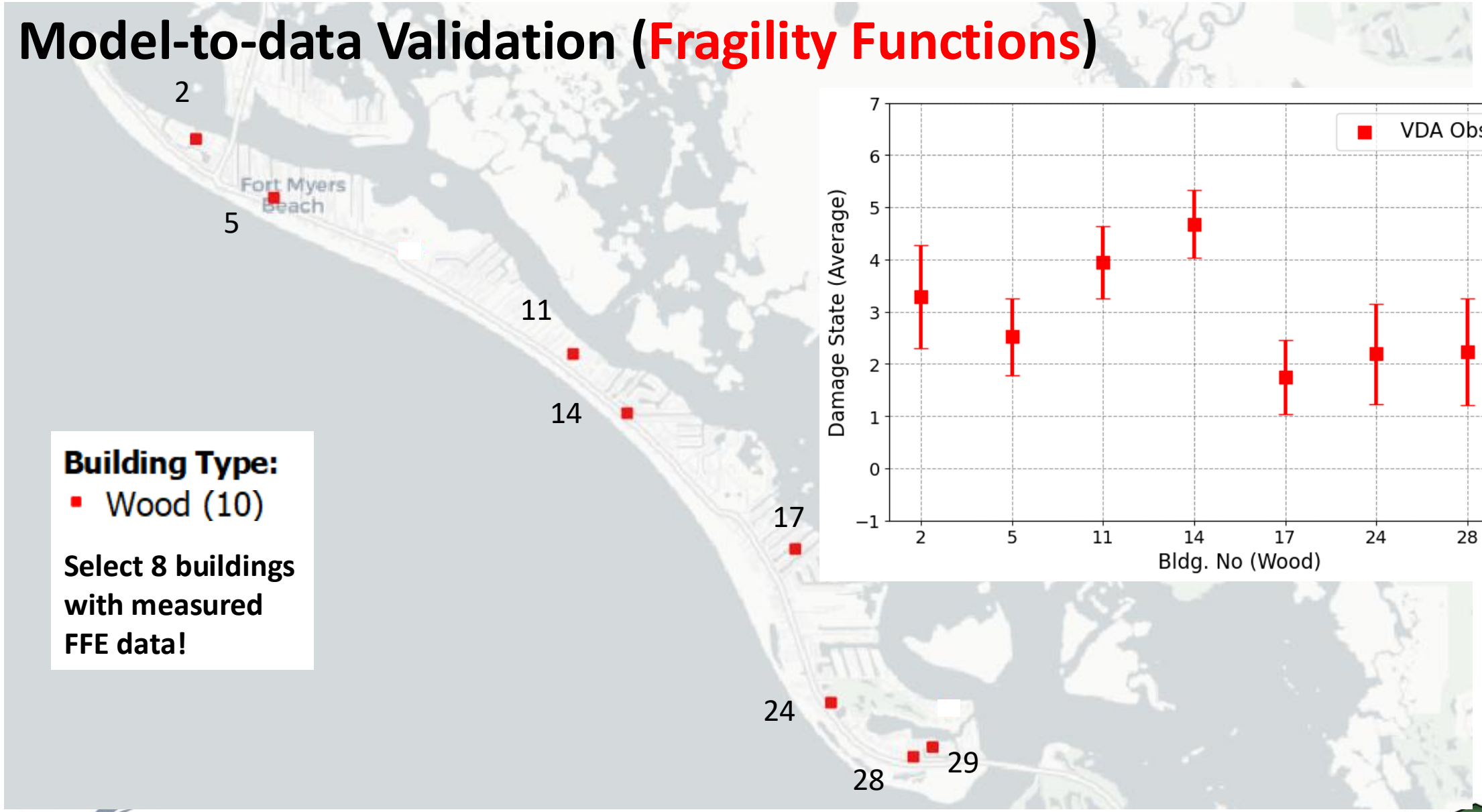
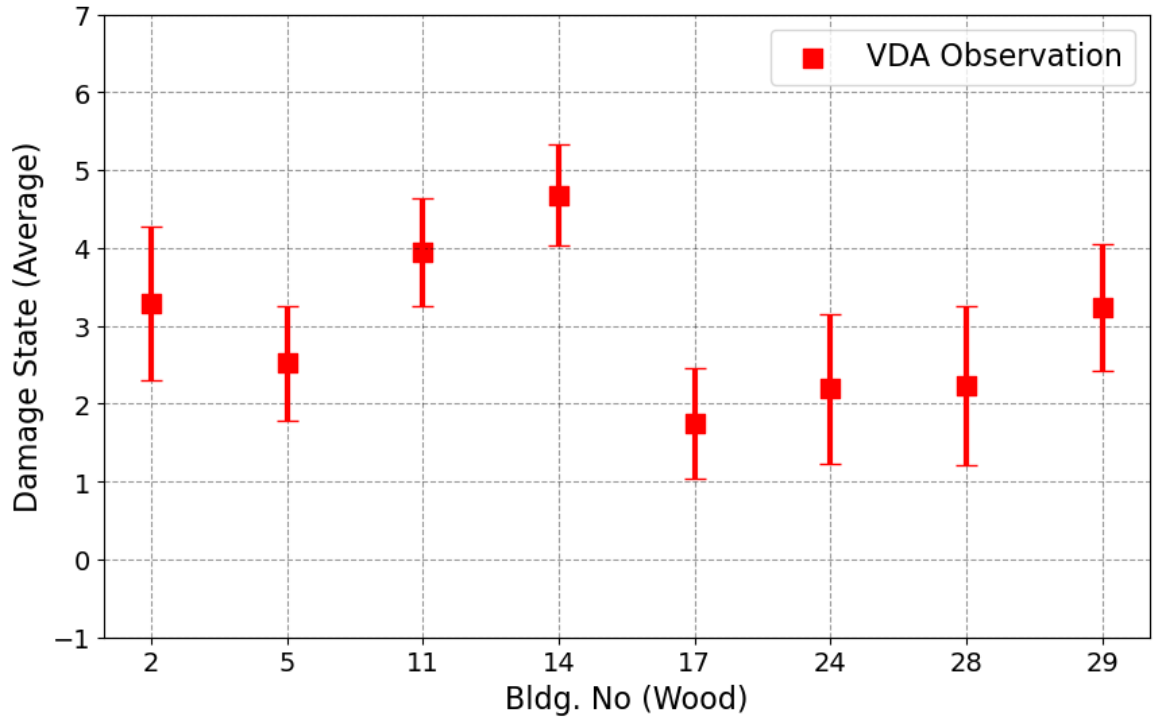
Model-to-data Validation (Fragility Functions)



