

# Predicting Housing Damage in Hurricanes

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This collaborative project combines county-level housing data with detailed rain, wind, and flood data from NOAA and social vulnerability data from the CDC to formulate a regression model for predicting post-hurricane housing damage. Using damage data collected by the Red Cross and applying a systematic approach to model selection, the project team was able to generate an optimal predictive model for the historical context of Hurricane Michael. This poster presents and discusses the preliminary results of extending this initial work to other disaster events, in order to characterize the ability of the model to generalize beyond its initial setting and thus to provide value for future decision making.

## Hurricanes

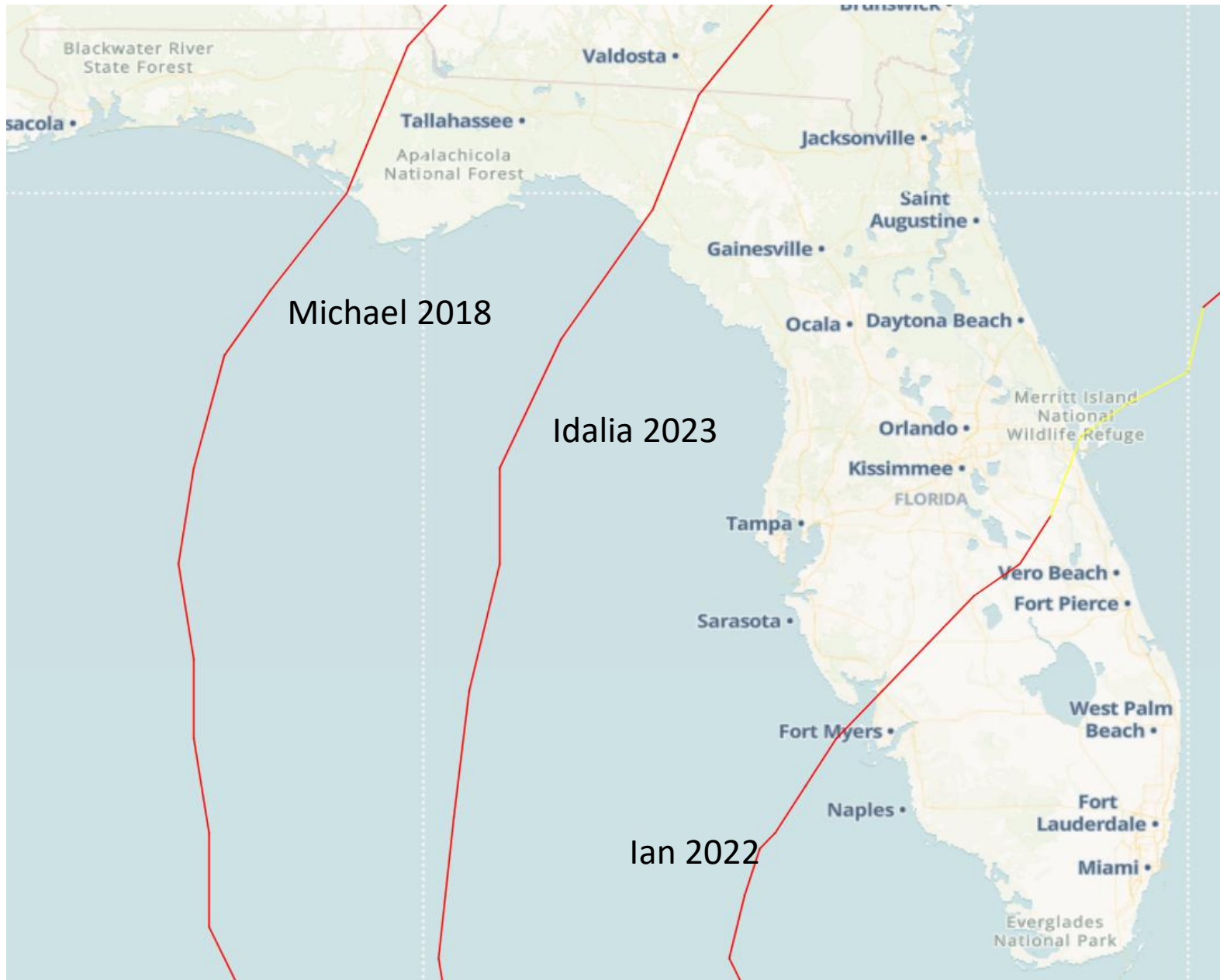
This research utilizes data from three Hurricanes that made landfall in Florida: Hurricanes Michael in 2018, Ian in 2022, and Idalia in 2023.

