Flood Modeling and Reserving Considerations

9/17/2019

Who We Are

KatRisk is an independently owned catastrophe modelling business formed in 2012. We are located in the United States and Germany representing a combined >100 years of catastrophe modelling experience.

We service clients ranging in size from multinational industry leaders to super regional specialty carriers primarily within the insurance and financial services industries including:

- Three of the largest four worldwide reinsurance brokers
- Two of the top four worldwide non-life reinsurers
- Four of the top 15 worldwide property insurers
- The United States Federal Emergency Management Agency (FEMA)
  - National Flood Insurance Program (NFIP)
- North Carolina Rate Board
- Total clients: ~45

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Questions

1. How are “Catastrophe Models” composed and what is different about flood vs other hazard models?

2. What are the major sources of uncertainty in a cat model?

3. How are cat models used for reserving before and after an event (Case Study with Hurricane Florence)

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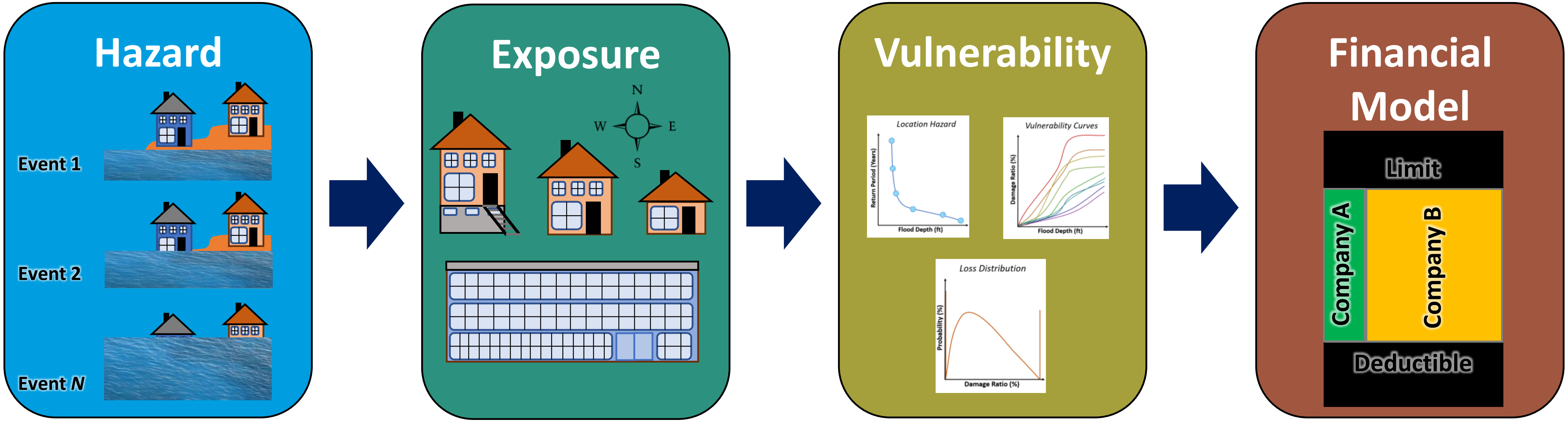
What is Catastrophe Modelling



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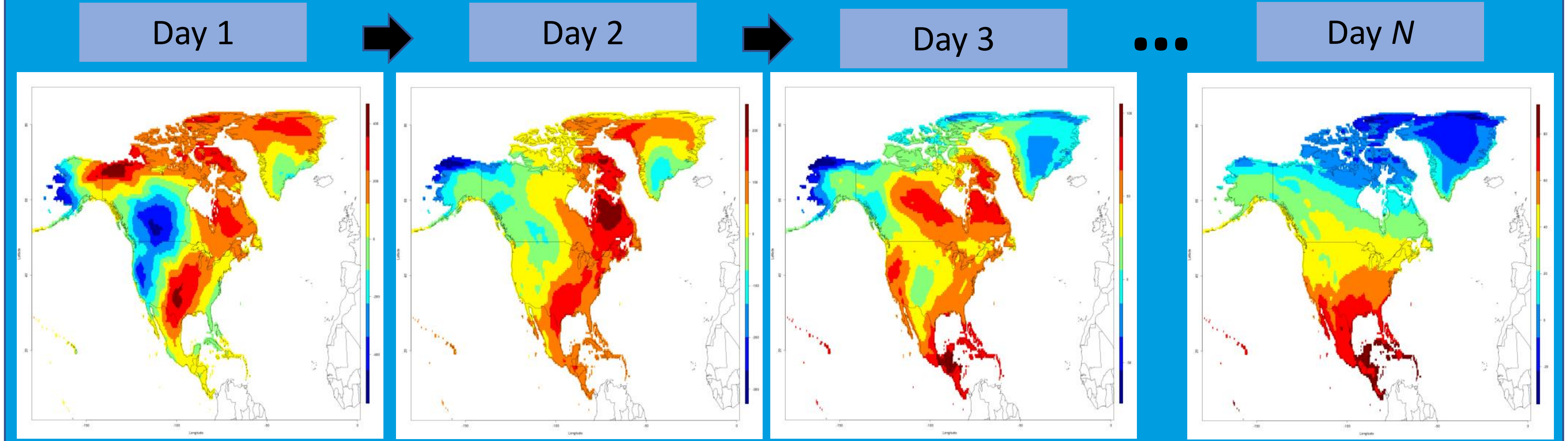
What is Catastrophe Modelling

Create stochastic inputs, sub-daily temperature, precipitation, etc. for thousands of years



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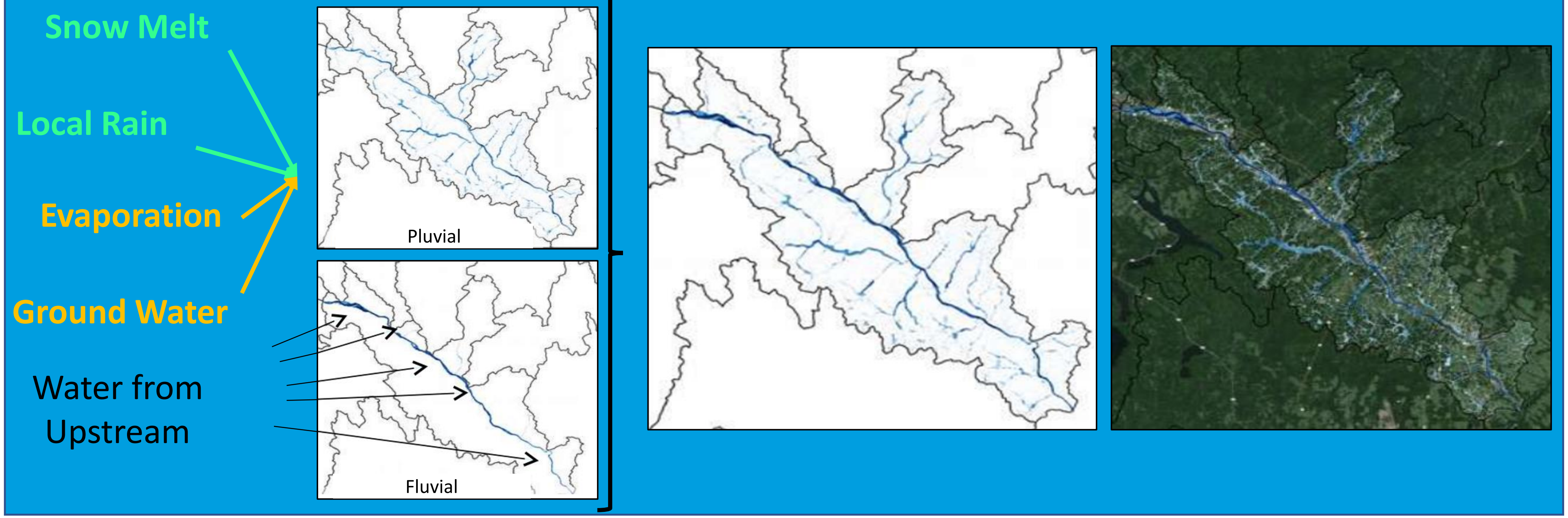
What is Catastrophe Modelling

Daily inputs drive hydraulic/Hydrologic models, resulting in thousands to millions of flood pluvial and fluvial events



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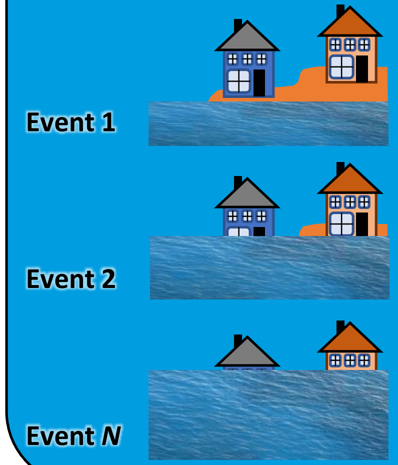
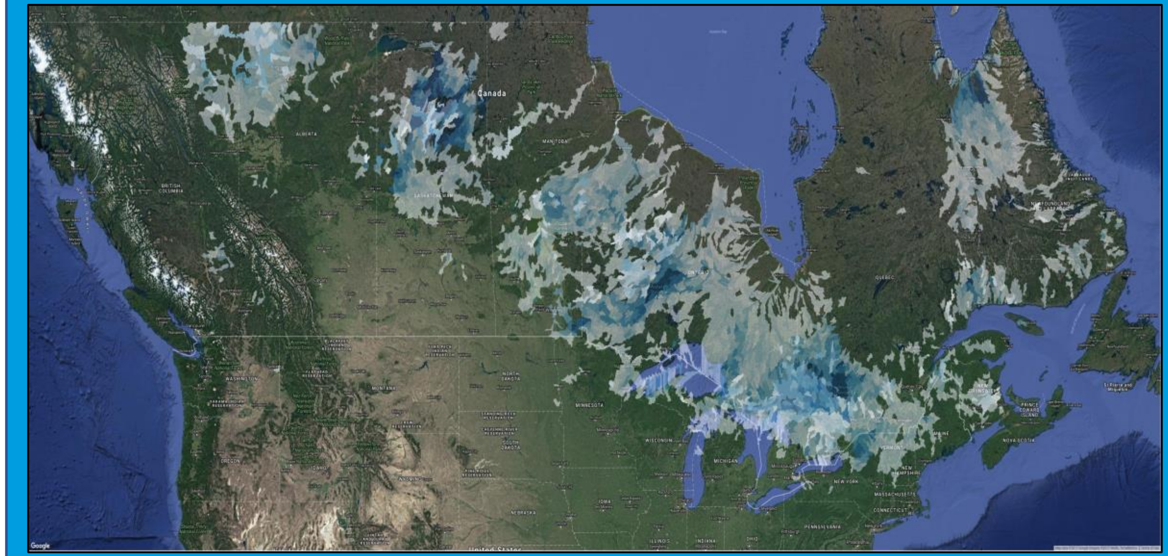
What is Catastrophe Modelling

Hazard



Generate Events from Simulations



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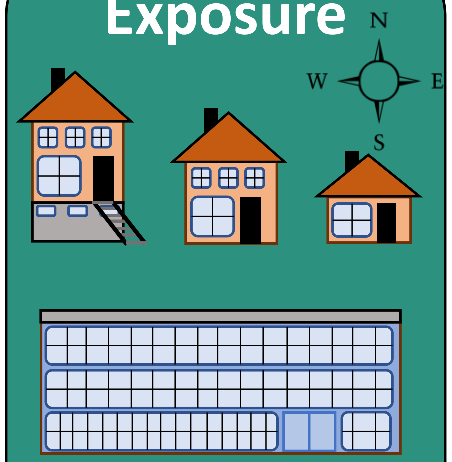
What is Catastrophe Modelling

Exposure



The buildings being insured can have many different features that matter for different types of hazards

Flood

- ❑ Number of Floors
- ❑ Year Built
- ❑ Presence of Basement
- ❑ First Floor Elevation
- ❑ Etc.

Earthquake

- ❑ Number of Floors
- ❑ Year Built
- ❑ Building Frame Type
- ❑ Wall Anchor Type
- ❑ Etc.

Windstorm

- ❑ Number of Floors
- ❑ Year Built
- ❑ Roof Slope
- ❑ Roof Anchor Type
- ❑ Etc.