Building Type:
- Wood (10)

Select 8 buildings with measured FFE data!



Model-to-data Validation (Fragility Functions)

Tomiczek et al. (2014): **collapse limit state** -> 2,000 wood-frame buildings; Hurricane Ike (2008)

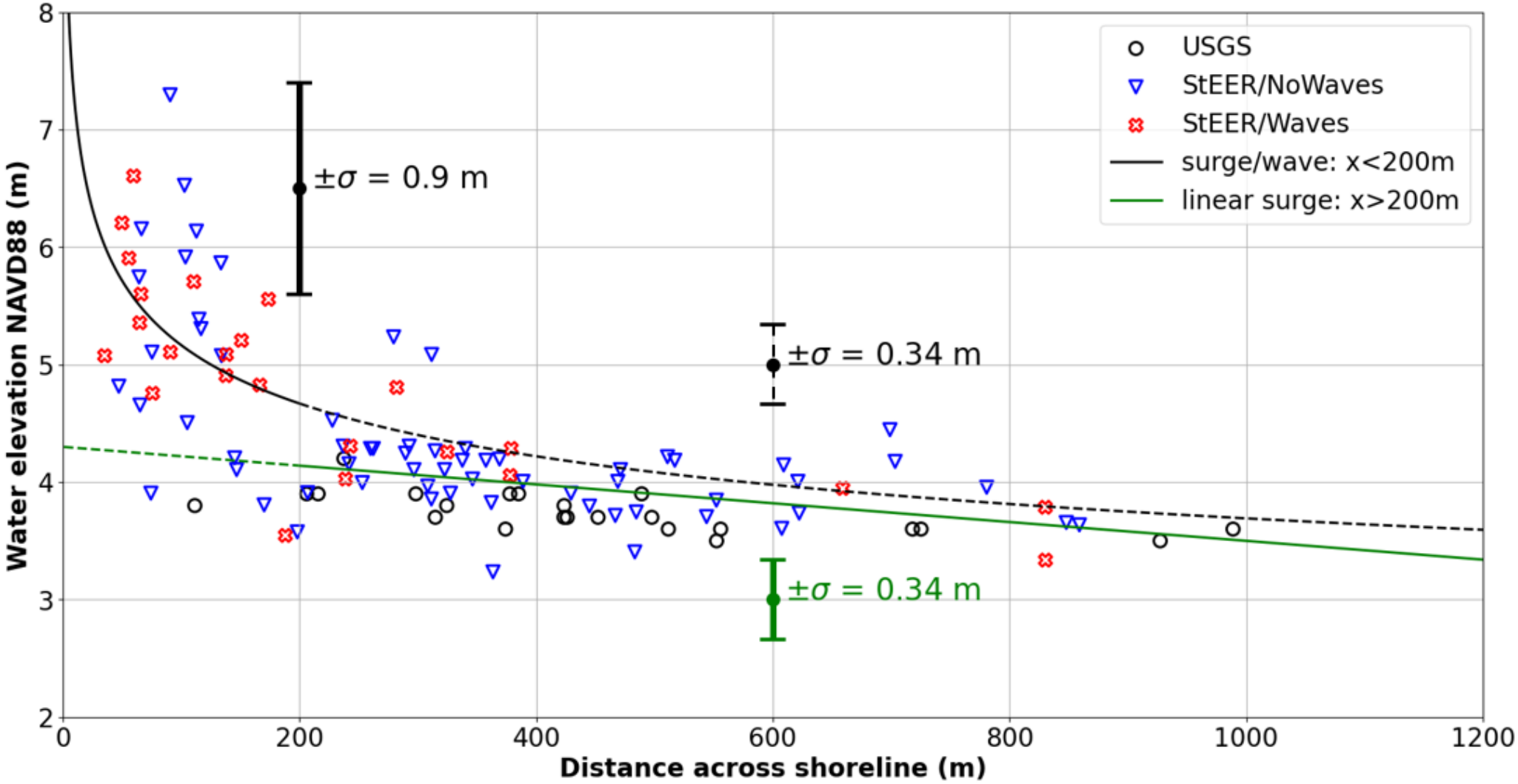
Table 1. Residual Variances for Fragility Regressions