Hurricane Michael made landfall in the Florida Panhandle on October 10, 2018. The storm was the first Category 5 hurricane to hit the contiguous United States since 1992. Maximum sustained wind speeds were 140 mph after landfall and there were rainfall amounts up to 16" reported in some locations. Storm surges reached 6-9' levels in the area of landfall. There were 59 deaths in the United States due to the storm, and an estimated \$25 billion in damages. FEMA Disaster Declaration 4399 provided assistance for impacted individuals in 12 counties in Florida.

Hurricane Ian made landfall in the Fort Myers area on September 28, 2022. The storm was weakened to Category 4 just before coming ashore, and was the strongest storm to impact this area of Florida in 18 years. Maximum sustained wind speeds were over 135 mph with rainfall amounts exceeding 20" in many locations. Storm surges reached 10-15' in the Fort Myers, Cape Coral and Naples areas. There were 161 deaths in the United States (150 of those in Florida) due to the storm, and an estimated \$112 billion in damages, the costliest in Florida history. FEMA Disaster Declaration 4673 provided assistance for impacted individuals in 26 counties in Florida.

Hurricane Idalia made landfall in the Big Bend region on August 30, 2023. The storm was Category 3 at the time, with wind speeds at 125 mph and rainfall totals . Storm surges were 7-12' in areas of the Big Bend. There were 12 deaths in the United States due to the storm, and an estimated \$3.5 billion in damages. FEMA Disaster Declaration 4734 provided assistance for impacted individuals in 18 counties in Florida.

