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A Systematic Revision of the NFIP Claims Hazard Data in Florida for Flood Risk Assessment

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Abstract: The hazard components of National Flood Insurance Program (NFIP) claims data in Florida were systematically analyzed and revised in the current study. The provided fields in NFIP claims data are not always complete or accurate and are often missing. The authors associated each claim to a proper flood hazard event by updating the provided catastrophe number using the National Hurricane Center HURDAT2 (best track data). The claims with presumably incorrect *cause of loss* fields were identified and revised by adding a variety of other available information to claims data. These datasets included tropical cyclone events, rainfall maxima, and distances to the nearest coast. The enhanced information assisted in identifying the cause or likelihood of a hazard event or attributing a particular hazard event to a loss claim. The revised NFIP claims data will be intensively used to validate the outcomes from flood hazard (i.e., surge, wave and inland flooding) models and to develop a flood vulnerability model in the forthcoming Florida Public Flood Loss Model (FPFLM).

Keywords: NFIP claims; flood risk; flood insurance; flood cause of loss; HURDAT; catastrophe model

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1. Introduction

The Florida Commission on Hurricane Loss Projection Methodology (FCHLPM), under legislative direction, published Flood Standards Reports of Activities [1] similar in concept to the current hurricane wind hazard standards [2]. Accordingly, the Florida Office of Insurance Regulation (FLOIR) requested the Florida Public Hurricane Loss Model (FPHLM) [3] group to undertake a project to develop a flood risk model officially called the Florida Public Flood Loss Model (FPFLM). The flood catastrophe model is to estimate and/or predict aggregated insured losses for properties in the form of annual expected losses and probable maximum losses, which can be employed by Florida state regulators and insurance companies to help evaluate premium rate filings. A developed model will be delivered to the FCHLPM, which would be acceptable under the current flood standards. The FPFLM (a catastrophe model) is to estimate possible losses caused by coastal and inland flood events. It includes three main components: (1) hazard, (2) vulnerability, and (3) actuarial components. During the development process of a risk model, flood claim (and/or exposure) data are necessary for calibration and validation of flood model outputs.

Because the Department of Homeland Security's (DHS's)/Federal Emergency Management Agency's (FEMA's) National Flood Insurance Program (NFIP) claim data have not been publicly available, there have not been many in-depth analysis studies on flood insurance claims until recently. Kousky and Michel-Kerjan [4] examined the NFIP flood insurance claims in the continental United States and found six claim characteristics (e.g., claims are lower for elevated properties and higher from storm surges). A series of studies have also concentrated on flood losses, all of which involved a translation from inundation depth to its economic impacts, e.g., [5]. Wing et al. [6] used over two million NFIP claims to assess flood depth and damage functions (or curves) for economic evaluation. They showed that the NFIP damage data could partially remedy the uncertainties in the currently employed flood depth and damage functions, which involve disparate relationships that match poorly with observations. However, these studies used the original NFIP claim data without any modification attempts in their analysis and/or development of vulnerability curves.

The widely used standard flood depth and damage curves were compiled by the United States Army Corps of Engineers (USACE) [7]. The USACE developed these curves beginning in 1970 using early NFIP loss data, local Corps studies, and the collective judgment of experts [8]. They were assumed to be well calibrated and universally applicable when used in the majority of engineering communities, even though their simple relationships do not match well with observations. Therefore, Pinelli et al. [9,10] developed a better set of flood vulnerability curves using some modified NFIP claim data for the FPFLM project. However, they did not present the detailed analysis and revision process for the NFIP loss data in their paper.

The FLOIR provided the FPFLM group with the NFIP claim data in Florida. Benefiting from this special access, the authors analyzed the NFIP claims filed between 19 July 1975 and 10 January 2014 in the current study. The claim data contained flood hazard information (e.g., date and type of event, cause of loss) and building information (e.g., house location, values, elevation, age). However, the provided NFIP claim data were not always complete or accurate. Thus, it was necessary to make significant modifications to the NFIP claim data to properly assess the risk of all significant hazard events leading to flooding. The authors undertook a major task to identify the hazard event associated with each claim in the NFIP database. While the NFIP claim data included a *catastrophe number* that purports to identify the event, it was found that this information was often incorrect or identified as unknown. Furthermore, the NFIP database listed a *cause of loss*, which the authors also found to be inaccurate or unknown.

The paper is organized as follows: the provided NFIP claim data and additional data used to revise the claims hazard information are presented in Section 2; Section 3 shows the revision process of the NFIP claim hazard data, the results thereof, and further analyses for flood risk assessments; and the conclusions follow in Section 4.

2. Materials and Methods

2.1. NFIP Claim Data in Florida

Florida accounts for roughly 37% of all NFIP policies according to FEMA. The number of total claims in the provided NFIP loss data was 240,469 for the period of 19 July 1975 to 10 January 2014. Among them, only 153,751 (63.9%) were paid claims and were hence used in the current study. The paid claim locations are shown in Figure 1.