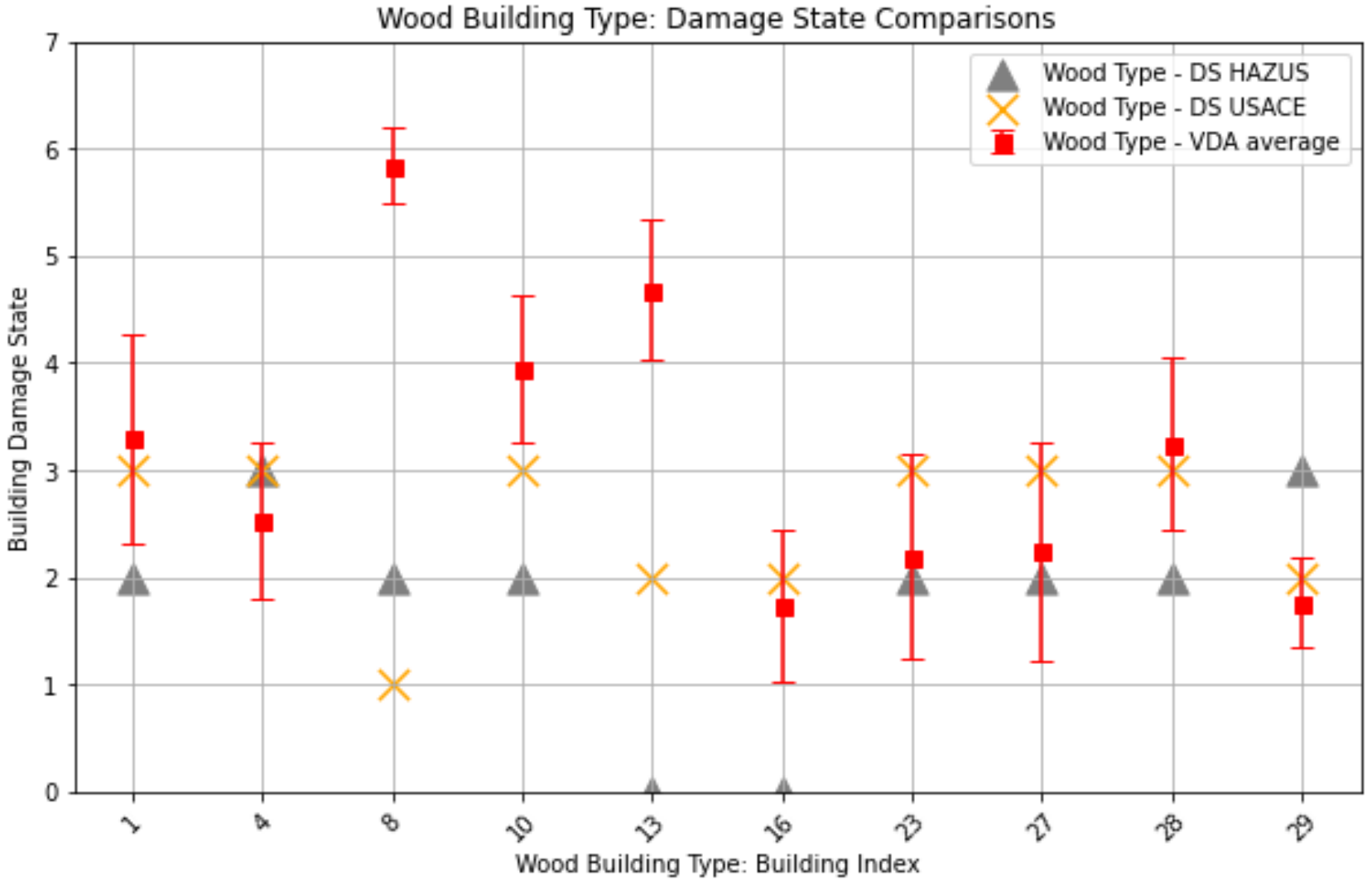
Regression variant	H_S (m)	FB_{Hs} (m)	Age group	V_{H2O} (m/s)	All FEMA/ ASCE loads	Modified slamming load ($H_{1/250}$)	Relative residual variance RY^2
1			X		X		0.634
2			X	X			0.7612
3		X	X	X			0.5647
4	X	X	X	X			0.3618
5	X	X	X				0.3909
6			X			X	0.3921
Data range	(0.75, 2.23)	(−4.0, 1.8)	(1, 2, 3, 4)	(0.43, 1.61)			
Useful regression limits	(0.8:2)	(−3: 1)	(1, 2, 3, 4)	(0.5:1.5)			

Note: X's denote variables used in each regression variant.

1. Age + ASCE/FEMA equations show some skill, but fairly large residual
2. Age + V_{H2O} gives worse agreement (wave height is important)
3. Age + V_{H2O} + FB improves skill somewhat
4. Age + V_{H2O} + FB + Hs shows best overall skill
5. **Age + FB + H_s shows good skill (V_{H2O} does not add as much as H_s)**
6. Mod. Slamming Force shows good skill

Water Elevation (including wave effects)