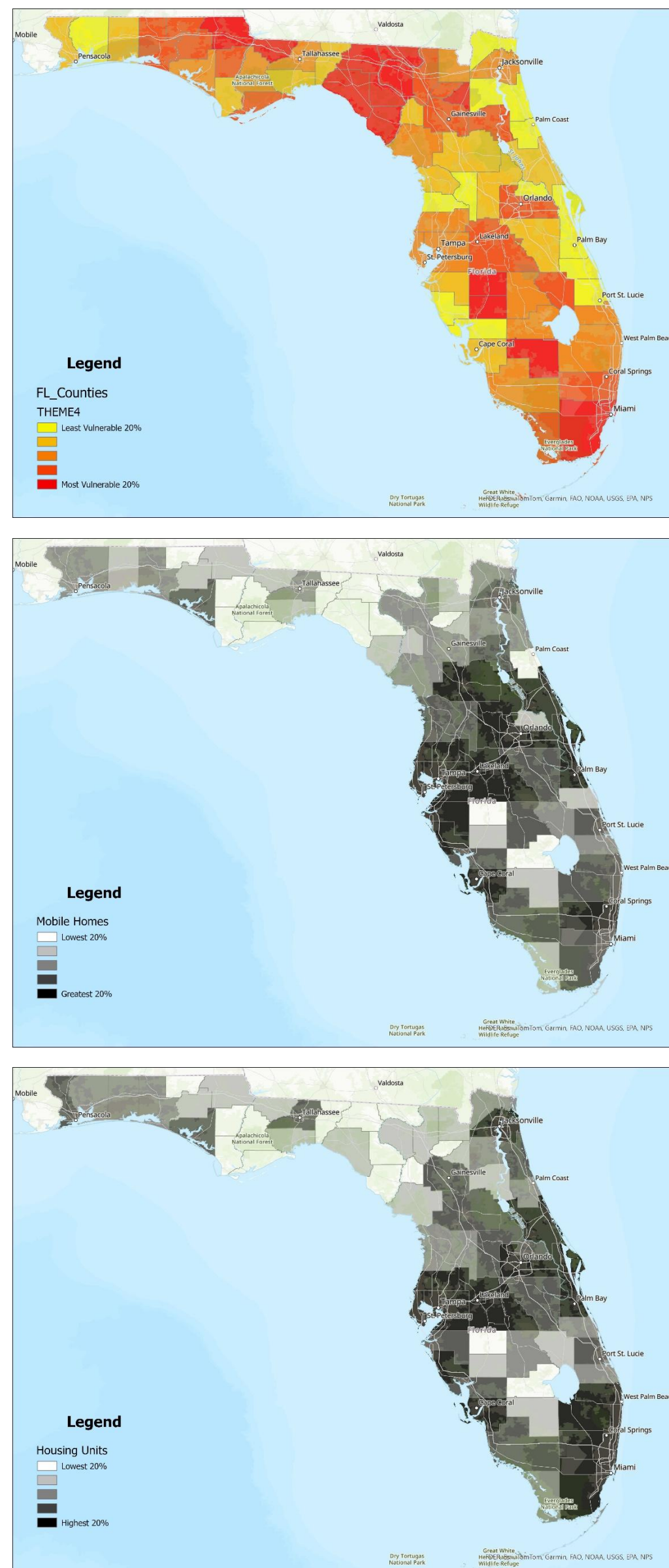
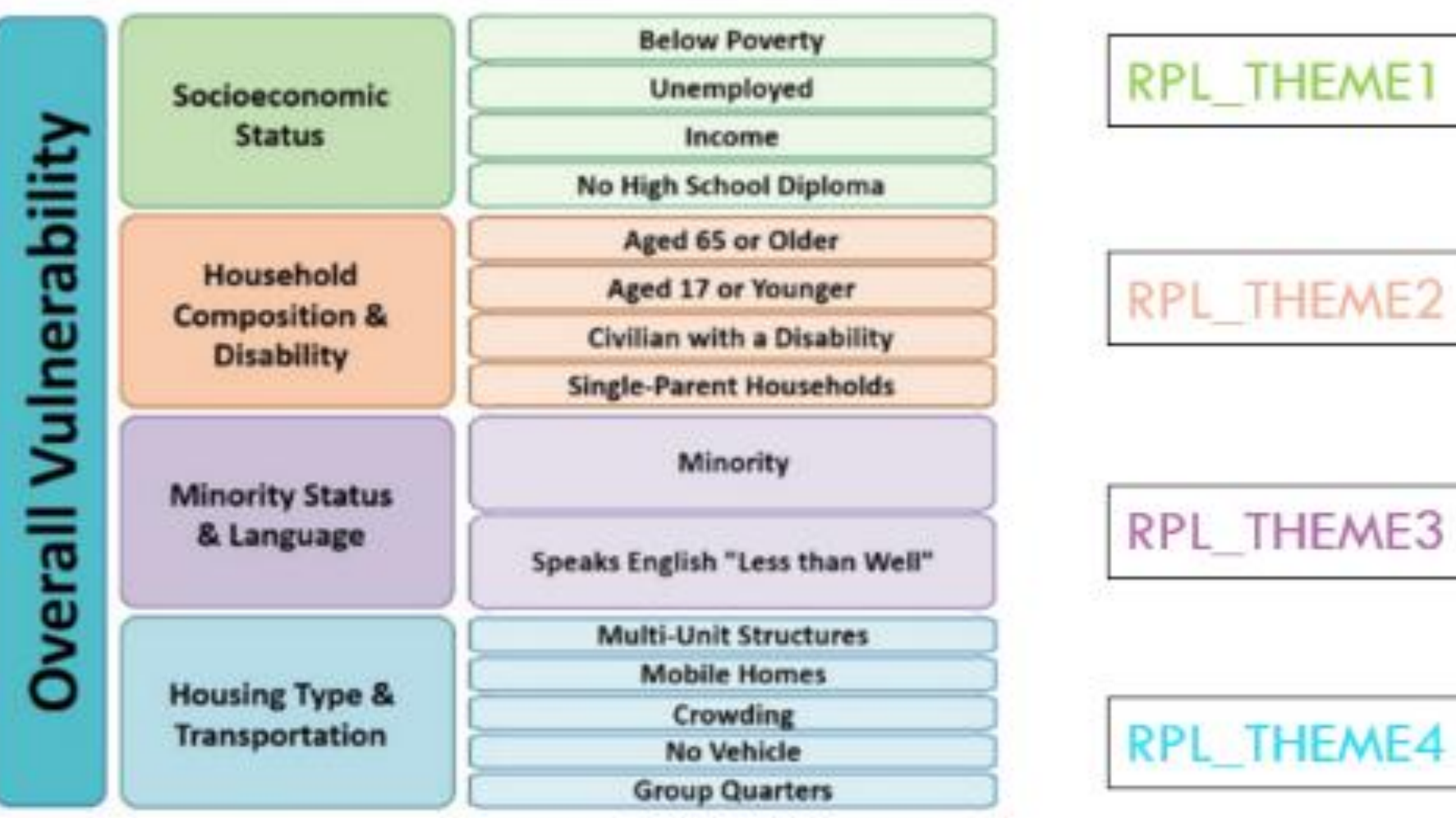
Data was collected from NOAA and AWOS stations and interpolated in ArcGIS to find the maximum wind speeds and maximum amount of rainfall for each county. While USGS flood data was available for Michael, there was no data for Idalia, and data for Ian was inconsistent, so flooding was removed from this analysis. However, preliminary analysis for Hurricane Michael showed that flooding was inconsistent at the county-level, with rainfall being a stronger predictor. To account for the possibility of storm surges that can cause flooding, we have included a binary independent variable for each county indicating if it resides along the coast.