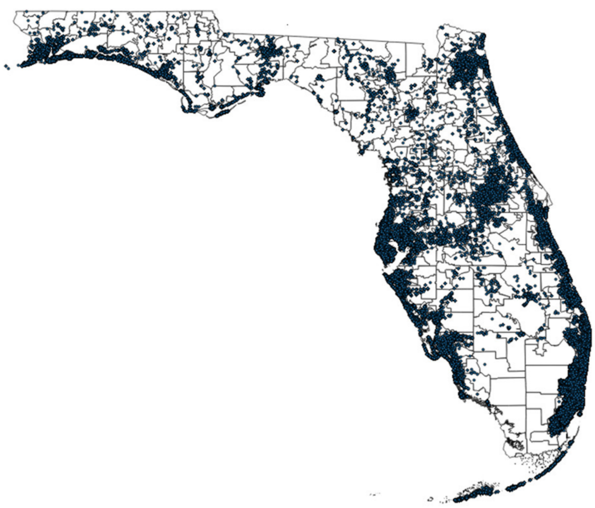


Figure 1. The NFIP paid claim data in Florida (claims period: 19 July 1975–10 January 2014).

The majority of flood damages were claimed along coastal and urban areas (e.g., Miami, Orlando, Jacksonville, and Tampa) as expected, partly because of the high frequency of storm surge hazards and partly because of the high density of the population. Although tropical cyclones are the major natural hazards, other frequently occurring intensive nontropical storm events can cause inundation damages in both coastal and inland areas of Florida.

The provided NFIP flood damage claim data contained 100 fields for hazard-, building, and actuarial-related information. These fields included *date of loss*, policy number, address (*latitude and longitude*), flood risk zone, occupancy type, *catastrophe number*, *cause of loss*, lowest floor elevation, base flood elevation, building claim payment, contents claim payment, etc. The hazard-related fields (italic font) were the main target fields to be assessed in the current study. To respect privacy, sensitive information (e.g., homeowner's address) was neither exposed nor explicitly used.

Brief descriptions of several claim fields are as follows:

- occupancy type: single-family homes or other type;
- catastrophe number: the flood event with which it is associated;
- base flood elevation (BFE): 100 year flood elevation (i.e., 1% chance of flooding);
- building and contents claim payment: how much was paid by the NFIP;
- flood risk zone: to indicate the risks in different parts of the United States, FEMA has assigned a character from the alphabet to each zone. The most hazardous flood zones are V (usually the first row of beachfront properties) and A (usually, but not always, properties near a lake, river, stream, or other body of water). Any building located in an A or V zone is considered to be in a Special Flood Hazard Area and lower than the BFE;
- cause of loss: the natural hazard cause identification for the claimed loss, as follows—0: other causes, 1: tidal water overflow, 2: stream, river, or lake overflow, 3: alluvial fan overflow, 4: accumulation of rainfall, 7: erosion—demolition, 8: erosion—removal, 9: earth movement, landslide, land subsidence, sinkholes, etc.

2.2. Additional Data to Claims

To revise inaccurate flood hazard information in the provided NFIP claim data, additional hazard-related information and land surface characteristics were added to the claim data for each claim location from a variety of resources. This information could help in identifying the cause or likelihood of a hazard event or attributing a particular hazard event to a loss claim.

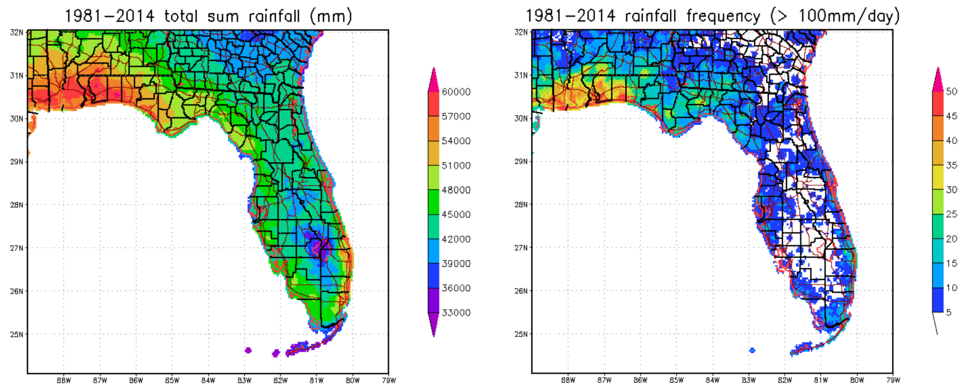
2.2.1. HURDAT2

Atlantic HURDAT2 comprises the best track data available from the National Oceanic and Atmospheric Administration National Weather Service National Hurricane Center (NOAA NWS NHC; available at http://www.nhc.noaa.gov/data/#hurdat, 11 February 2022). This dataset has a comma-delimited text format with six-hourly information on the location, maximum winds, central pressure, and size of all known tropical cyclones and subtropical cyclones. It is updated at least once per year to include the previous year's best tracks and/or historical reanalysis tracks [11].

Since many of the NFIP claims are due to tropical storms or hurricanes, HURDAT2 might be the best resource for matching historical storms to loss claims properly in Florida. The date and time of the storm track positions can be compared to the claim location and time of loss using spatial and temporal metrics to determine possible storm influence. Additional information concerning the storm intensity level (depression, tropical storm, or hurricane) can be added to the provided claims as well.