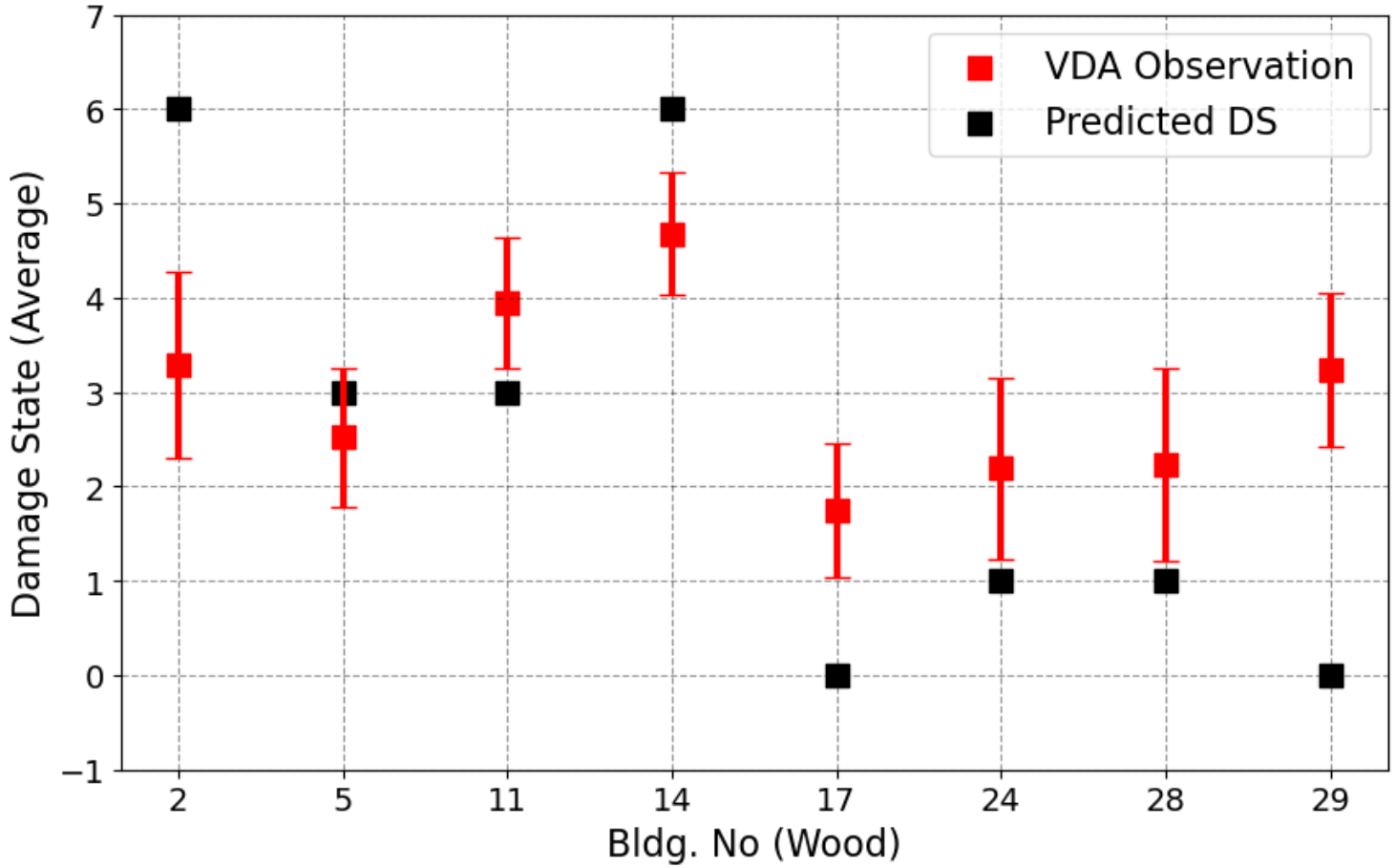


Damage State	Description	Damage as a % of Structure Value
DS0	None	0 %
DS1	Minor	0 to 10 %
DS2 and DS3	Moderate	10 to 30 %
DS4	Major	30 to 60 %
DS5 and DS6	Severe	60 to 100 %

USACE (2015) North Atlantic Coast Comprehensive Study - Resilient Adaptation to Increasing Risk: Physical Depth Damage Function Summary Report http://flrules.elaws.us/reference/ref-13158

Model-to-data Validation (Fragility Functions)

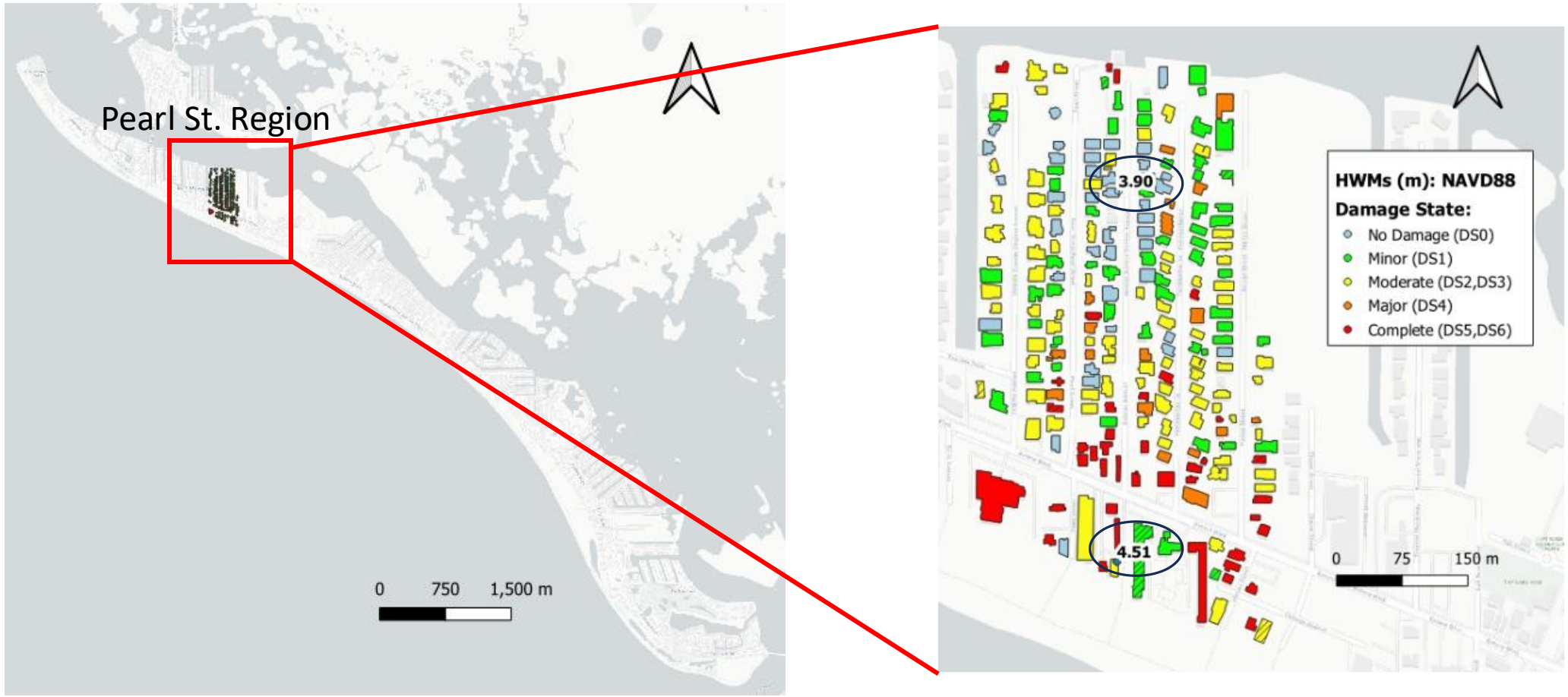
- A set of **new empirical fragility** functions based on multinominal logistic regression:
  - input variables: distance from shoreline, freeboard above water level, and year-built.