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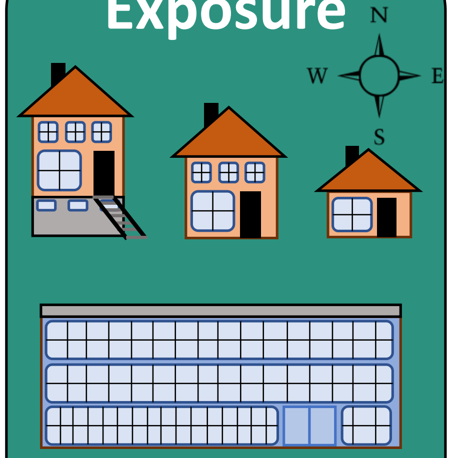
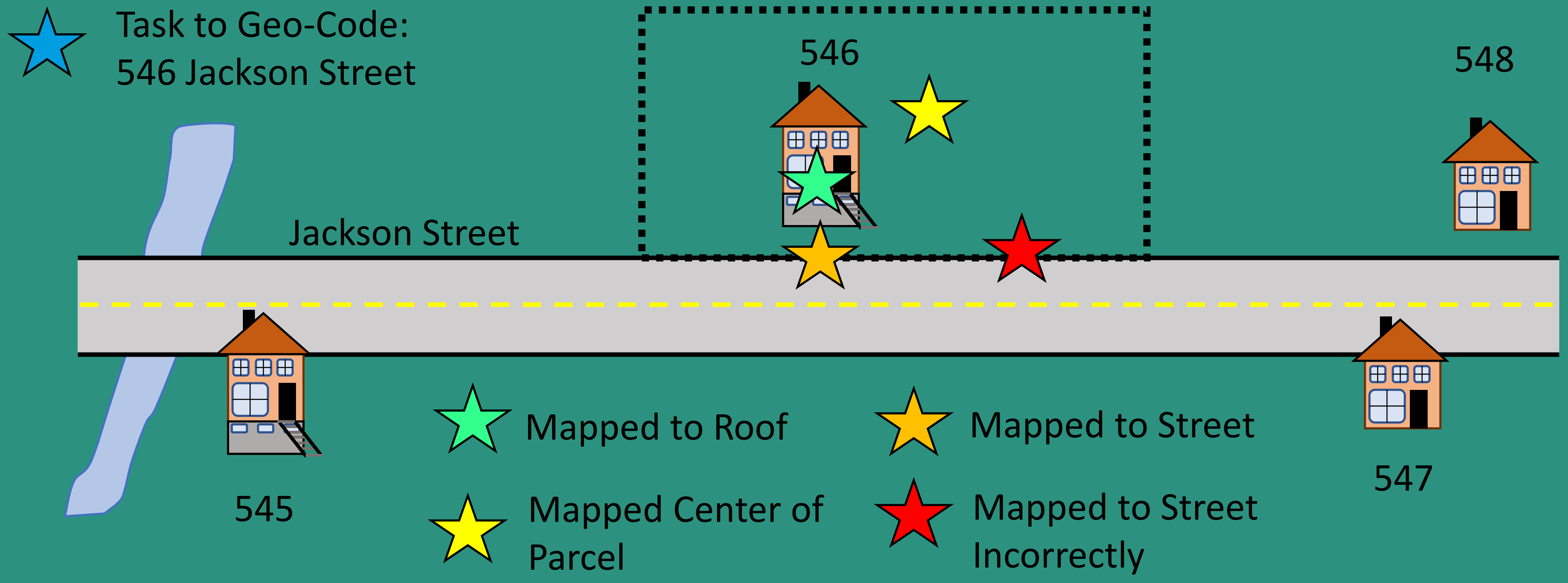
What is Catastrophe Modelling

Exposure



The buildings location, or geocoding, matters



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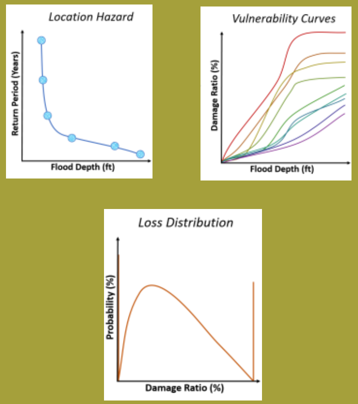
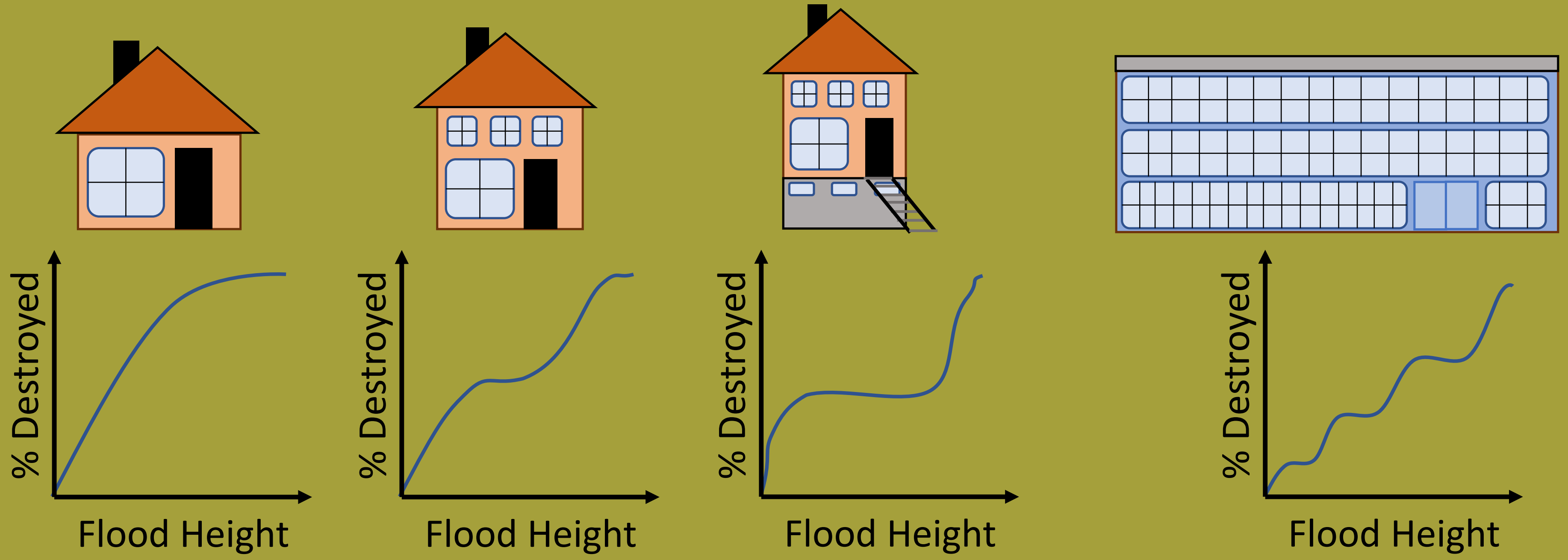
What is Catastrophe Modelling

Vulnerability



Vulnerability tells us how damaged a structure will be given a hazard (ex/ 1 vs 2 feet of flood)



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What is Catastrophe Modelling

Financial Model

The financial model can be as straightforward or as complex as required

Single Location

- ❑ Limit
- ❑ Deductible

Single Location

- ❑ Limit
- ❑ Deductible
- ❑ Coverage Deductible
- ❑ Earthquake Deductible
- ❑ Windstorm Deductible

Portfolio with Reinsurance

- ❑ Limits
- ❑ Deductibles
- ❑ Coverage Deductibles
- ❑ Earthquake Deductibles
- ❑ Windstorm Deductibles
- ❑ Site Limits
- ❑ Site Deductibles
- ❑ Blanket Deductibles
- ❑ Quota Share Reinsurance Treaties
- ❑ Etc.

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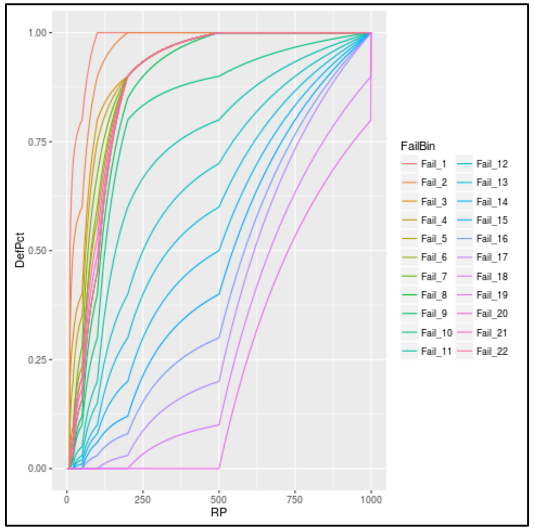
What is Catastrophe Modelling

Loss Model (Defense, Vulnerability, Uncertainty)

1. Determine Defense
2. Map Vulnerability Curves
3. Sample Vulnerability Loss Curve

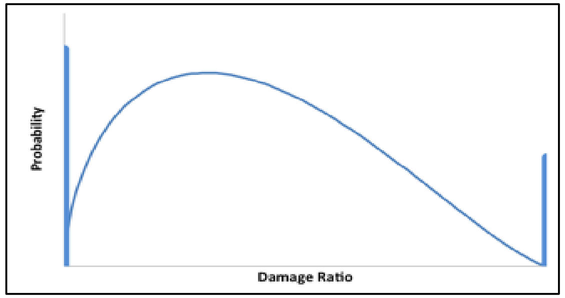
Defense Fragility Curves



KatRisk Vulnerability Modifiers

First Flood Elevation		Unit Start/End Floor		Basement Only	
Occupancy	Construction	Number of Stories	Basement	Mobile Home Tie Down	Finished Basement
Residential	Wood	1	Yes	Yes	Yes
Commercial	Masonry	2	No	No	No
Industrial	Concrete	3	Unknown	Unknown	Unknown
Auto	Steel	>3			
Unknown	Light Metal	Unknown			
	Mobile Home				
	Unknown				

4-Parameter Beta Distribution



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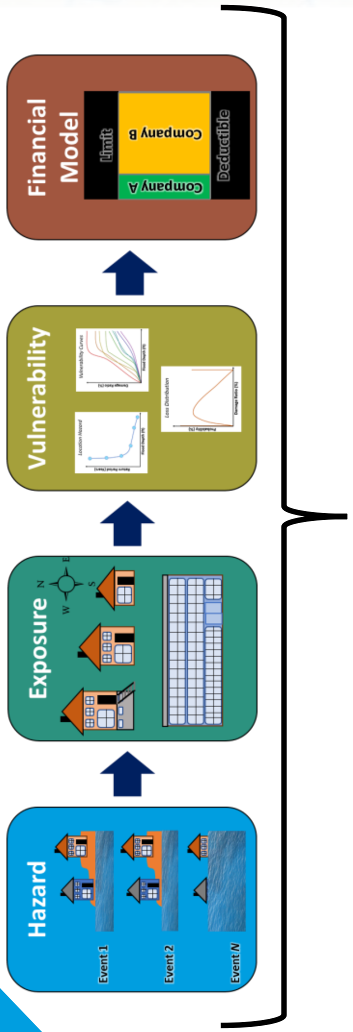
What is Catastrophe Modelling



Loss Statistics

Event Loss Table
(ELT)

Event ID	Loss
1574425	51,235
1574625	65,412
1000215	51,581
988878	0
…	
TOTAL	$10B

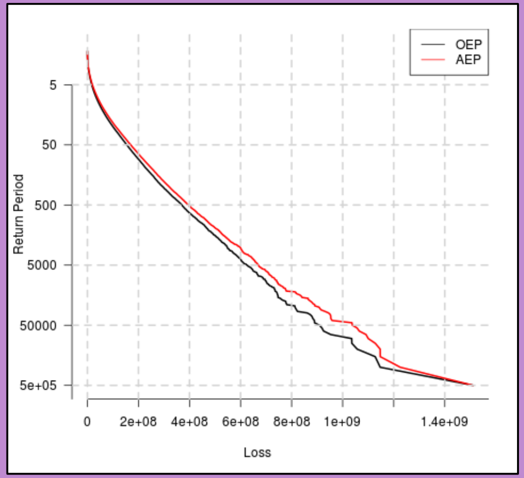
Average Annual Loss
(AAL)
[aka Pure Premium]

Assuming 10k years of events:

$$AAL = \frac{\$10B}{10k}$$

$10,000

Exceedance Probability
Curve (EP)



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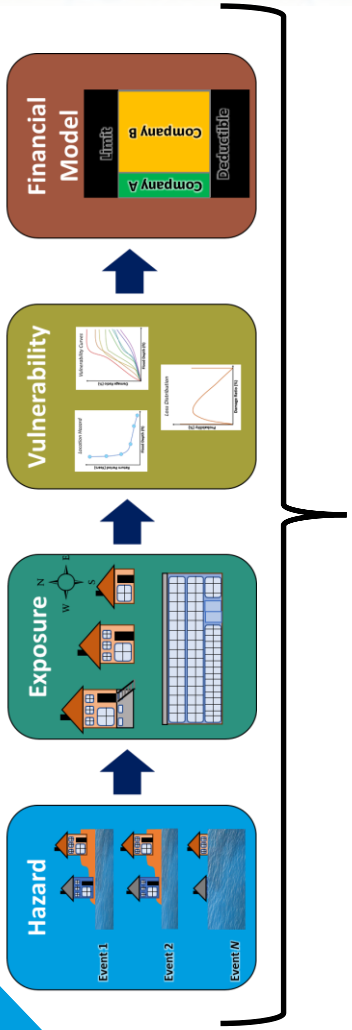
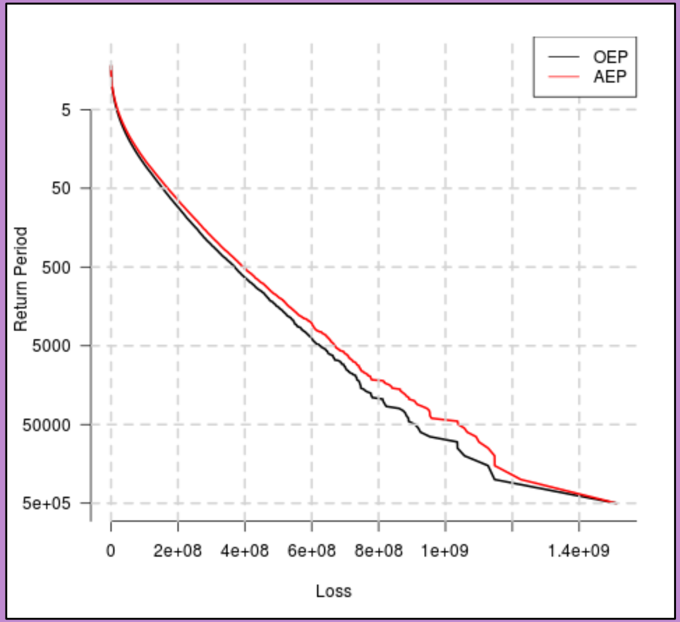
What is Catastrophe Modelling



Loss Statistics - OEP vs AEP



OEP
Occurrence Exceedance Probability

- If you have, say 500k years of events:
  - Take the event with the highest loss every year and order the losses

AEP
Aggregate Exceedance Probability

- If you have, say 500k years of events:
  - Sum all the events for each year and order the losses

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Flood vs. Other Hazards?