2.2.2. PRISM Rainfall

The PRISM (Parameter-Elevation Regression on Independent Slopes Model) analysis, from the PRISM climate group at Oregon State University, is particularly interesting because of its high spatial resolution (800 m to 4 km). It provides daily rainfall from 1 January 1981 to recent [12]. As a demonstration of the quality of the PRISM, rainfall total and frequency statistics for the period of 1981–2014 are shown in Figure 2. The area averaged rainfall total amount was approximately 46,000 mm for these 34 years. The right panel shows a frequency count map of rainfalls of more than 100 mm/day (i.e., ~4 inches; extremely high chance of flooding events). The Western Panhandle region of Florida appeared to be most susceptible to heavy rainfall events, along with coastal areas. Indeed, one notable recent event was heavy rain around Pensacola in 2014. In addition, Hurricane Ivan (2004) made landfall around this area, producing a strong inundation event by surge and inland flooding. Figure 3 shows the total rainfall for the Hurricane Ivan event.



(**a**) (**b**)

Figure 2. Rainfall total (**a**, unit is mm) and frequency (**b**) statistics for the period of 1981 to 2014 derived from the PRISM dataset.

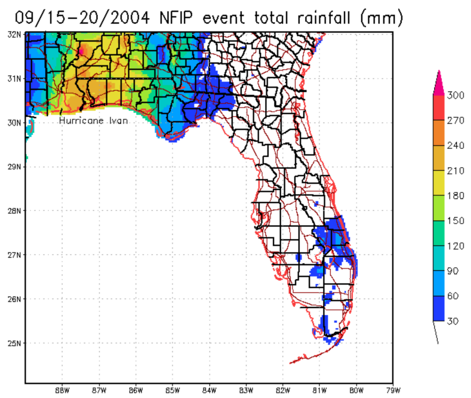
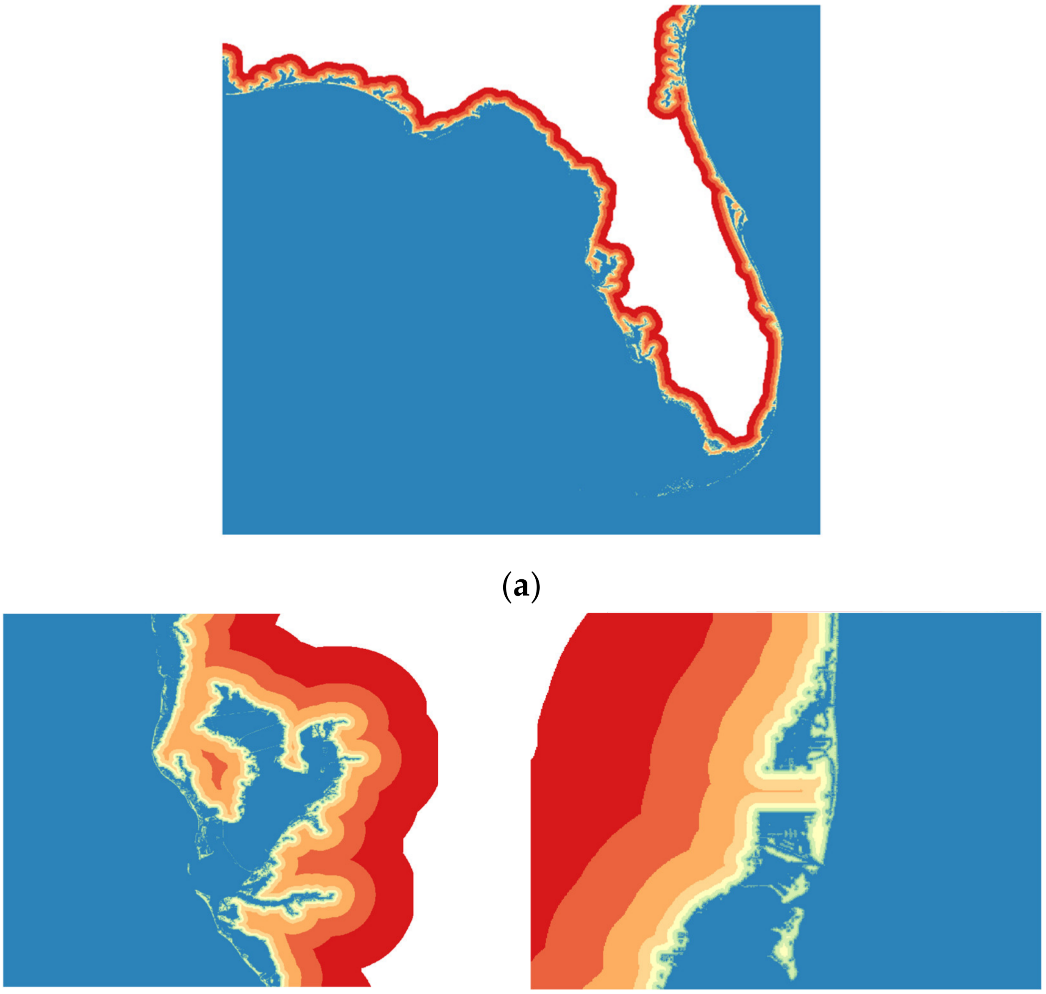


Figure 3. Cumulative rainfall for the Hurricane Ivan (2004) heavy rain event near Pensacola, Florida based on the PRISM dataset. Unit is mm. The provided event period of NFIP claims was from 15 to 20 September 2004.

Precipitation maximum data were derived from the 4 km PRISM daily rainfall database. The largest precipitation amount that occurred with ±1 day and within 10 km of the claim property location was recorded. This information helped determine whether the cause of loss could have been accumulation of rainfall.