Amini, M., S. A. Figueira, D. T. Cox, & A. R. Barbosa, A. Luettich, M. V. Bilskie, Z. Cobell. (**in preparation**). Vulnerability Analysis and Empirical Structural Damage Fragilities Considering Distance from Shoreline for On-grade Buildings Impacted by Hurricane Surge and Waves. Journal of Structural Engineering, ASCE.

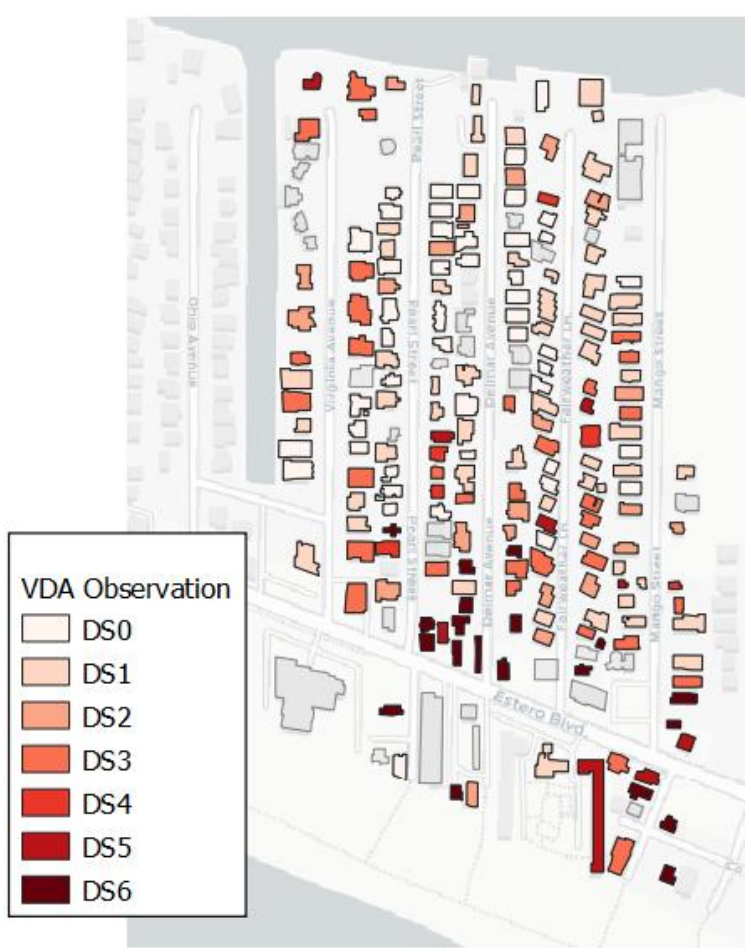
Model-to-data Validation (Fragility Functions) … NEXT STEPS

- There are a total of 247 buildings in the Pearl St. Region.



Model-to-data Validation (Fragility Functions) … NEXT STEPS

Pearl St. Region



Predicted damage (TBD)

Use of IN-CORE for validation of loss assessments considering uncertainties in:

- Water Elevation/Inundation
- VDA vs NSI characteristics
  - Building type
  - First floor elevation
- Damage state measurements
- Fragility functions
  - New empirical fragility
  - USACE
  - Hazus