Resolution

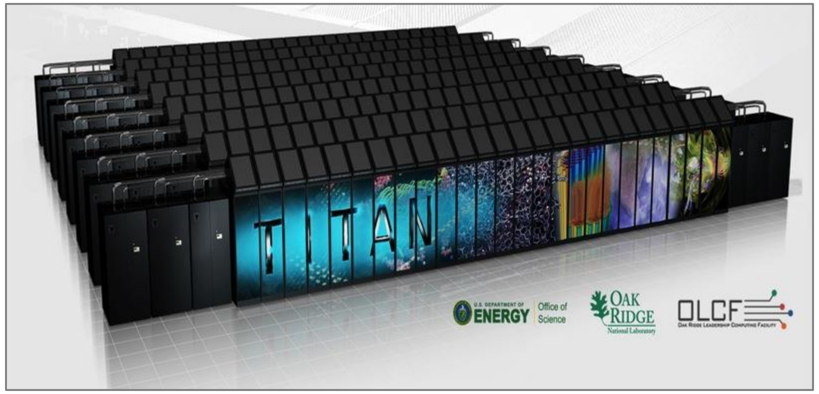
- Compute Time
- Run Time
- Geospatial Accuracy

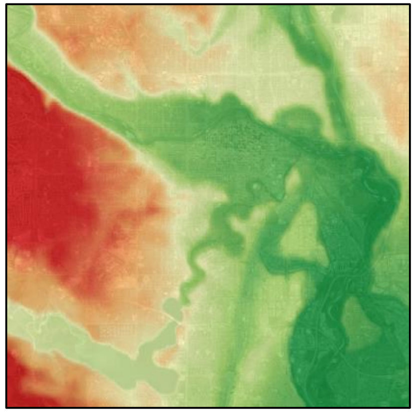
Data Availability

- High Resolution Input Data
- Historic Loss Data

Demand

- NFIP





NATIONAL FLOOD INSURANCE PROGRAM

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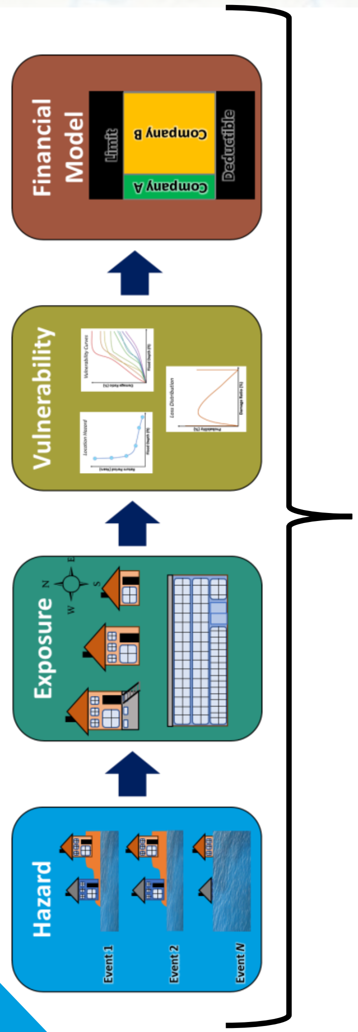
Sources of Loss Uncertainty



- **Hazard**
  - **Input Data**
    - **Resolution (Temporal and Spatial)**
    - **Accuracy**
  - **Historic Calibration**
  - **Simulation**
    - **Number of Sims (Convergence)**
    - **Completeness**
  - **Defenses**

- **Geocoding**
- **Vulnerability**
  - **Accuracy**
  - **Catastrophic/unexpected failure**
- **Contract Evaluation**

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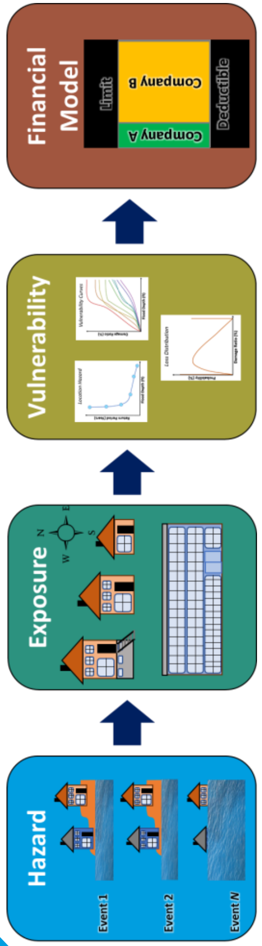
Sources of Loss Uncertainty



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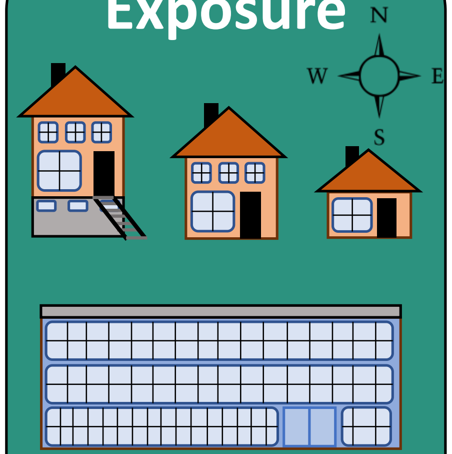
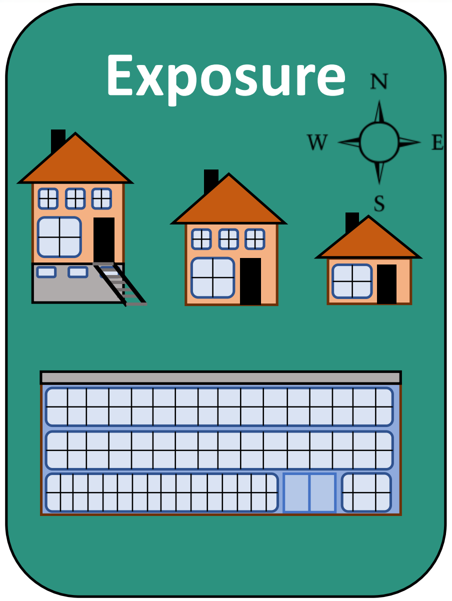
Location Uncertainty

Exposure



Flood is highly variable, roads flood first!

Location Uncertainty

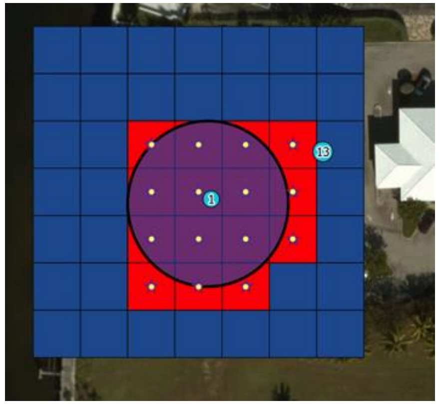


Tabular

- Specify:
  - Geometry (Ellipse or Rectangle)
  - Length
  - Width
  - Rotation

Spatial

- .GMT Vector:
  - Hand drawn or purchased footprints
  - Must have an attribute which links to locations within an imported exposure file



Multiple Calculation Modes over each Footprint

Minimum, Maximum, Mean, Inverted Loss

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Location Uncertainty

Loss differences based on building footprint loss averaging methodology

		IF GU AAL ($)									Pct Difference from Point							
			MIN		MEAN		Inverted		MAX		MIN		MEAN		Inverted		MAX	
ITEMID	TIV	Point	Tabular	GMT	Tabular	GMT	Tabular	GMT	Tabular	GMT	Tabular	GMT	Tabular	GMT	Tabular	GMT	Tabular	GMT
1	3,300,000	145.90	44.90	44.90	111.14	147.52	115.28	177.39	194.15	372.57	-69%	-69%	-24%	1%	-21%	22%	33%	155%
2	540,000	7.06	7.06	7.06	7.06	7.06	7.06	7.06	7.06	7.06	0%	0%	0%	0%	0%	0%	0%	0%
3	540,000	7.54	7.46	7.46	7.55	7.55	7.52	7.53	8.22	8.22	-1%	-1%	0%	0%	0%	0%	9%	9%
4	540,000	7.38	7.29	7.29	7.38	7.38	7.34	7.35	8.37	8.05	-1%	-1%	0%	0%	-1%	0%	13%	9%
5	540,000	8.36	7.33	7.33	7.84	7.84	7.81	7.81	8.45	8.45	-12%	-12%	-6%	-6%	-7%	-7%	1%	1%
6	540,000	7.06	7.06	7.06	15.87	14.51	16.02	14.68	23.03	23.03	0%	0%	125%	106%	127%	108%	226%	226%
7	540,000	23.15	23.15	23.15	23.15	23.15	23.15	23.15	23.15	23.15	0%	0%	0%	0%	0%	0%	0%	0%
8	540,000	14.52	7.05	14.52	14.52	17.27	14.71	17.32	23.15	23.15	-51%	0%	0%	19%	1%	19%	59%	59%
9	540,000	7.14	7.10	7.14	8.01	7.14	8.19	7.14	14.86	7.14	-1%	0%	12%	0%	15%	0%	108%	0%
10	540,000	6.99	6.81	6.81	6.89	6.89	6.88	6.88	7.86	7.86	-3%	-3%	-1%	-1%	-2%	-2%	12%	12%
11	1,070,000	17.93	5.24	5.24	16.64	16.64	7.44	7.44	118.90	118.90	-71%	-71%	-7%	-7%	-59%	-59%	563%	563%
12	2,150,000	18.46	18.46	18.35	18.46	18.45	18.46	18.47	18.46	18.85	0%	-1%	0%	0%	0%	0%	0%	2%
13	660,000	8.69	4.08	4.08	6.29	6.29	1.39	1.39	8.69	8.69	-53%	-53%	-28%	-28%	-84%	-84%	0%	0%
SUM	12040000	280.18	152.99	160.39	250.8	287.69	241.25	303.61	464.35	635.12	-45%	-43%	-10%	3%	-14%	8%	66%	127%

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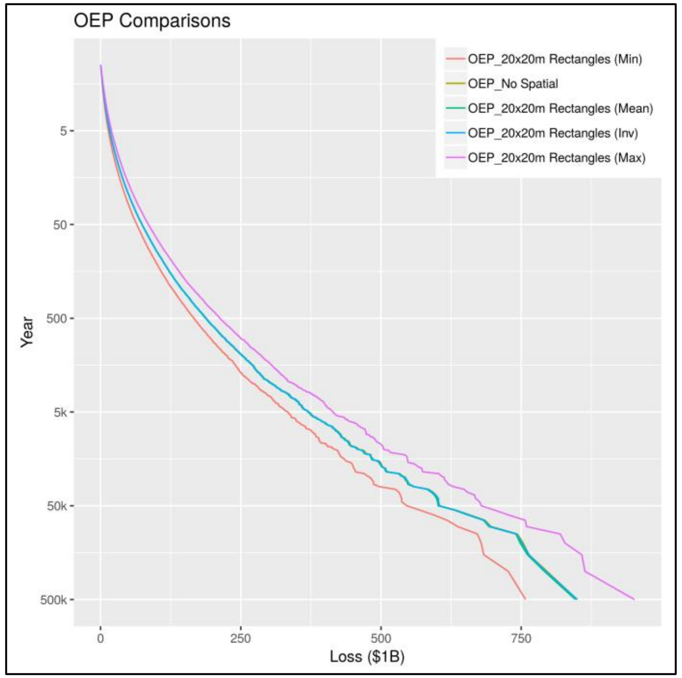
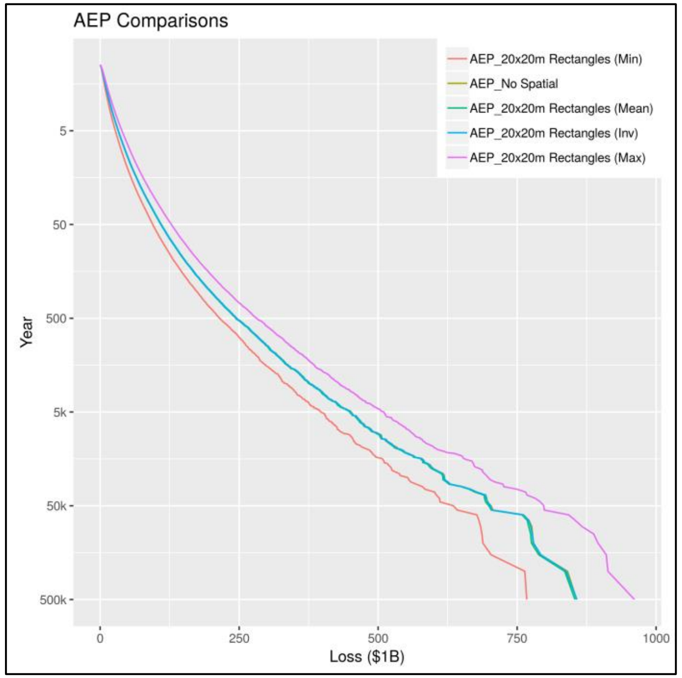
Location Uncertainty

No Spatial Footprints	20mx20m Rectangle (Min)	20mx20m Rectangle (Mean)	20mx20m Rectangle (Inv)	20mx20m Rectangle (Max)
Expo Import Time: 49 mins	Expo Import Time: 3.7 hrs	Expo Import Time: 3.7 hrs	Expo Import Time: 6.1 hrs	Expo Import Time: 3.7 hrs
Analysis Time: 1 hr	Analysis Time: 1 hr	Analysis Time: 1 hr	Analysis Time: 1 hr	Analysis Time: 1 hr
LC: $0.28	LC: $0.23	LC: $0.27	LC: $0.28	LC: $0.33