2.2.3. NLCD Distances

The distance to coast was the distance of each claim location to the nearest coast. This information was helpful to decide whether a coastal surge flood was likely to occur. The distance was calculated using the 2011 Multiresolution Land Characteristics Consortium (MRLC) National Land Cover Database (NLCD) [13] to identify water and land locations. The NLCD has approximately 30 m resolution, allowing for a reasonably accurate calculation. Figure 4 demonstrates the quality of computed distance to coast for the Florida coastal lines, the area around Tampa, and the area around Miami.



(**a**)

(**b**) (**c**)

Figure 4. Distance to coast maps for the Florida coastline (**a**), the area around Tampa (**b**), and the area around Miami (**c**). Intervals: 20 m, 100 m, 500 m, 1 km, and 2 km.

The distance to the nearest body of water was computed in the same manner as the distance to the coast, but the distance was to the nearest body of water, regardless of water body type. This computed distance data could help to determine whether flooding could be due to river, stream, or lake overflow. However, these data were not explicitly used in the current analysis.

3. Results and Discussion

3.1. NFIP Claims Hazard Revision

The NFIP claim data had several fields that contained information that could be used to associate each claim to a flood hazard event. Among these fields were the *date of loss*, *property location*, *catastrophe number*, and *cause of loss*. The information provided by these fields was not always complete or accurate and often did not provide sufficient detail concerning the flood hazard event. For example, the catastrophe number was often missing, or multiple hazard events may have been assigned the same number if they occurred around the same time period. The cause of loss often appeared to be incorrect based on other information. There were cases, for example, in which the loss was listed as *tidal water overflow* even though the property was too far from the coast to be affected by tidal water.

The claim data often did not provide important details of the hazard, such as the flood elevation or wave conditions.

3.1.1. Catastrophe Event Number Matching

Our first task was to attribute meteorological events to claim data that were grouped by a *catastrophe number* or *date of loss*. Using a summary table provided by NFIP, the authors were able to determine the causative event for most of the groups of claim data. The results of this work were used to determine which historical events should be focused on in our modeling studies. These results, however, did not provide details of the cause of loss on the individual claims level. Our initial focus was on determining the types of events that we may need to consider in order to update the FPFLM hazard models.

Among the paid claims, 34,257 (22.3%; money-wise USD 498,827,000 (13.4%)) did not include catastrophe event numbers. The HURDAT2 tropical cyclone information was used to match tropical events to the NFIP claim data. If loss claims were located within 700 km of a storm center during the event date, it was considered that the claims belonged to that storm event. Of the 153,751 claims studied, 108,244 were detected by the HURDAT2 storm name check within claim event dates to keep and/or modify the original catastrophe event number. In addition to the provided claim count and paid amount, the revised statistics are shown in Table 1 for selected catastrophe events. The event number zero was assigned for the unidentified events. While the distinguishable number of claims were now attributed to several of the last century's hurricanes (Major Hurricane (MH) Frederic (1979), MH Georges (1998), MH Mitch (1998), etc.), not many claims were modified for recent hurricanes, perhaps because of a better collection system for claim data in the NFIP. An example of catastrophe event number updates is shown in Figure 5.

Table 1. NFIP catastrophe event number revision (selected events among total 158 events).

Catastrophe Event Number	Provided		Revised		Event
	Claim Count	Paid Amount (Thousands of USD)	Claim Count	Paid Amount (Thousands of USD)	
0	34,257	498,828	27,080	374,330	
22	32	814	897	8686	MH Frederic (1979)
131	3248	40,163	4258	51,425	MH Georges (1998)
133	1466	20,518	854	14,323	
134	8	51	206	2471	MH Mitch (1998)
182	2492	49,429	2515	49,656	MH Charley (2004)
564	3247	139,821	3278	140,967	MH Andrew (1992)
615	241	3386	779	11,787	H Earl (1998)
641	3278	106,816	4789	139,913	MH Frances (2004)
643	10,353	945,500	10,619	959,392	MH Ivan (2004)
646	3800	90,497	3918	93,128	MH Jeanne (2004)
649	3375	109,045	3698	116,507	MH Dennis (2005)
659	9411	355,267	9616	363,625	MH Wilma (2005)

H: hurricane, MH: major hurricane.

Many claims around Miami and Keys were attributed to the event of MH Mitch (1998). The majority of claims were assigned to more reliable and accurate meteorological events in the NFIP flood loss data.

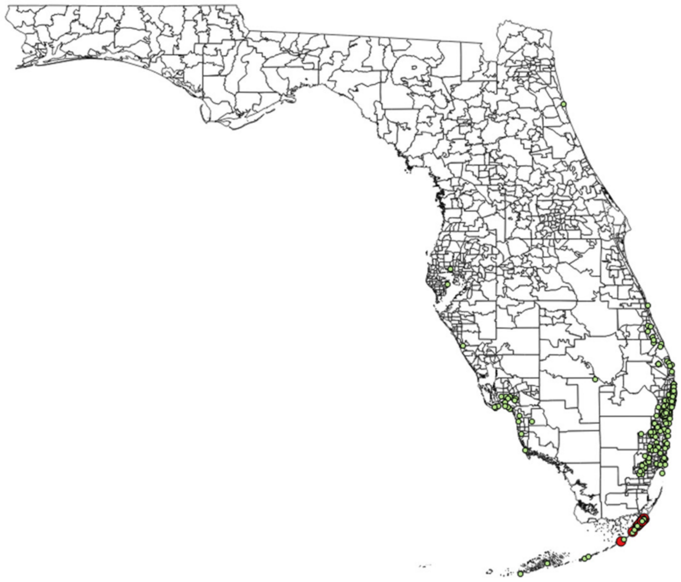


Figure 5. NFIP catastrophe event number update: Major Hurricane Mitch (period: 4 November 1998–6 November 1998); event number = 134 (see Table 1). Provided claim count = 8 (**red dots**) vs. revised claim count = 206 (**green dots**).