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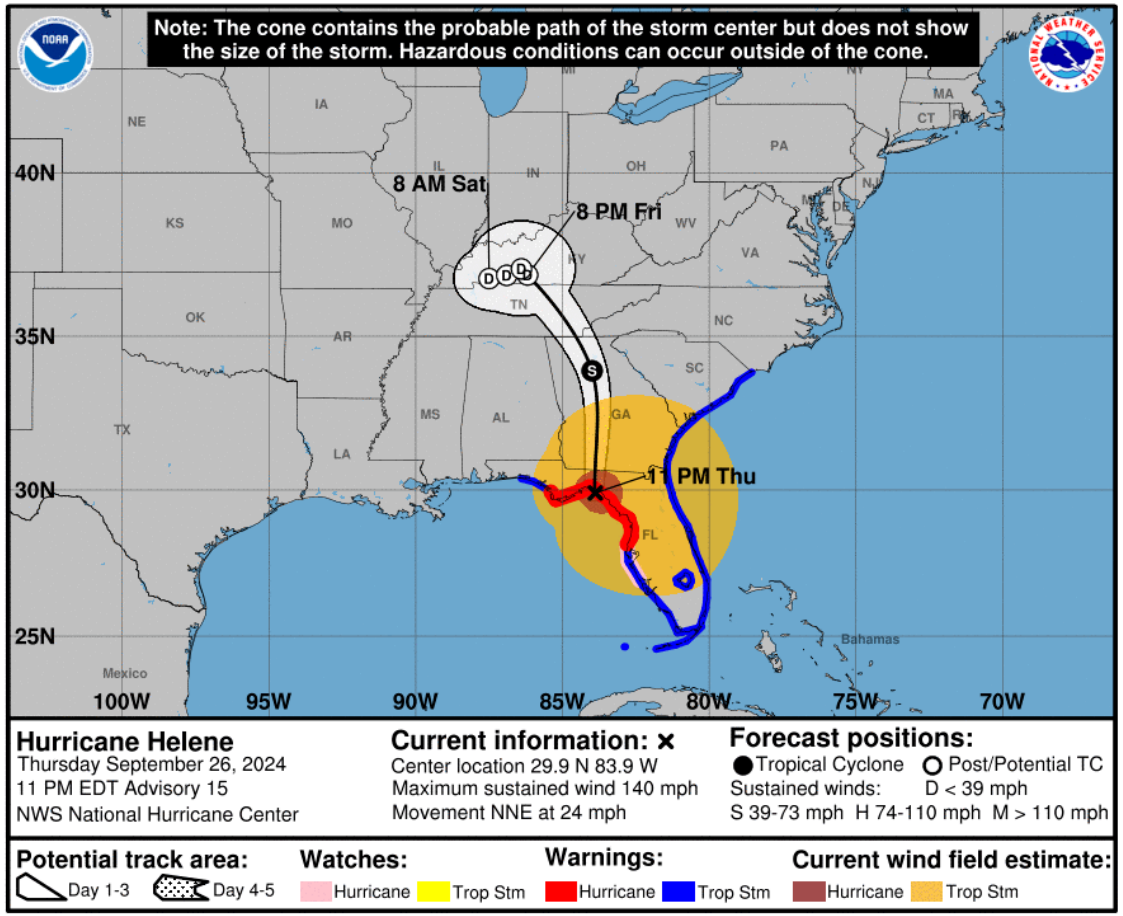
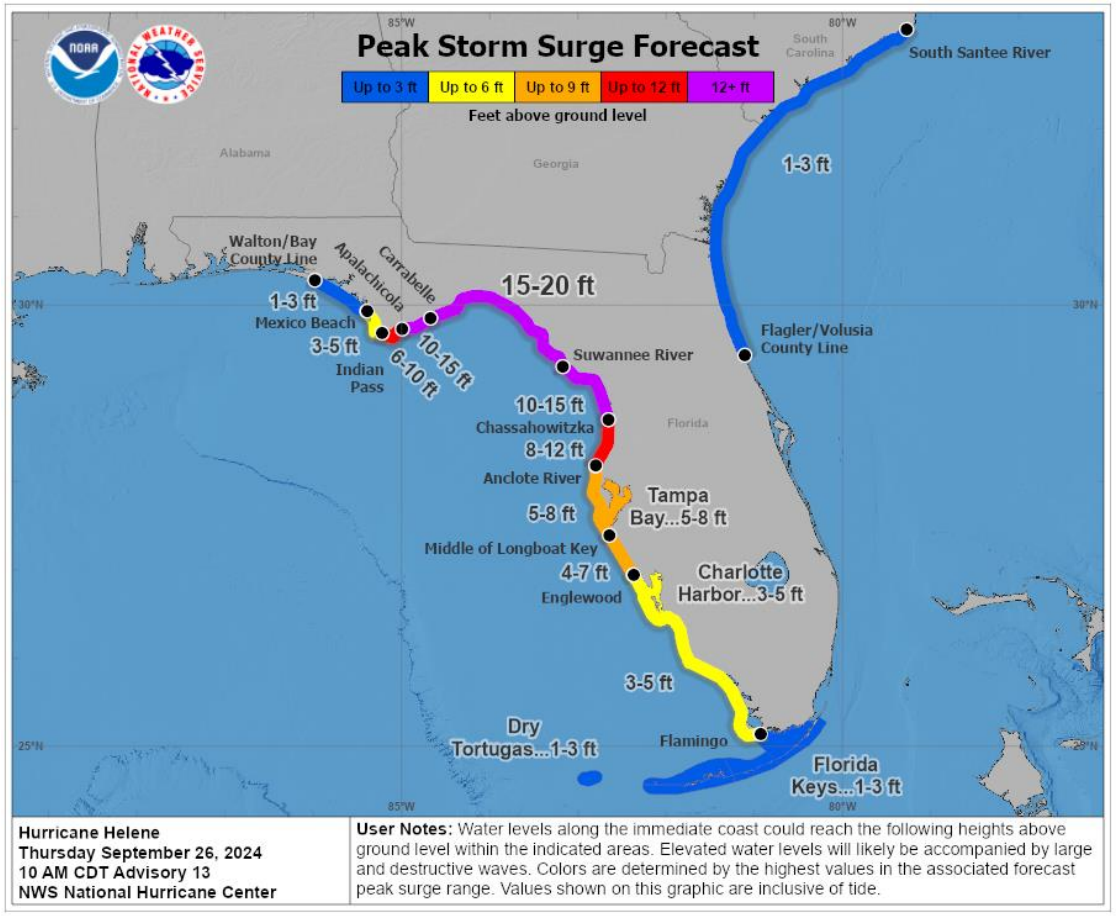
Hurricane Helene (2024)