11M
Locations
NAIF_wDS
10 Samples
25 Processors





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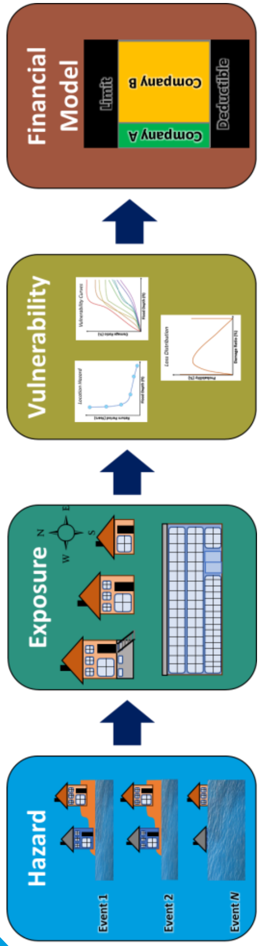
Sources of Loss Uncertainty



- Hazard
  - Input Data
    - Resolution (Temporal and Spatial)
    - Accuracy
  - Historic Calibration
  - Simulation
    - Number of Sims (Convergence)
    - Completeness
  - Defenses
- Geocoding
- Vulnerability
  - Accuracy
  - Catastrophic/unexpected failure
- Contract Evaluation

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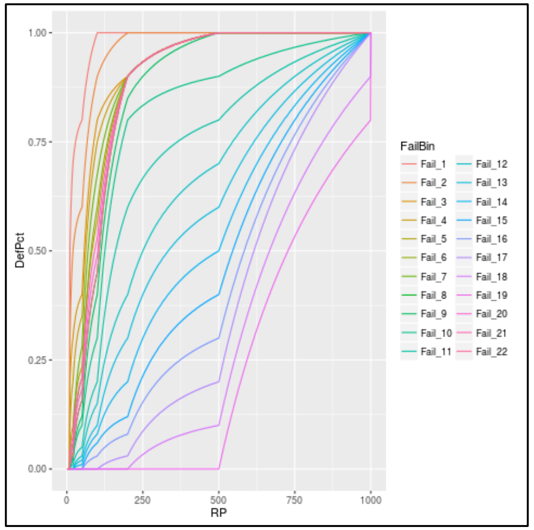
Defense Uncertainty

Loss Model (Defense)

1. For each location/event
   (Based on user input or FEMA/USACE dam and levee location information)
   a) Determine if location is defended from pluvial and/or fluvial

Defense Fragility Curves

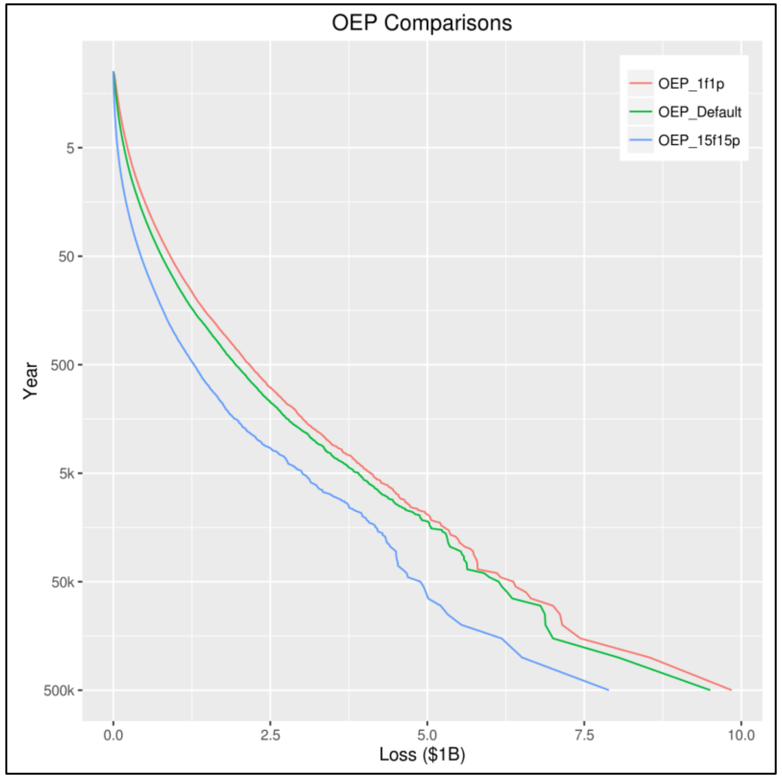


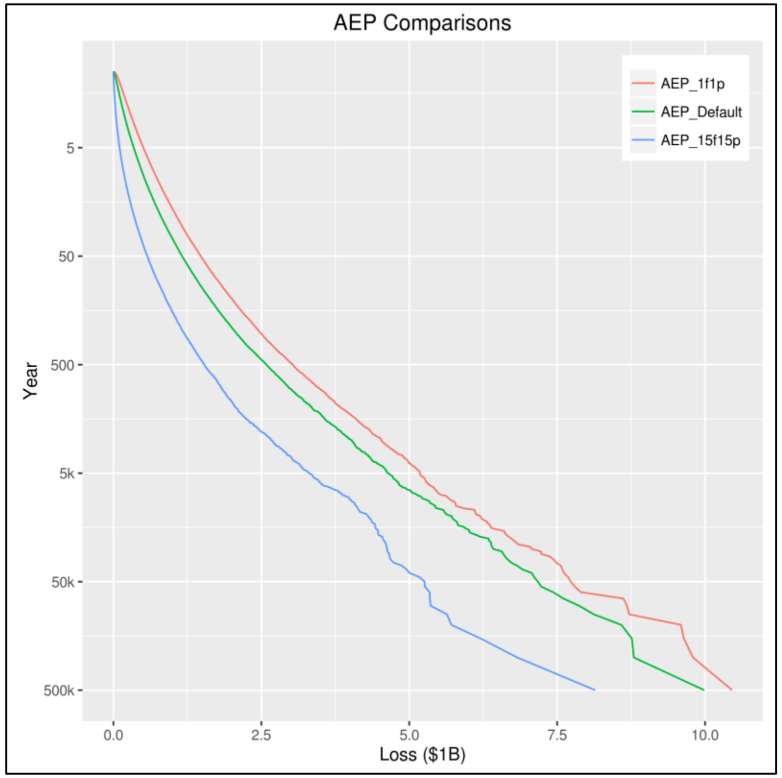
Defense Uncertainty

	OEP ($1B)		
RP	15f15p	Default	1f1p
10	$ 0.137	$ 0.297	$ 0.376
20	$ 0.242	$ 0.472	$ 0.575
50	$ 0.439	$ 0.770	$ 0.908
100	$ 0.641	$ 1.053	$ 1.222
200	$ 0.871	$ 1.411	$ 1.599
500	$ 1.285	$ 1.948	$ 2.169
1,000	$ 1.664	$ 2.419	$ 2.669
2,000	$ 2.113	$ 2.997	$ 3.228
5,000	$ 3.009	$ 3.903	$ 4.098
500,000	$ 7.891	$ 9.505	$ 9.847

	AEP ($1B)		
10	$ 0.201	$ 0.538	$ 0.752
20	$ 0.334	$ 0.777	$ 1.037
50	$ 0.573	$ 1.161	$ 1.476
100	$ 0.808	$ 1.510	$ 1.868
200	$ 1.082	$ 1.920	$ 2.325
500	$ 1.537	$ 2.586	$ 3.030
1,000	$ 1.941	$ 3.159	$ 3.650
2,000	$ 2.466	$ 3.813	$ 4.328
5,000	$ 3.311	$ 4.640	$ 5.183
500,000	$ 8.144	$ 9.986	$ 10.458

	AAL ($1B)		
GU AAL	$ 0.082	$ 0.238	$ 0.349





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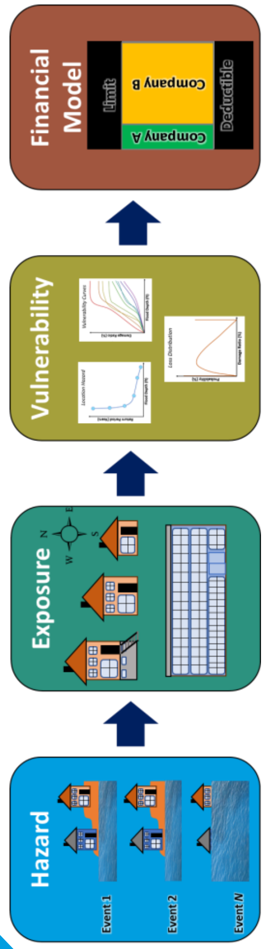
Sources of Loss Uncertainty



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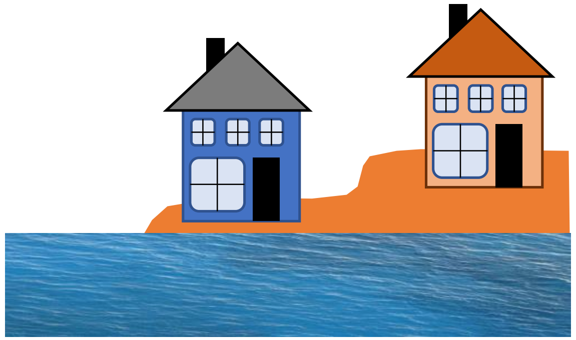
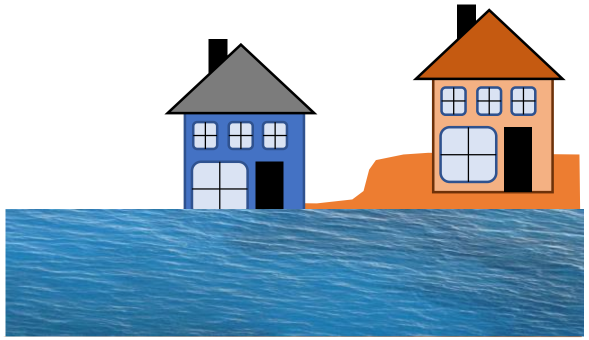
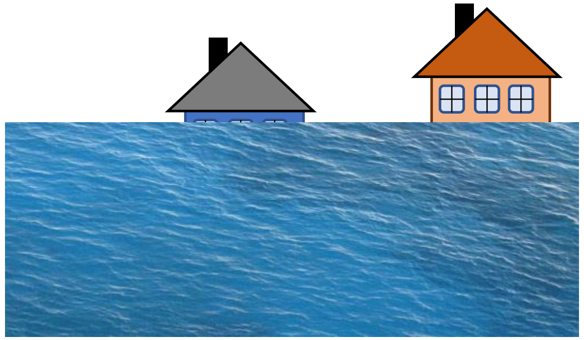
Climate Uncertainty



- X cm Current Day Mean Sea Level



Current Day Mean Sea Level



+ X cm Current Day Mean Sea Level

(Currently Available)

Change Global Sea Level

Increases/Decreases loss due to TC Storm Surge

(Near Future)

Change Local Sea Level

Raster Lookup, mean sea level change can be different by location

(Near Future)

Inland Flood Frequency Modification

Increases/Decreases loss due to Inland Flood

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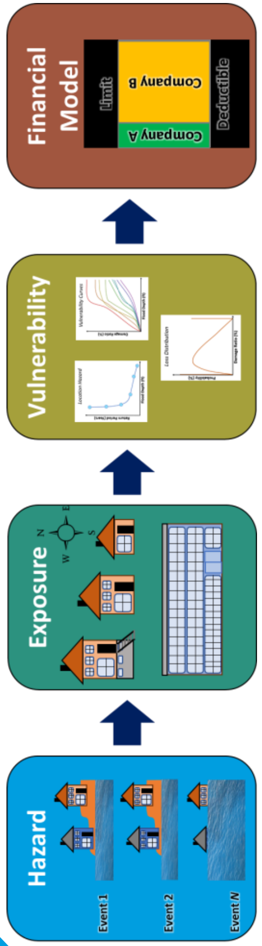
Sources of Loss Uncertainty



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  - Simulation
    - Number of Sims (Convergence)
    - Completeness
  - Defenses ✓
- Geocoding ✓
- Vulnerability
  - Accuracy
  - Catastrophic/unexpected failure

★ Contract Evaluation ✓

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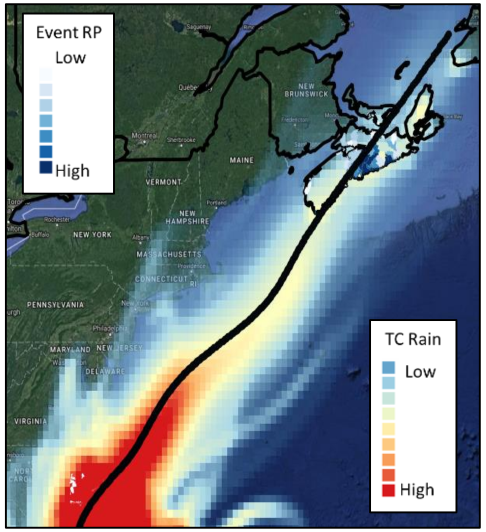
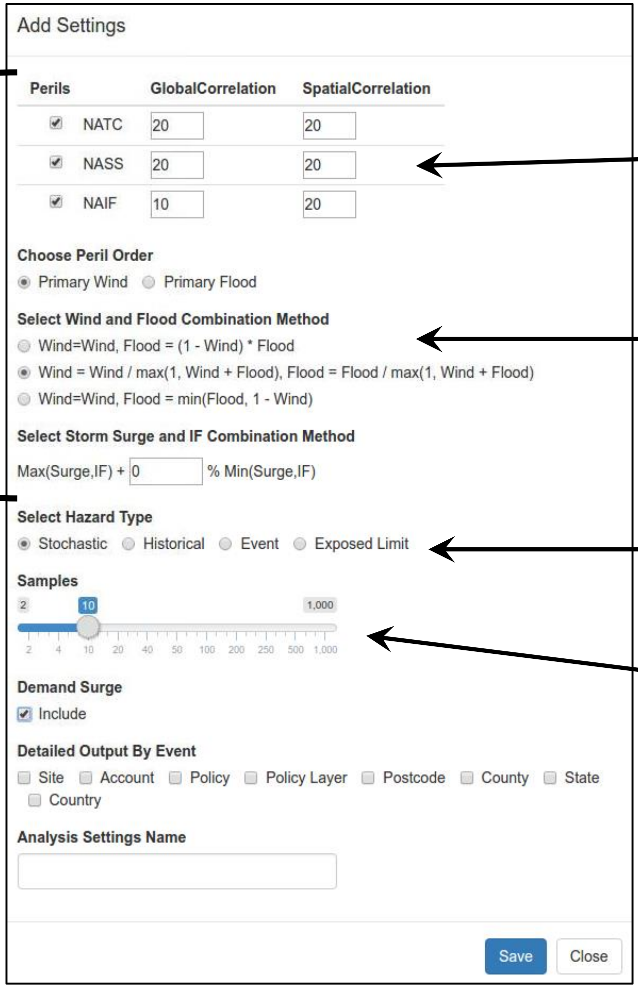
Contract Evaluation Uncertainty