## Social Vulnerability

Social vulnerability is a measure of the effect that socio-economic and demographic characteristics have on a community in the face of a disaster (natural or anthropogenic). This project focuses on the Social Vulnerability Index (SVI) created by the Centers for Disease Control and Prevention (CDC), in conjunction with the Agency for Toxic Substances and Disease Registry (ATSDR). This metric is widely used by government agencies and NGOs such as the Red Cross. The SVI utilizes 16 different variables drawn from US Census data, combining them into four categories (themes). The CDC ranks the counties for each theme within the state, and all models utilize the same SVI values per county.

Additionally, mobile homes and the number of housing units per county are two additional independent variables.

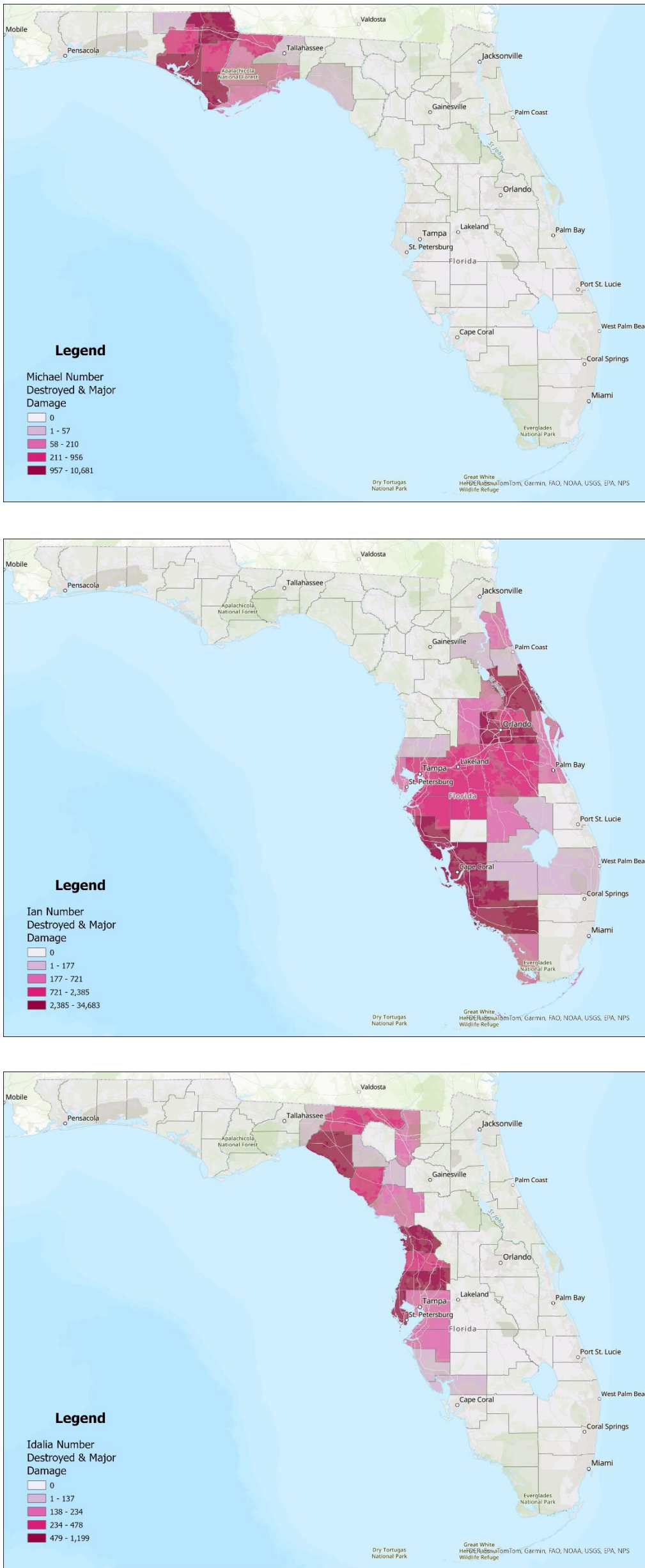
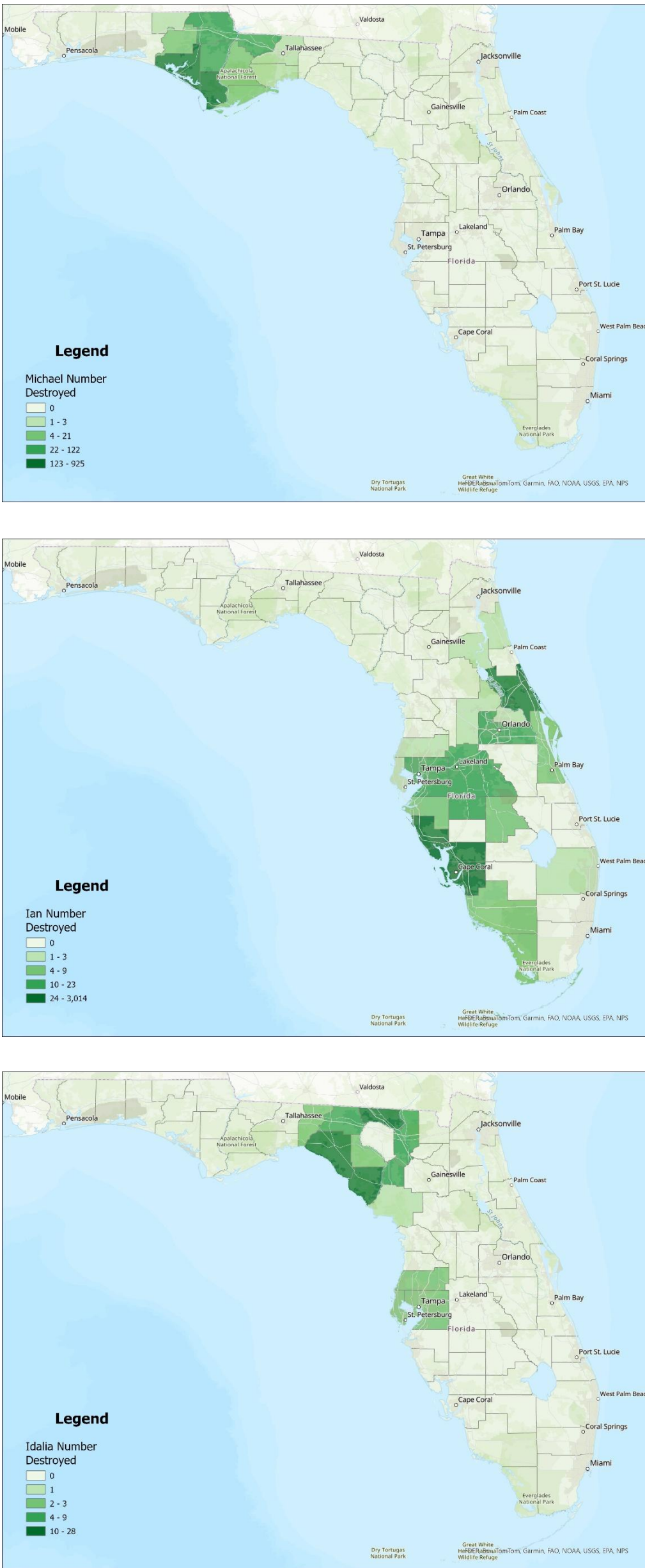