3.1.2. Cause of Loss Revision

The following fields were added to the original NFIP claim data: HURDAT2 storm identification, storm flag (tropical depression (TD), tropical storm (TS), hurricane (HU) or nontropical storm (NA)), revised catastrophe number, rainfall maximum, and distances to the nearest coast and body of water. Using these collected information permitted a revision of the cause of loss when the original loss cause was in clear error or ambiguous.

The algorithms for the revision were as follows:

- if the provided cause of loss was tidal water overflow (surge; cause number 1), but the distance to coast was greater than 20 km (based on personal communication with surge modeling experts), the rainfall maximum for the location was checked. If it was greater than 25 mm/day, the cause was revised to be accumulation of rainfall (cause number 4). Otherwise, it was designated as questionable, likely wrong address (see Figure 6);
- for hurricane events, if the original cause of loss was unknown for a property that was less than 20 km to the coast, and the precipitation maximum was greater than 25 mm/day, the cause of loss was marked as undetermined (cause number 5) but was either tidal water overflow or accumulation of rainfall, and further investigation was warranted. Otherwise, the cause of loss was marked as cause number 1;
- for nonhurricane events, if the original cause of loss was unknown for a property that was greater than 20 km to the coast and the precipitation maximum was greater than 25 mm/day, the cause of loss was marked as cause number 4;
- if the original cause of loss was 4 in inland areas, but the precipitation maximum was less than 5 mm/day, then the cause of loss was marked as questionable, possible error in address or date;
- for hurricane-only events, if the distance to the coast was less than 1 km, claims with cause numbers 2, 3, and 4 were revised to tidal water overflow (cause number 1). Figure 7 shows why this might be a practical revision algorithm. Hurricane Ivan (2014) hit the northwest coast of Florida (see Figure 3) and caused widespread surge damages according to FEMA. However, the cause of loss in many NFIP paid claims was marked as accumulation of rainfall (cause number 4), even in the apparent isolated island areas. All these areas were damaged by the storm surge according to the FEMA observed flood estimates.

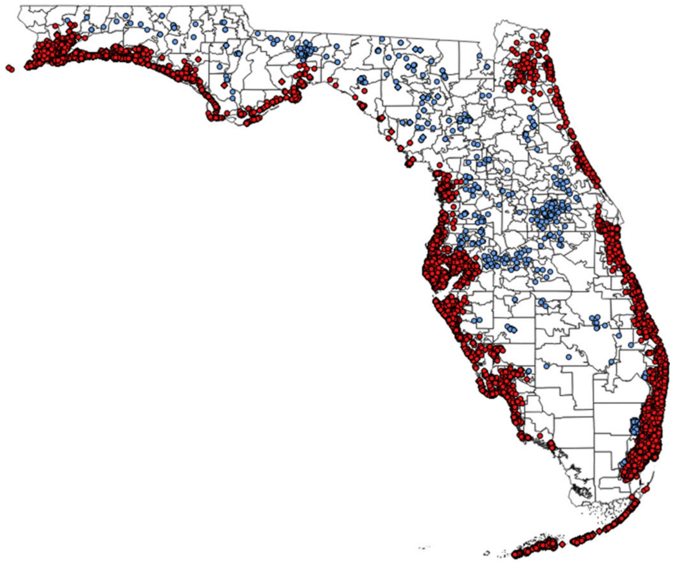


Figure 6. NFIP cause of loss revision—incorrect surge claims. All circles denote the provided NFIP surge claims. Red circles denote revised surge loss claims, while blue circles denote incorrect surge claims.

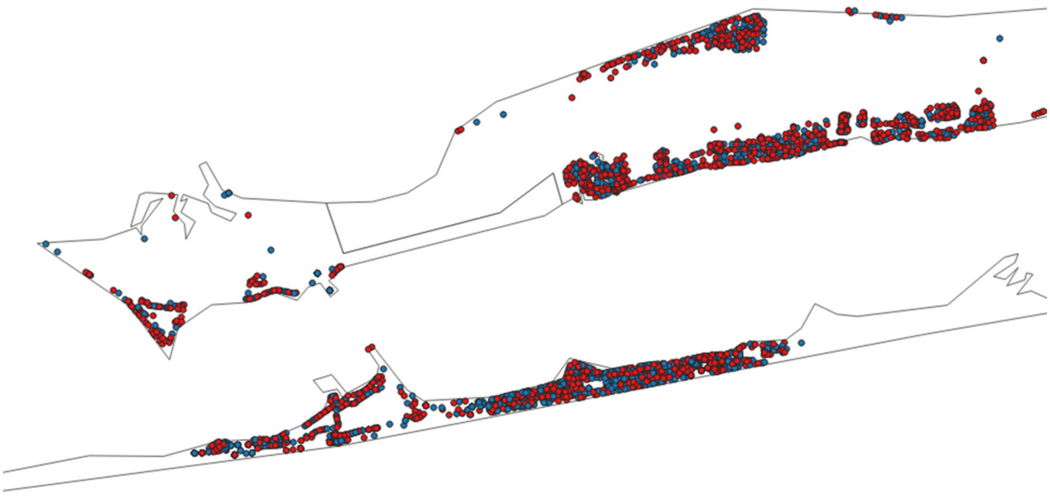


Figure 7. NFIP cause of loss—Hurricane Ivan (2004). Red dots denote surge claims, and blue dots denote accumulation of rainfall claims. Domain: −87.21 W to −87.04 W and 30.3 N to 30.4 N.