Contract Evaluation

- Multi-Peril Inuring Order
- Explicit Multi-Peril Loss Statistics





Correlation Modeling

Combining Perils

Analysis Type

Variable/Repeatable Sampling

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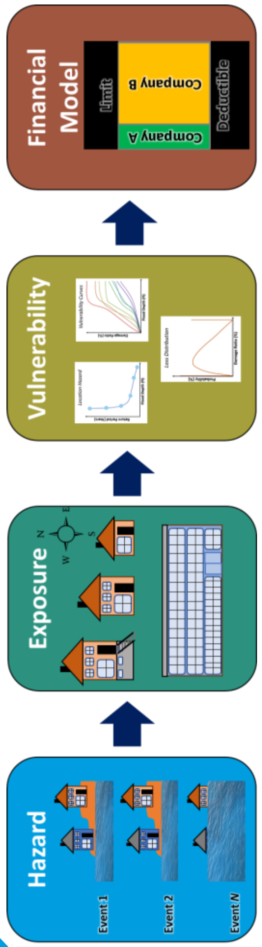
Sources of Loss Uncertainty



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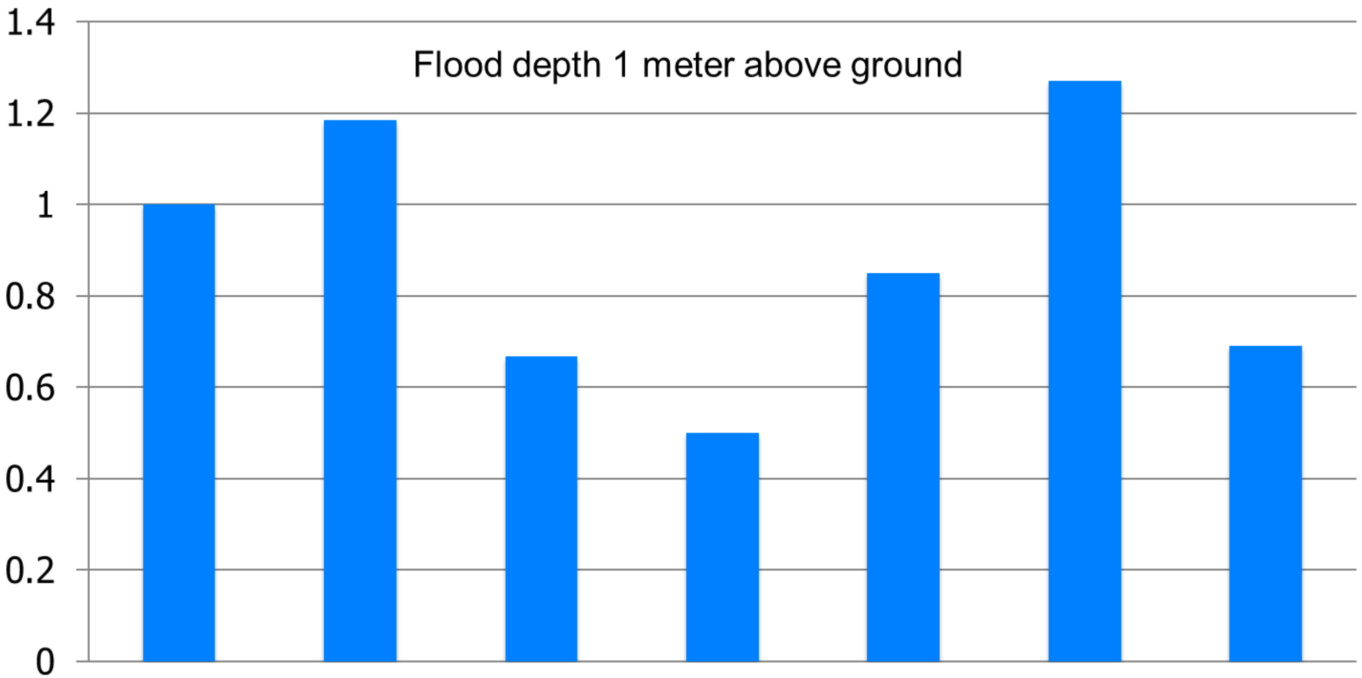
Vulnerability Uncertainty

Note that First Floor Elevation has the largest impact of all factors as all floods of depth < the first floor elevation have vulnerability curves with very small Mean Damage Ratios



constr	wood	wood	wood	wood	masonry	wood	wood
stories	1	1	2	3	1	1	1
basement	no	yes	no	no	no	no	no
FF elev	2	2	2	2	2	0	3

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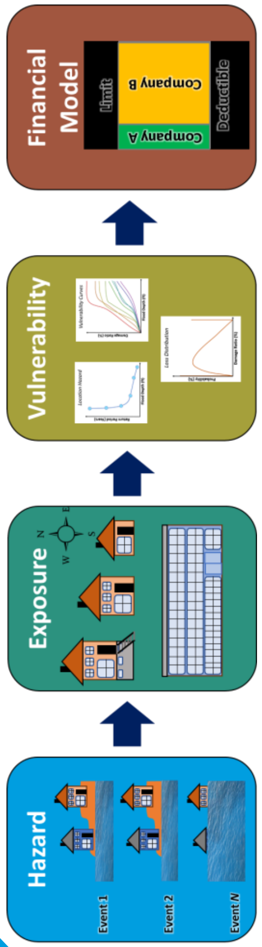
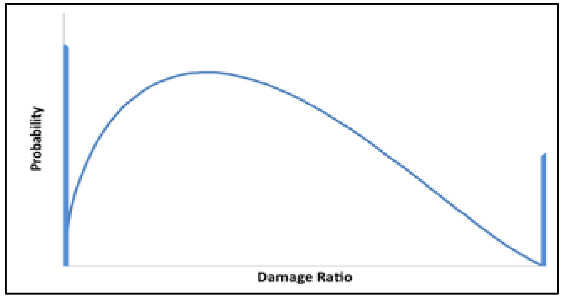
Sources of Loss Uncertainty



- Hazard ✓
  - Input Data
    - Resolution (Temporal and Spatial)
    - Accuracy
  - Historic Calibration
  - Simulation ✓
    - Number of Sims (Convergence)
    - Completeness
  - Defenses ✓
- Geocoding ✓
- Vulnerability ✓
  - Accuracy
  - Catastrophic/unexpected failure
- Contract Evaluation ✓

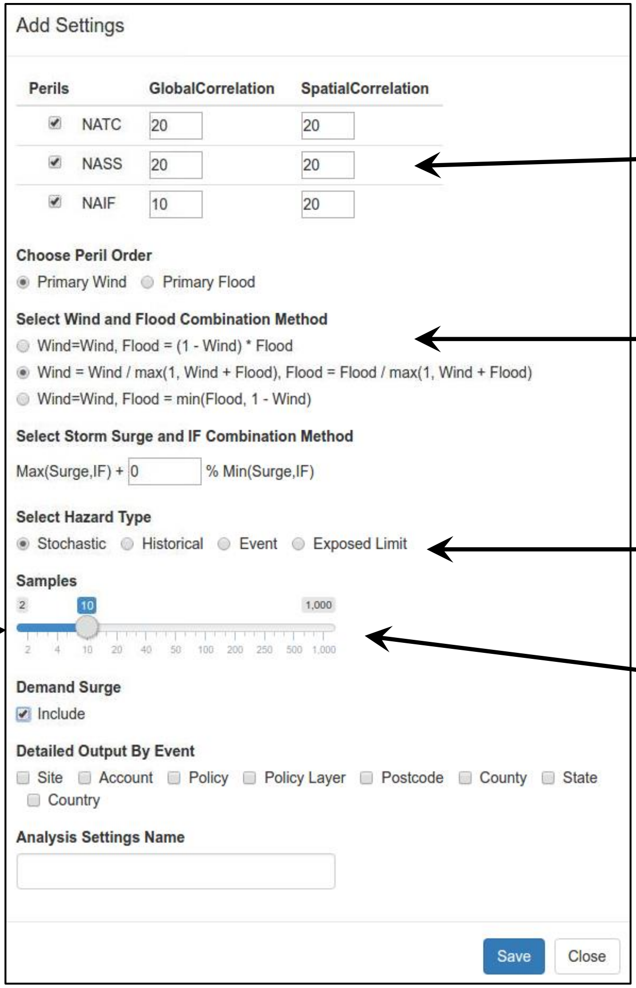
Sampling Uncertainty

4-Parameter Beta Distribution



All Other Uncertainty

- Fully repeatable MDR sampling (2 to 1k samples)
- Accounts for total loss and zero loss, and in between



Correlation Modeling

Combining Perils

Analysis Type

Variable/Repeatable Sampling

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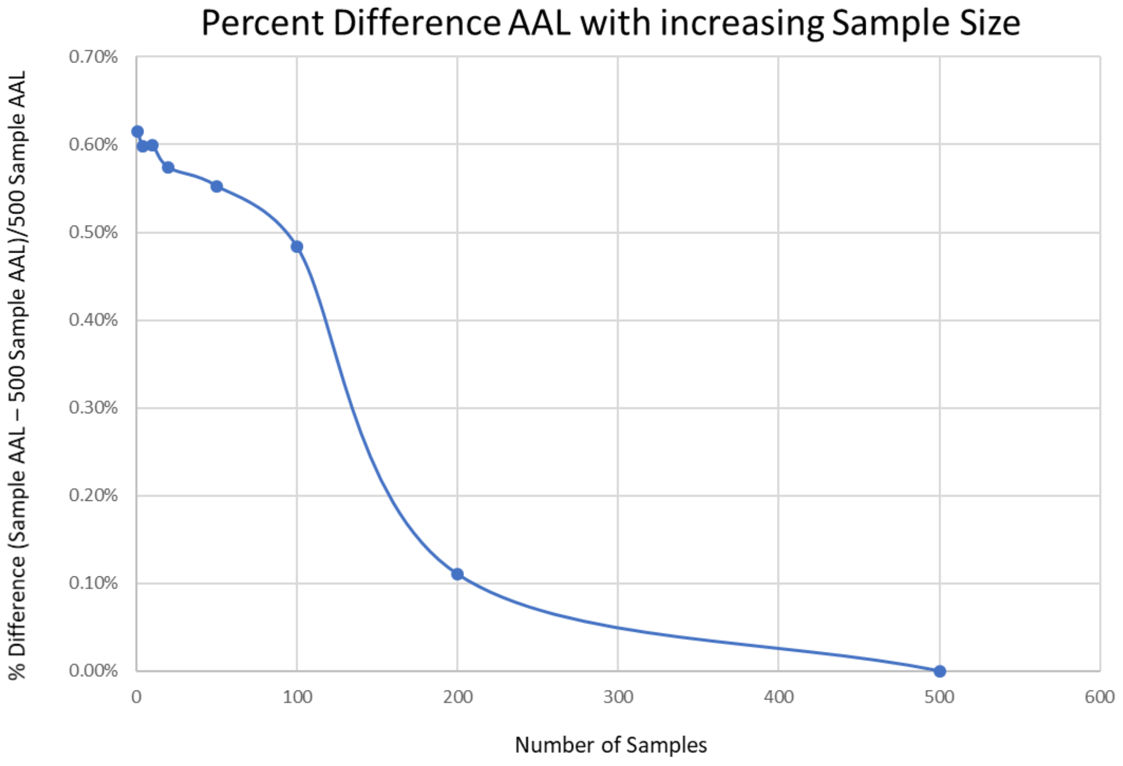
Sampling Uncertainty

20 Location Portfolio (Mix of very low and very high AALs)



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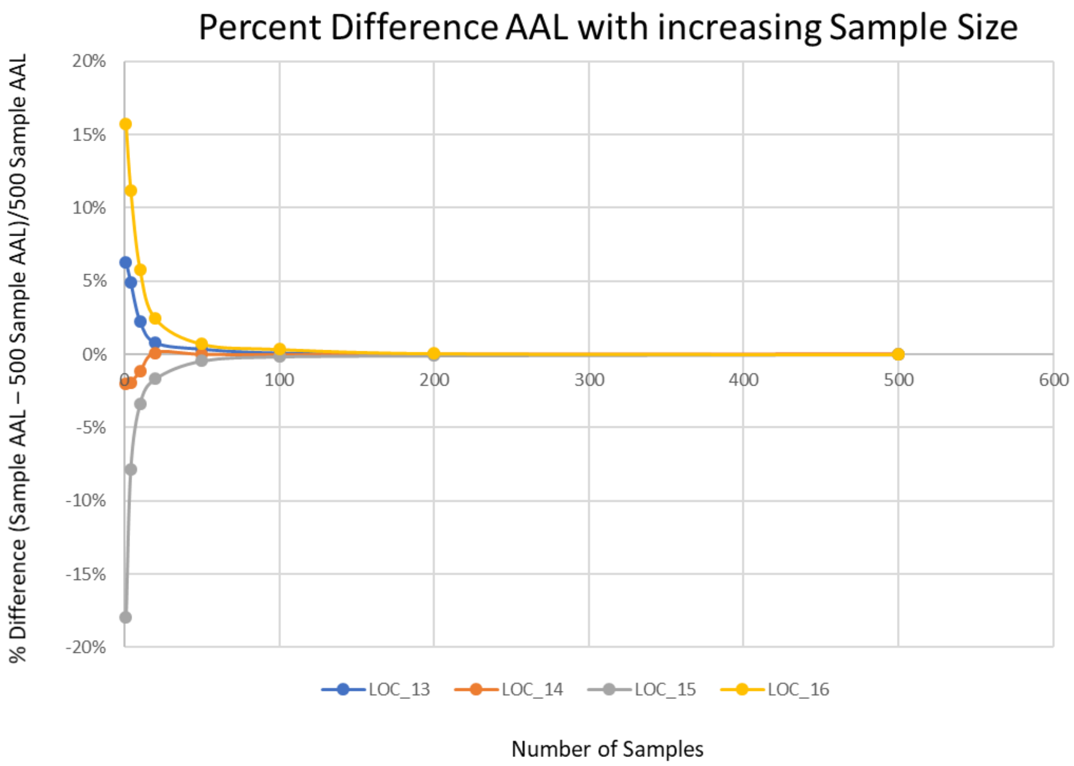
Sampling Uncertainty