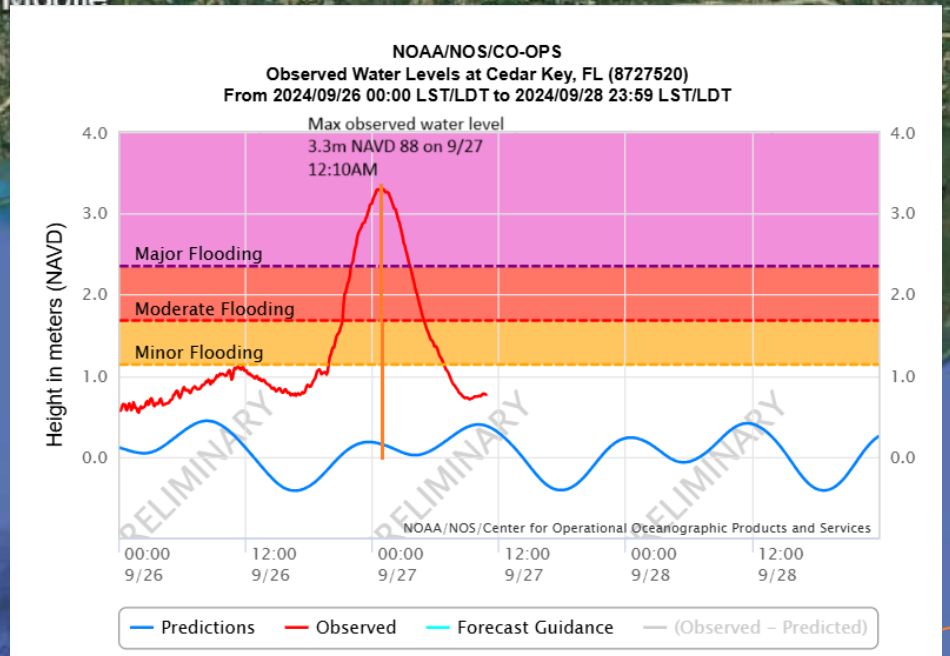
- Made landfall as a Category 4 Hurricane on September 26, 2024 (wind speed 130-156 mph)

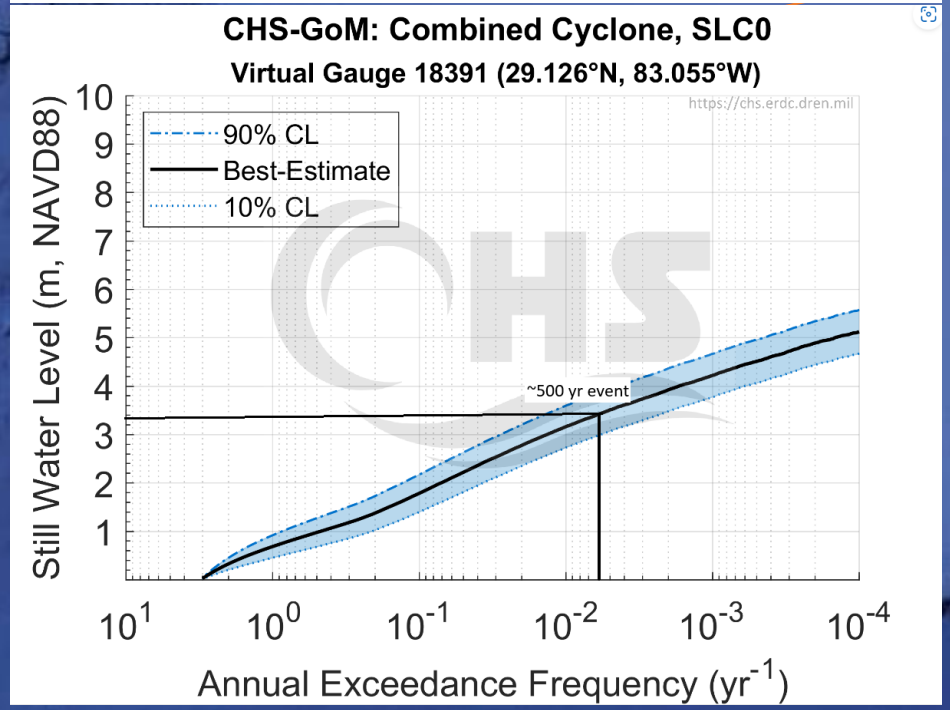




Source: https://www.nhc.noaa.gov/archive/2024/HELENE_graphics.php

Hurricane Helene (2024)