## Damage

The Red Cross conducts initial damage assessment after a disaster. This information is provided to FEMA and serves as the starting point for claims to be processed. Both organizations utilize a four-level damage assessment tool, going from least severe to most severe as follows: affected, minor, major, and destroyed. Our research focuses mostly on the major and destroyed category, as people residing in structures that sustain these levels of damage are most likely to require sheltering by the Red Cross in the aftermath of a hurricane.

Given the varying intensity, and the locations, of the storms, the amount of damage varies greatly across these three hurricanes.

- For Hurricane Michael, there were 98,975 claims across 12 counties, with 1,335 destroyed (1.35%) and 14,374 major (14.52%) claims.
- For Hurricane Ian, there were 898,824 claims across 25 counties, with 3,434 destroyed (0.38%) and 78,699 major (8.76%) claims.
- For Hurricane Idalia, there were 63,192 claims across 17 counties, with 88 destroyed (0.14%) and 6,330 major (10.02%) claims.



## Preliminary Results

A negative binomial regression model was created to assess the relationship between vulnerability, weather, housing, and damage. The dependent variable was the number of households that fell into the combined destroyed & major damage categories within each county. The independent variables included the four SVI themes, the two weather values (wind and rain), location of the county (coastal / inland), and the normalized number of mobile homes and total housing units in each county. Each storm was analyzed separately, and all three storms were also analyzed together. Models were created for all different possible combinations of independent variables, restricting the results to models with VIF < 10 and using the AIC and McFadden R<sup>2</sup> values to assess model quality. The resulting best model in each case was as follows.

	(intercept)	theme1	theme2	theme3	theme4	wind	rain	housing	mobile_homes	coastal
Idalia	1.82 **	3.86 ***	-1.42 ***	-3.12 ***	1.89 ***	2.86 ***			3.95 ***	
Ian	6.65 ***		-3.80 ***				3.81 ***		2.19 **	
Michael	0.98 *			1.07 .		5.56 ***	1.79 ***	-30.48 ***	23.94 ***	-0.53 *
Combined	5.32 ***	-2.72 **			1.56 *	1.85 *	2.04 **	2.08 .		

. p<0.1, \* p<0.05, \*\* p<0.01, \*\*\* p<0.001

Recognizing, however, that there is very little difference in model quality across the top 10 best fit models in each of these four cases, and thus that these models are not necessarily representative of overall behavior, the charts below provide a more comprehensive view. Each pie chart gives the relative number of times each of the main factors appeared across the top 10 models, based on the AIC, for each storm (and for the combined data set across all three storms). The results show that wind and particularly rain tend to be predictive factors more often for Ian and Michael than for Idalia, while coastal locations tend to contribute less to the damage for Ian (and mobile homes tend to contribute more) than they do for the other two. The SVI themes also vary, with vulnerability taking on more importance overall for Idalia, along with a greater focus on themes 1 and 4 than in the other two storms – this more significant role for vulnerability is also reflected in the combined results. Ongoing efforts are working on refining these results further.