4 Locations with very low AALs



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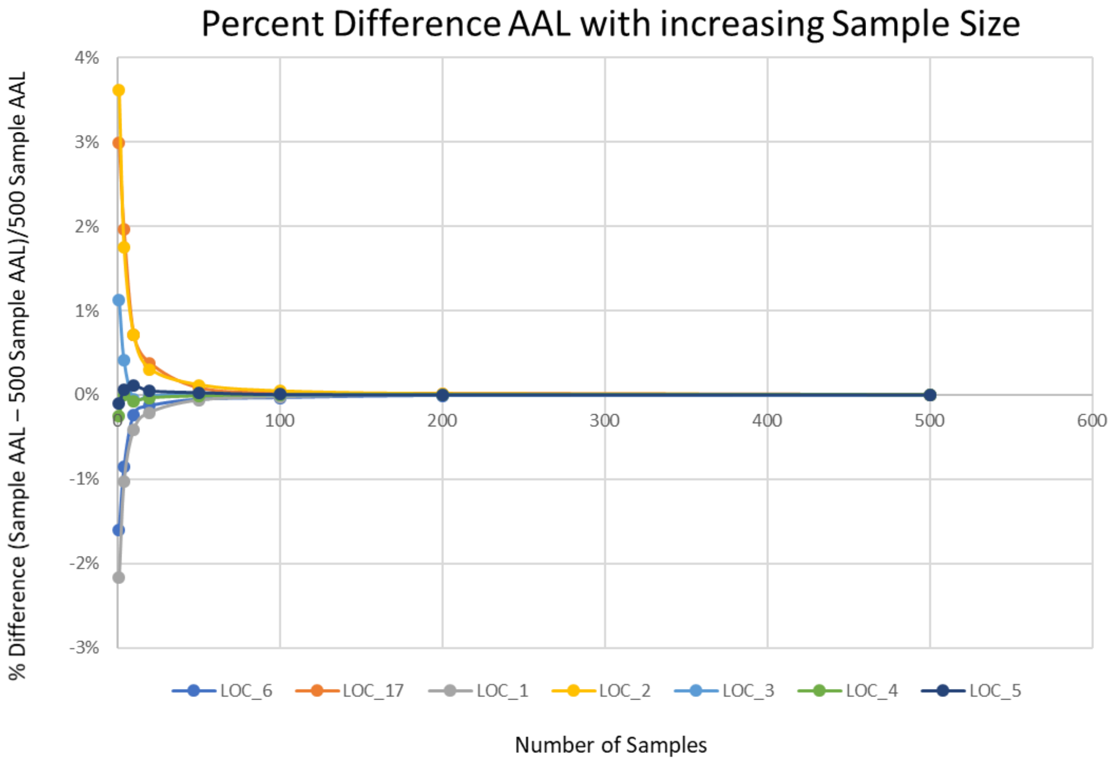
Sampling Uncertainty

8 Locations with low AALs



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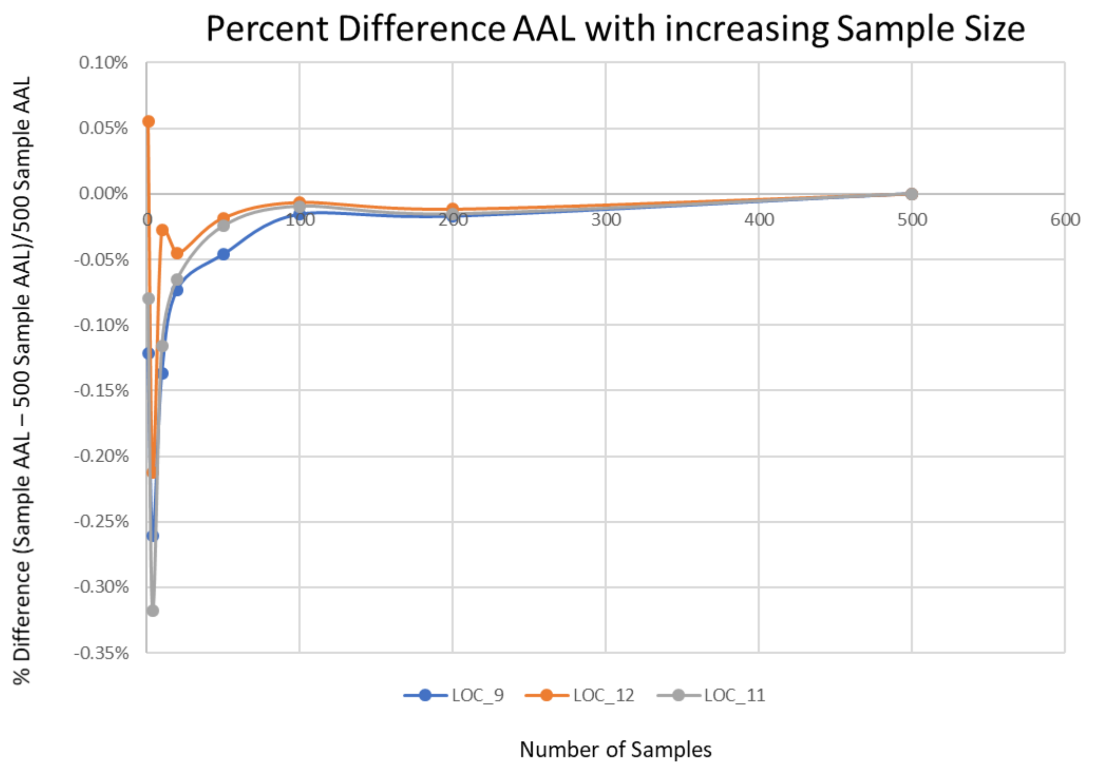
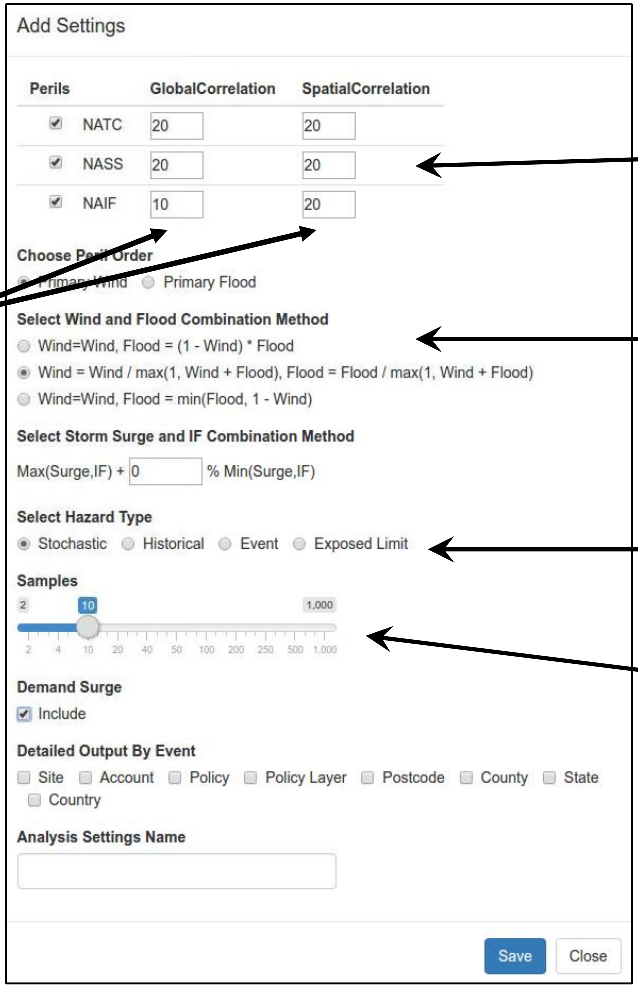
Sampling Uncertainty

3 Locations with medium/high AALs



Sampling/Correlation Uncertainty

Also allows one to increase or decrease correlation for globally for an event, or locally by event using an e-folding distance of 8km



Correlation Modeling

Combining Perils

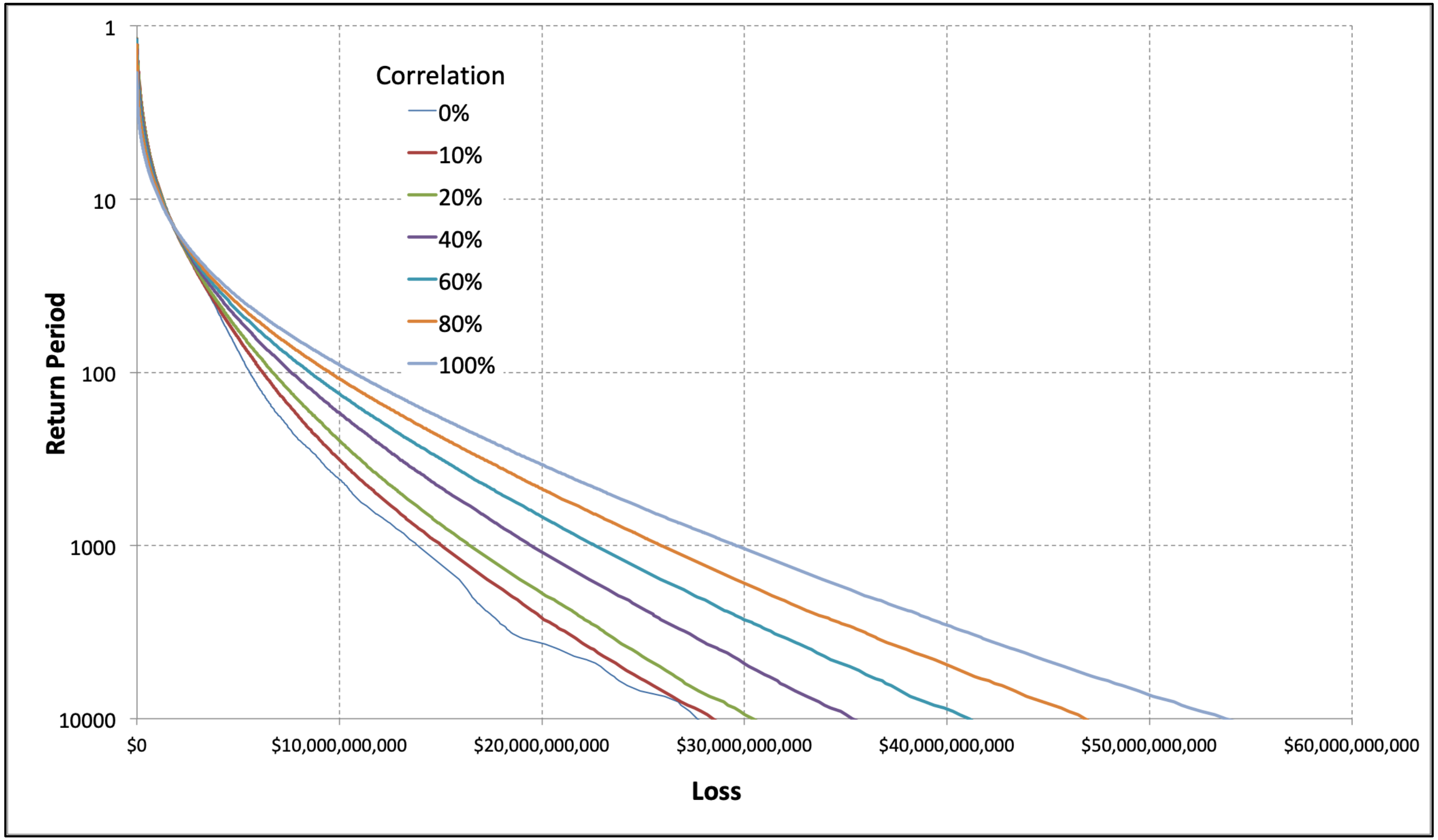
Analysis Type

Variable/Repeatable Sampling

KatRisk

Sampling/Correlation Uncertainty

Correlation Sensitivity



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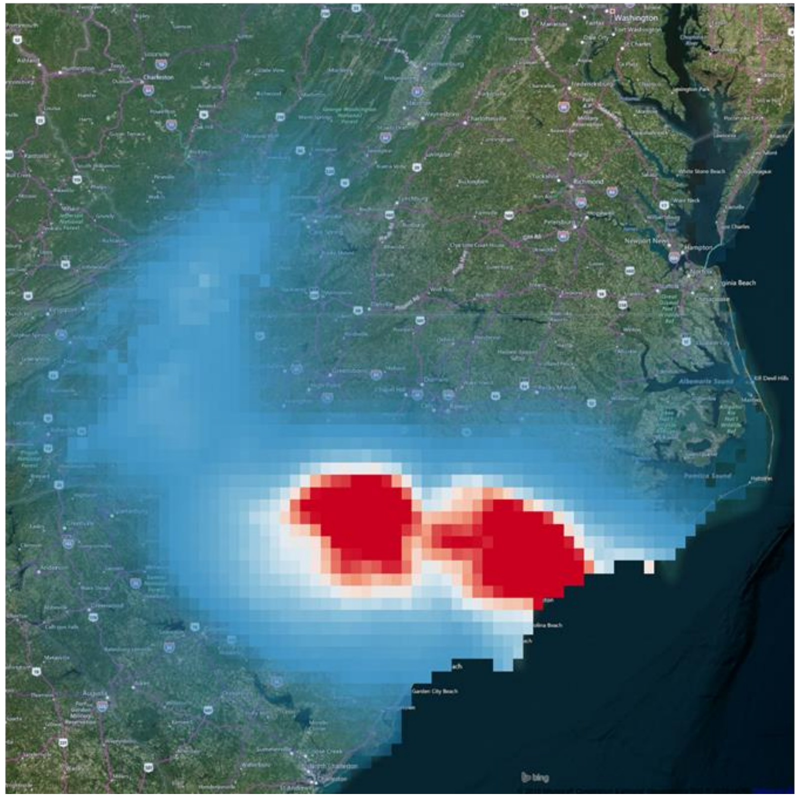
Pre/Post Event (Florence)