3.1.3. Summary of Revised Claims

The provided and revised NFIP claim counts and paid loss amounts with percentages are shown in Tables 2 and 3, respectively. Before our revision, the majority of flood loss causes in Florida were considered due to the accumulation of rainfall (53.1% in claim count and 46.6% in paid loss), followed by surges (29.4% in claim count and 36.6% in paid loss). Hence, it can be misinterpreted that the main flood cause of loss in Florida was accumulation of rainfall. After our systematic revision, this misinformation was dramatically changed to the following: the main cause of flood loss in Florida was storm surge events. Tidal water overflow now explained 46.4% of claims by count and 65.0% of paid losses. While there was just a ca. 17% increase in claim count, there was an increase of more than USD 1 billion (USD 2415 million out of 3714 million) in the paid loss amount.

Table 2. The NFIP claims count summary in accordance with the cause of loss.

Cause	Provided		Revised	
	Count	%	Count	%
0	11,069	7.2	215	0.1
1	**45,222**	**29.4**	**71,386**	**46.4**
2	11,303	7.4	7401	4.8
3	1919	1.2	1522	1.0
4	**81,614**	**53.1**	**59,364**	**38.6**
5	0	0	9596	6.2
6	2624	1.7	4267	2.8
all	153,751	100	153,751	100

0: other causes; 1: tidal water overflow; 2: stream, river, or lake overflow; 3: alluvial fan overflow; 4: accumulation of rainfall; 5: indeterminate, cause 1 or 4; 6: all other causes.

Table 3. The NFIP claims paid loss amount summary in accordance with the cause of loss (see Table 2 for the cause number reference).

Cause	Provided		Revised	
	Paid Loss (Thousands of USD)	%	Paid Loss (Thousands of USD)	%
0	318,190	8.6	4046	0.1
1	**1,358,612**	**36.6**	**2,414,944**	**65.0**
2	260,414	7.0	132,077	3.6
3	42,905	1.2	32,738	0.9
4	**1,729,295**	**46.6**	**810,876**	**21.8**
5	0	0	286,971	7.7
6	4770	0.1	32,534	0.9
all	3,714,186	100	3,714,186	100

A summary of the general types of meteorological events and their respective portions of the claim data is provided in Table 4 for the revised NFIP events. In this table, it can be seen that hurricanes were by far the primary cause of flooding damage in Florida, accounting for 72.1% of the revised claim losses and 54.5% of claims by count. The losses labeled tropical storm and depression did not reach hurricane strength while damage occurred. These events accounted for approximately 13% of the losses in the revised claims. While the losses for tropical storms were lower than for hurricanes, the number of potential events that may need to be considered could be larger. Tropical storms may produce lower surges than hurricanes, but the rainfall from such storms can often be quite significant. The third class of general flood hazard events in Table 4 was nontropical systems. These events are usually heavy rainfall events that are not caused by tropical systems. These events, however, do include nontropical cyclones, such as the *Storm of the Century* (March, 1993). These cyclones can cause surges as well as heavy rain. Currently, the FPFLM does not have any model to take these types of events into account.

Table 5 shows the detailed breakdown of NFIP paid losses due to each type of meteorological events and cause of loss. For hurricane events, approximately 80% of paid losses were due to storm surges. Meanwhile only 21.6% were due to surges in tropical storm events. The accumulation of rainfall explained 9.5% for hurricane, 58.5% for tropical storms, 81.9% for tropical depressions, and 49.1% for nontropical events. The importance of nontropical cyclone events to storm surges and associated coastal inundation was examined through the NFIP claim data. Based on the revised NFIP, the number of nontropical surge claims was 10,564 (~7% of the paid claims and ~15% of storm surge claims), accounting for paid losses of USD 179,719,000 (~5% of the paid claims and ~7.6% of storm surge claims). The Storm of the Century accounted for 5875 surge claims out of total 8846 claims, amounting to paid losses of USD 132,764,000 (79%) for coastal surge claims.

Table 4. The revised NFIP paid loss amounts and corresponding claim counts in accordance with the type of meteorological event.

Cause	Revised NFIP Events			
	Paid (Thousands of USD)	%	Claim Count	%
Nontropical	574,612	15.5	38,733	25.2
Tropical Depression	160,431	4.3	9467	6.2
Tropical Storm	302,267	8.1	21,733	14.1
Hurricane	**2,676,876**	**72.1**	**83,818**	**54.5**
All	3,714,186	100	153,751	100

Table 5. Breakdown of the NFIP claim paid loss amounts due to each type of event as a function of cause of loss (see Table 2 for the cause number reference).