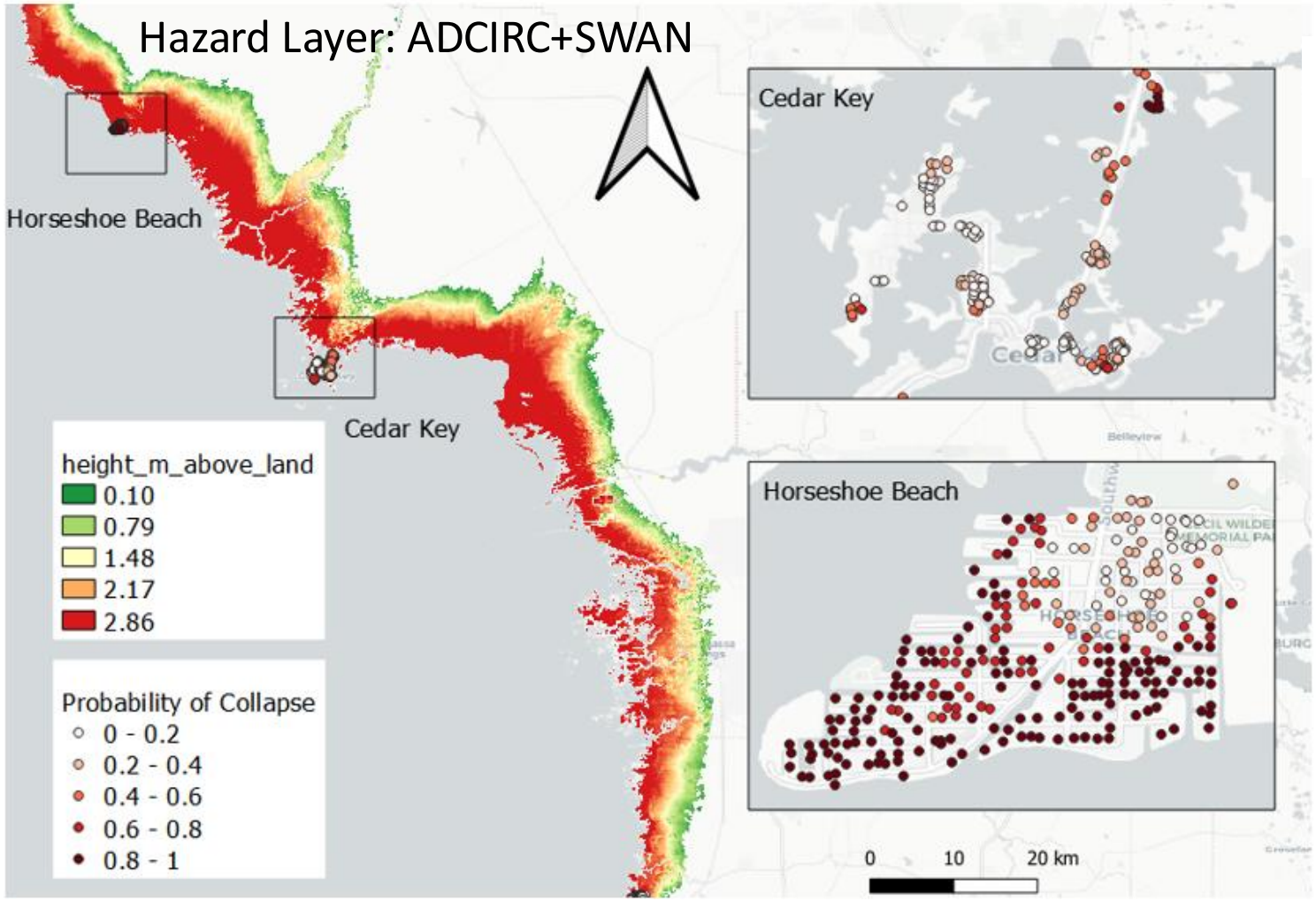


Cedar Key, FL

Tallahassee
Jacksonville
St. Augustine
Gainesville
Palm Coast
Daytona Beach
Ocala
The Villages
Orlando
Spring Hill
Tampa
Kissimmee
Melbourne
Clearwater
FLORIDA
St. Petersburg
Port St. Lucie
Sarasota
West Palm Beach
Fort Myers
Fort Lauderdale
Naples
75
4
95

NOAA stations
Coastal Hazards System (CHS)

Hurricane Helene (2024) – Near Real-time Forecast (24 hrs. before landfall)



IN-CORE **Open Source Platform for Community Resilience Modeling**

- Hazard layer is provided by Dr. Rick Luettich from the NOPP team.
- Building inventory is based on NSI data (wood-frame buildings).
- Using collapse-limit fragility functions developed after Hurricane Ike, Tomiczek et al. (2014).

NOPP National Oceanographic Partnership Program

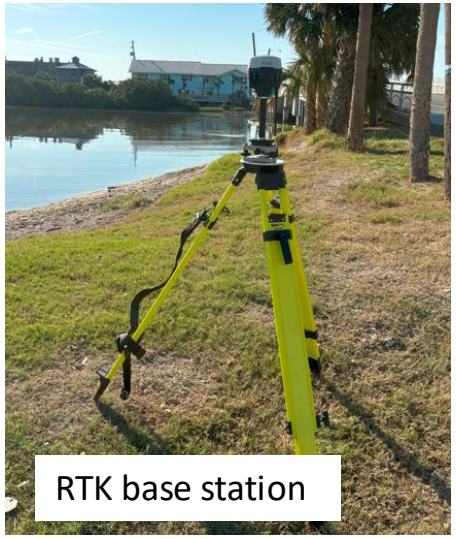
Contact: Mehrshad Amini (mehrshad.amini@uri.edu)

Hurricane Helene (2024) – Post-event Reconnaissance

- Collaboration: OSU, USNA, URI, NSF StEER, and local partners.

Selected sites for reconnaissance work 30 days after the disaster. The assessment will be repeated every 3 to 4 months to capture the recovery of the community.

- Capture 360° video of all streets for virtual damage assessment.
- Measure LHSM/FFE along with conducting damage assessment.
- Measure high-water marks (HWMs).
- Capture drone footage for regions with high levels of damage.


RTK base station


Laser level


HWMs

Future Work for V&V

- Characterize uncertainty in hazards, including flow velocity and overland wave heights (e.g., higher spatial resolution for collecting HWMs)
- Conduct cross-walking between different flood damage and loss modeling:
  - Mapping interior damage to the exterior damage states
  - Cross-walk new empirical functions with USACE and Hazus-MH depth-damage and wave crest-loss functions.
  - Convert interior damage to the exterior damage to monetary losses (using claim data – pending on going conversations with FEMA).
- Compare VDA Damage Based Assessments using USACE, Hazus, and new empirical fragility function for the FMB

Upcoming presentation/workshop

- Model-to-data validation using IN-CORE:
  a. Preliminary presentation at NOPP meeting (UF, Nov 20).
  b. Presentation at NHERI computational symposium (UCLA, Feb 6+7).
- **NIST-sponsored Hurricane Ian workshop: Fort Myers, Florida, March 17 + 18, 2025. Please reach out for details!**
  - **Three main efforts: (1) impact of wind, (2) flood impacts, (3) evacuation and response.**