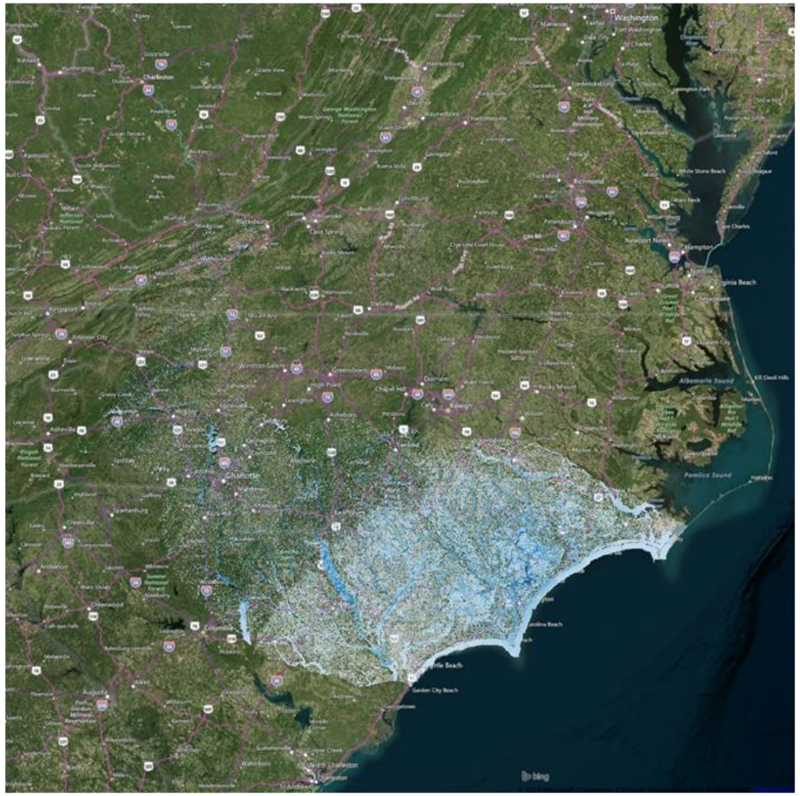
Florence: 4 days before landfall, using only forecasted precipitation

Sept 14th Forecast

Precipitation



Flood Depths



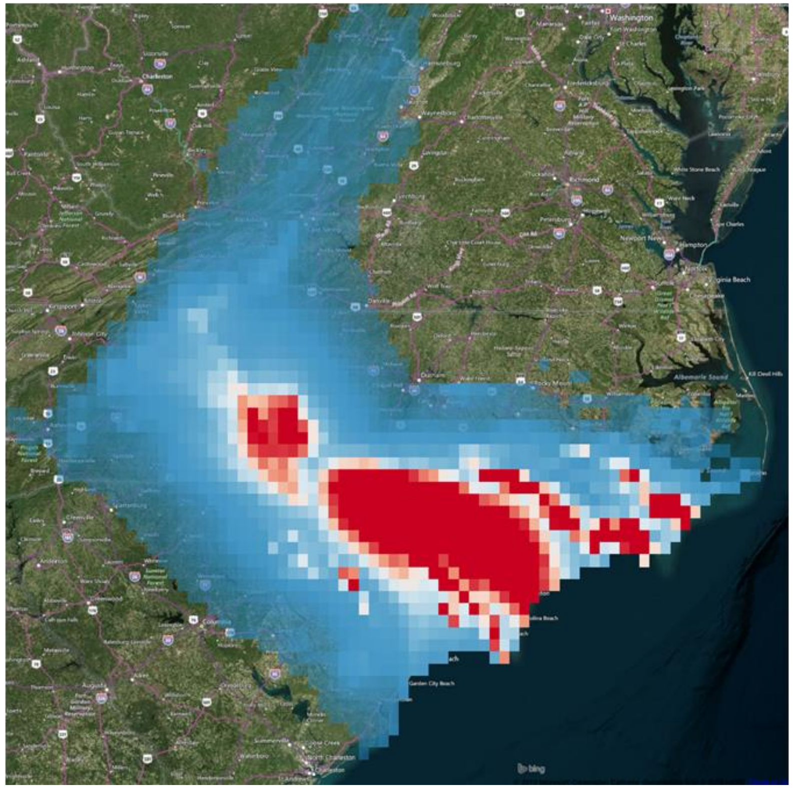
KatRisk

Pre/Post Event (Florence)

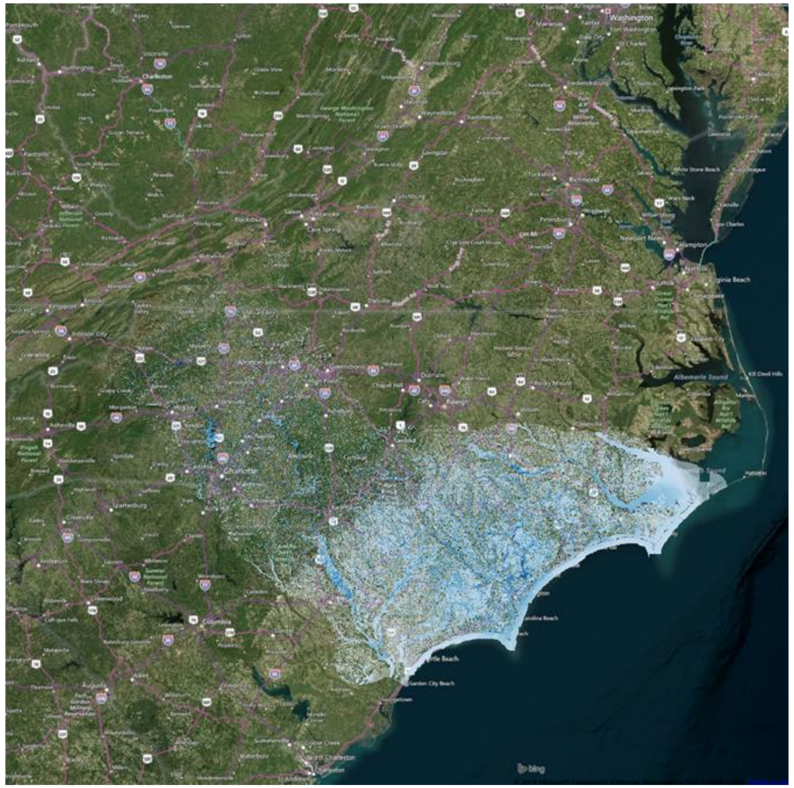
Florence: 2 days before landfall, using only forecasted precipitation and recorded rainfall accumulation

Sept 16th Forecast

Precipitation



Flood Depths



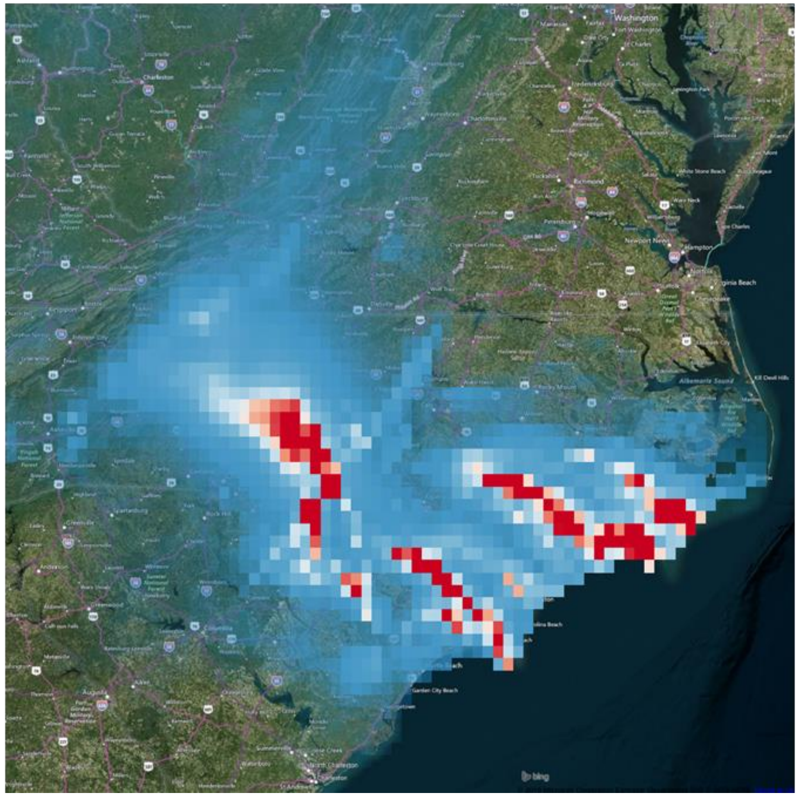
KatRisk

Pre/Post Event (Florence)

Florence: 1 day before landfall, using only forecasted precipitation and recorded rainfall accumulation

Sept 17th Forecast

Precipitation



Flood Depths

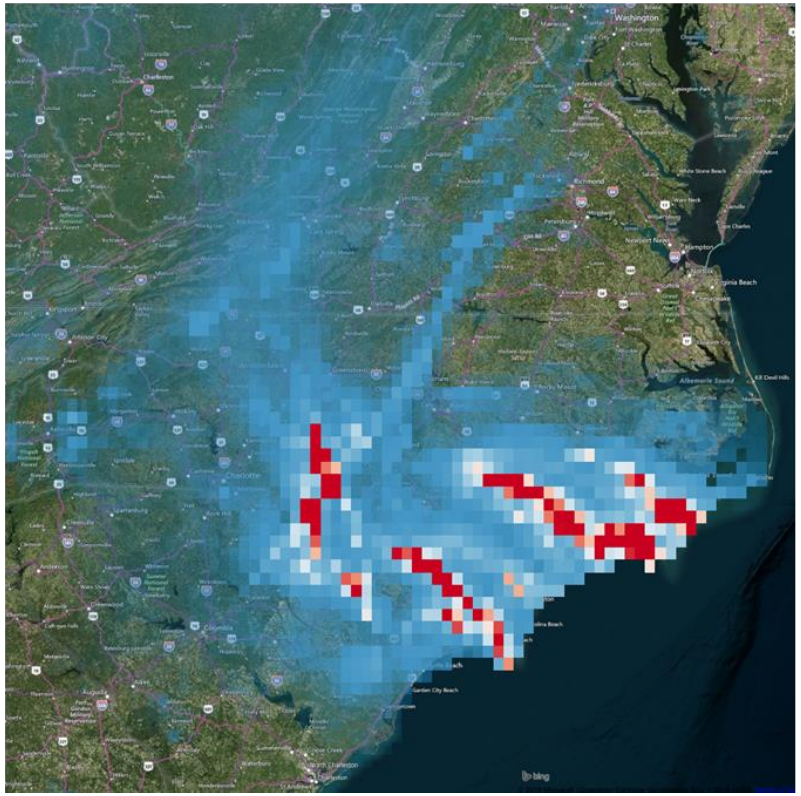
KatRisk

Pre/Post Event (Florence)

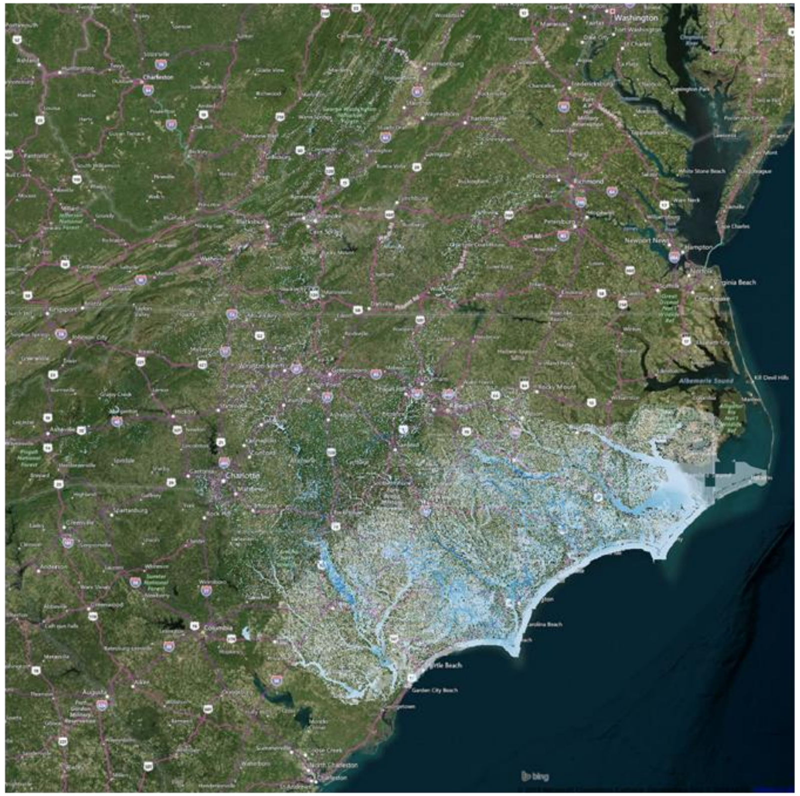
Florence: The event has completed, using only recorded rainfall accumulation