Cause	Hurricane Only		Tropical Storm Only	
	Paid Loss (Thousands of USD)	%	Paid Loss (Thousands of USD)	%
0	182	0	61	0
1	**2,128,099**	**79.5**	**65,284**	**21.6**
2	42,602	1.6	38,657	12.8
3	1106	0	920	0.3
4	**253,644**	**9.5**	**176,714**	**58.5**
5	247,293	9.2	19,970	6.6
6	3950	0.1	661	0.2
all	2,676,876	100	302,267	100
Cause	**Tropical Depression Only**		**Nontropical Only**	
	Paid Loss (Thousands of USD)	**%**	**Paid Loss (Thousands of USD)**	**%**
0	9	0	3794	0.7
1	**1207**	**0.8**	**179,719**	**31.3**
2	7633	4.8	50,562	8.8
3	184	0.1	30,933	5.4
4	**131,427**	**81.9**	**282,374**	**49.1**
5	19,709	12.3	0	0
6	262	0.2	27,230	4.7
all	160,431	100	574,612	100

3.2. Further Analyses for Flood Risk Assessments

3.2.1. Nontropical Flood Claims

In order to determine an appropriate method or model for estimate losses due to nontropical inland rainfall flood events, the analysis of the revised NFIP claim data was expanded. It was previously reported that approximately USD 574 million in losses were due to nontropical events (Table 4), specifically events that could not be directly attributed to an event in the HURDAT2 database. The authors further broke down the losses by excluding non-rainfall-related events, such as surges, and determining whether the claims were within 1 km (0.6 miles) of the coast. The results are summarized in Table 6. As shown in Table 6, the losses due to nontropical rainfall for inland locations totaled about USD 228 million. These were losses due to events that could be potentially modeled by a nontropical rainfall model (or set of models).

Table 6. Breakdown of the revised NFIP paid loss amount due to nontropical events.

	Loss (Millions of USD)	% of NFIP	Remarks
Nontropical flood	574	15	Includes surge due to nontropical cyclones
Nontropical nonsurge	394	11	Excludes all surge
Nontropical rain-related	372	10	Excludes surge and other/unknown
Nontropical rain—inland	**228**	**6**	Greater than 1 km to coast
Total NFIP all causes	3714	100	

To gain further insight into these types of only-rainfall-related losses, the authors show the top five loss events in Table 7. The largest loss, USD 29.7 million, was due to a heavy frontal rainfall event in December, 2009. The second largest event was due to the record El Nino winter of 1997–1998. That event lasted several months, and there were claims with dates of loss for nearly every day from 24 December 1997 to 10 April 1998. The fourth largest loss, about USD 12 million, was due to the *Storm of the Century* in March, 1993, which was a very unusually strong nontropical cyclone that entered Florida from the Gulf. Note that these losses did not include surge losses, which were larger. The third and fifth largest losses were possibly due to remnants of tropical disturbances or storms that were not fully recorded in the HURDAT2 database.

Table 7. The top five NFIP nontropical loss events in order of paid loss amount.

Claim Count	Loss (Thousands of USD)	Event Duration		Remarks
		Begin	End	
702	29,671	9 December 2009	20 December 2009	17 December 2009 heavy rain
1154	14,302	24 December 1997	10 April 1998	El Nino record event
558	13,618	28 October 2011	2 November 2011	Possible related to tropical disturbance
529	11,999	12 March 1993	24 March 1993	Storm of the Century
467	11,244	12 May 2009	29 May 2009	Possible remnant of tropical depression 1

Examination of these losses indicated that there were a number of unique and varied meteorological conditions that lead to these heavy rainfall events. This presents a challenge in terms of developing a robust rainfall model. Since the total rainfall-related losses that can be modeled accounted for less than 6% of the NFIP losses historically, a decision needs to be made as to whether these types of losses should be explicitly modeled as opposed to making an actuarial adjustment of the losses to include them implicitly.

3.2.2. Loss Convergence in 30 Zones

The Flood Standards [1] require that modelers create a minimum of 30 geographic zones and verify that any Monte Carlo simulations required by the flood model to estimate losses converge to within a standard error of 5% in each zone of Florida (unless otherwise justified). The authors developed a preliminary set of zones based on the nearest coastal target location using a carefully selected set of 30 target coastal city locations. All zones were developed to have coastal exposure, so that storm surge risk affected every zone. The zones were made somewhat smaller in more vulnerable regions and larger in less vulnerable regions, to ensure a sufficient loss in all zones, while maintaining a reasonable size and structure, so that risk convergence was suitably ensured over all of Florida. These zones are subject to revision once stochastic losses are available and we have better understanding of the distribution of the vulnerability. As stochastic losses had not become available, the NFIP claims data was used for guidance. Figure 8 shows the preliminary set of 30 zones, along with the target coastal locations that define the zones. In addition, the NFIP losses are shown for each zone in millions of USD (paid losses). The Pensacola zone had the largest loss, at USD 592 million, mainly due to Hurricane Ivan (2004). Next were Miami (USD 423 million) and Navarre (USD 415 million). The least vulnerable zone was St. Augustine Beach, at USD 11 million. Note that these losses were heavily influenced by singular events and thus should not be interpreted as an overall measure of risk. If a zone were to have no or negligible losses, then convergence may not be possible.