Sept 18th Final

Precipitation

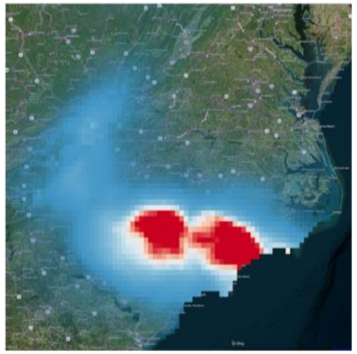


Flood Depths

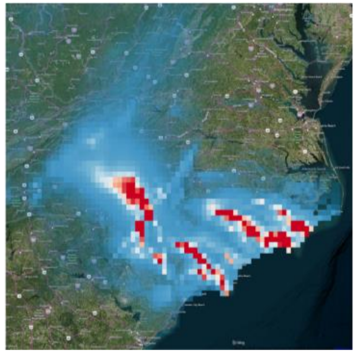


KatRisk

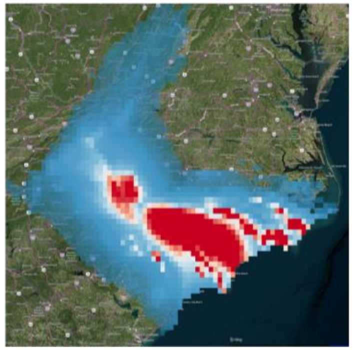
Pre/Post Event (Florence)



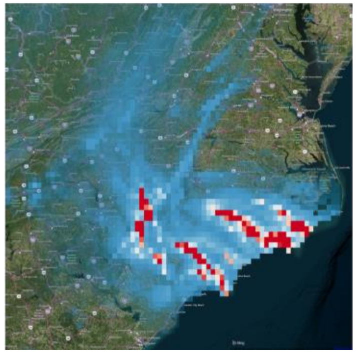
4 Days Before
% Effected TIV: 0.56%
GU/Effected TIV: 0.019



1 Day Before
% Effected TIV: 0.58%
GU/Effected TIV: 0.010



2 Days Before
% Effected TIV: 0.73%
GU/Effected TIV: 0.023



Post Event
% Effected TIV: 0.66%
GU/Effected TIV: 0.099

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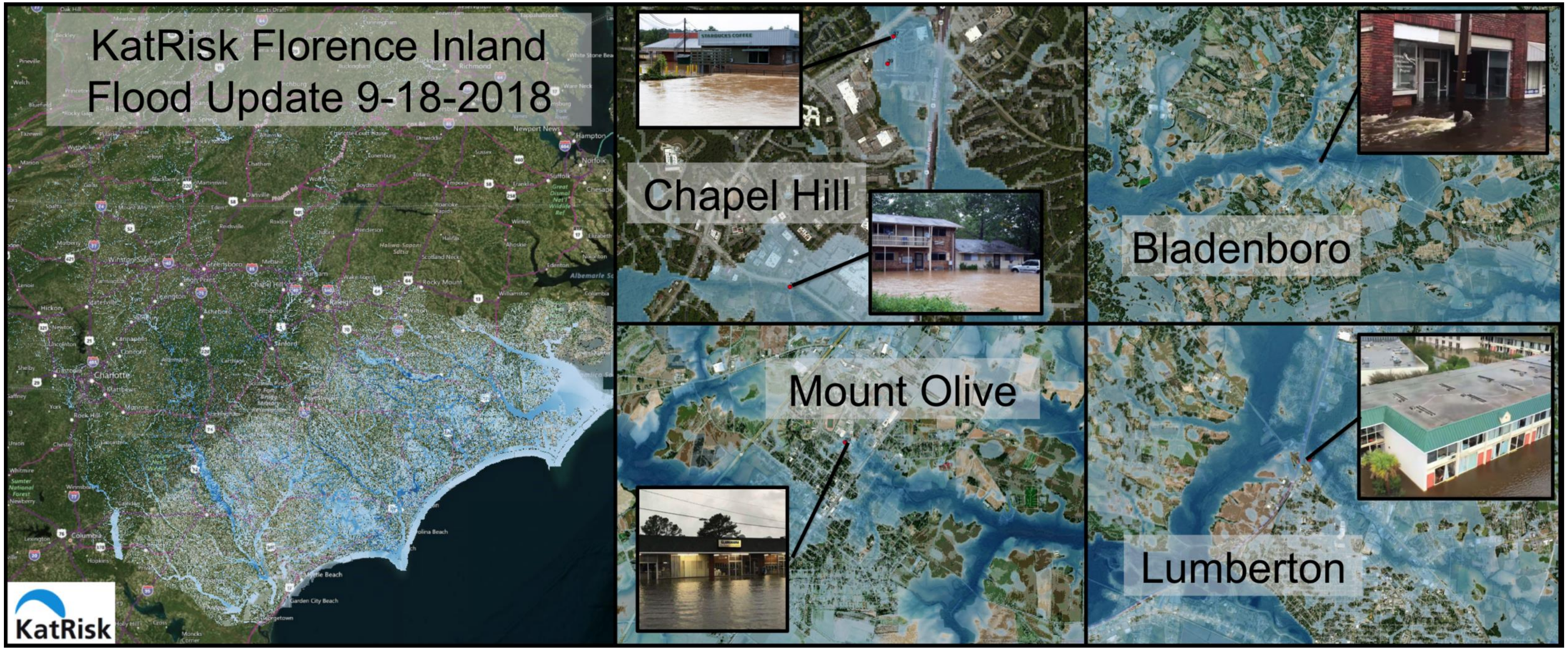
Post Event Reconstruction (Florence 2018)



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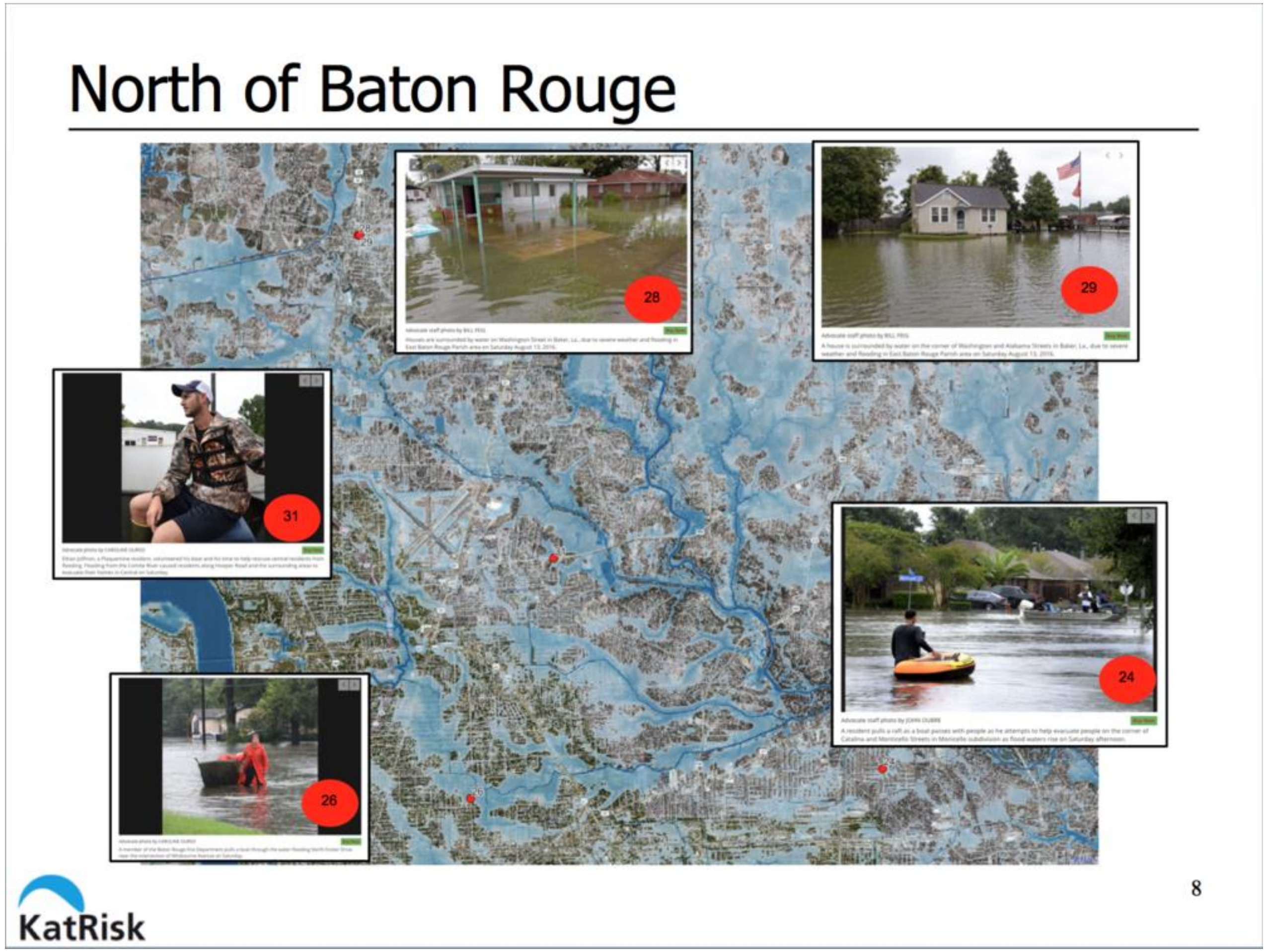
Post Event Reconstruction (Nate 2017)

Post Event Reconstruction (LA 2016)



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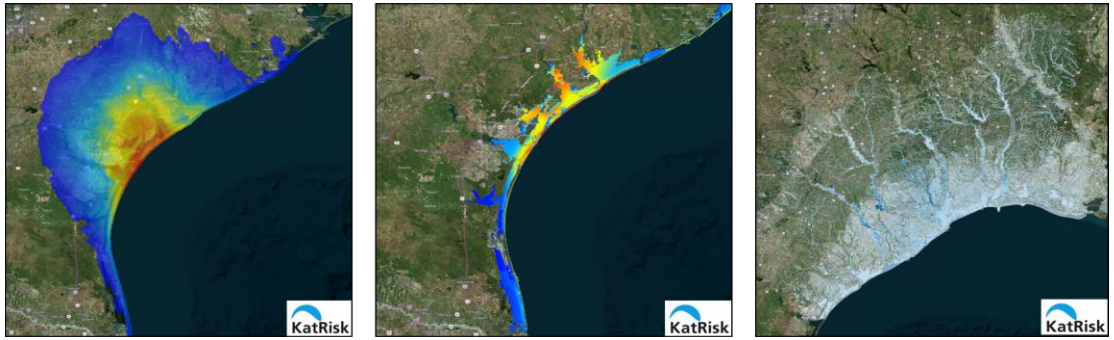
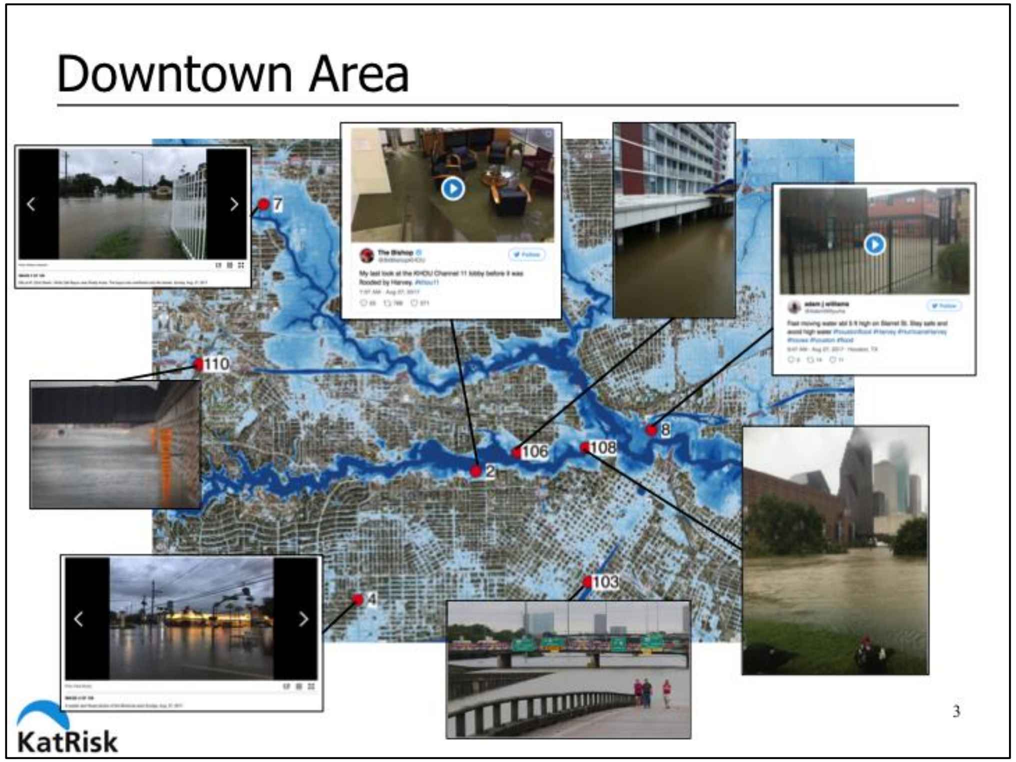
Post Event Reconstruction (Harvey 2016)

Hurricane Harvey



- KatRisk Provides footprint hazard maps within days of events
  - For Harvey, KatRisk released daily updated footprints
    - Included forecast flooding based on precipitation forecast data before and during the event
  - 8.8 million location IED in Texas
  - $40 - $50 billion GU Texas Inland Flood Loss
    - ~$80 billion total loss (Texas + Louisiana + other states)



KatRisk

Thank You!