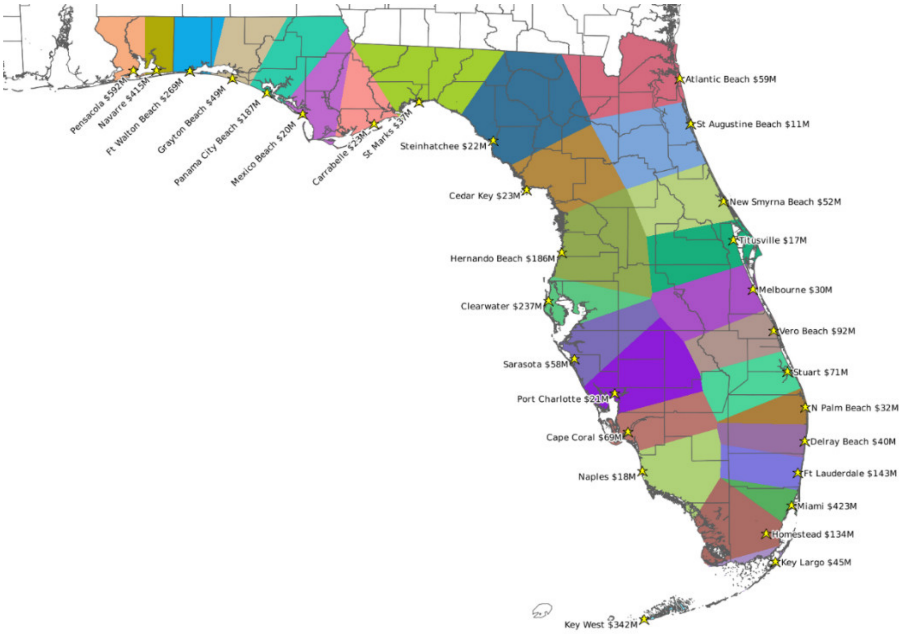


Figure 8. Preliminary creation of 30 zones to be used for Monte Carlo convergence tests. Yellow stars indicate target locations that define the zones. Losses for each zone were based on the analysis of NFIP claim data.

3.2.3. Historical Reconstruction

In general, observations of flood elevations and wave conditions are not available or very limited. To obtain estimates of these data, the authors used the FPFLM hazard models and other data to reconstruct select historical flood events. For storm surges, the Coastal Estuarine Storm Tide (CEST) model [14] was used. The CEST is forced by estimated observed winds from the H*Wind hurricane wind analyses [15] where available; otherwise, modeled winds are used. Wave conditions were determined by a wave model from the FPFLM that was based on the STWAVE (steady-state spectral wave) model [16]. For inland flooding, a simple two-dimensional modeling framework [17] was used. The modeled hazard data was interpolated to the claim locations, taking into account very-high-resolution 5 m DEM (Digital Elevation Model) elevation data. Based on the modeled results, each claim in the revised NFIP portfolio could be assigned to one of four hydrological states: inland flood with no waves; coastal flood with minor waves; coastal flood with moderate waves; and coastal flood with severe waves. A better set of flood vulnerability curves can be developed based on these hydrological states and can be validated using the modified NFIP claim data for the FPFLM project [9,10].

4. Conclusions

The NFIP claim data constitute an essential resource for developing, calibrating, and validating a flood risk model. They can be intensively used, for example, in the assessment of the flood outcomes from hazard (i.e., surge, wave and inland flooding) models and in the development process of a set of vulnerability curves. The provided original (especially hazard) fields in NFIP claim data are not always complete or accurate and often missing. In order to determine significant types of meteorological events that can cause flooding, the authors tackled the revision of the NFIP claim data in Florida filed between 19 July 1975 and 10 January 2014. The hazard fields in the NFIP claim data were systematically revised using existing meteorological and geographical data in Florida. Tropical cyclone events, rainfall maxima, and distance to coast information permitted revisions of the cause of loss when the provided claim loss causes were in clear error or ambiguous. After our revision, the number and paid loss amount of surge claims in Florida increased dramatically, while those of accumulation of rainfall claims decreased. Sample usages of the revised NFIP claim data are presented in this study as well in the analyses of nontropical flood claims, loss convergence, and historical reconstruction of hydrological states.

The types of meteorological events that can lead to flooding are varied. For hurricane events, the currently developing FPFLM has both a surge model and an inland flood model that have been implemented and are now being evaluated using the revised NFIP claim data. However, for nonhurricane events, we do not have such models. There are unusual cases, such as the tropical disturbance in southeast Florida in 2000 (2 October 2020–6 October 2000). At that time, there was no tropical cyclone present, but heavy rain from a disturbance caused significant flooding. A tropical storm later developed from this disturbance after it left the region. Based on the NFIP claim data, the damage due to these rainfall events appeared to exceed the flood damage due to Hurricane Andrew (1992), which impacted the same region. Since the event was not a cyclone at that time, we could not model this event.

It should be noted that our criteria used for the revision of cause of loss in the current paper were somewhat arbitrary, such as the radius of hurricane influence (700 km), rainfall criteria (25 or 5 mm/day), distance to coast for surge influence (20 km), and surge assignment for hurricane event (<1 km). If these criteria were selected more scientifically, the reliability of revised claim counts and loss amounts might be improved. For example, in lieu of a <1 km rule for surge assignment, we could use Florida DEM surge zones based on NHC SLOSH model runs with FEMA observed flood estimates. If there is still doubt about the revised cause of loss, individual claims should be checked manually with added meteorological and georeferencing information to attain a proper selection of cause of loss.

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