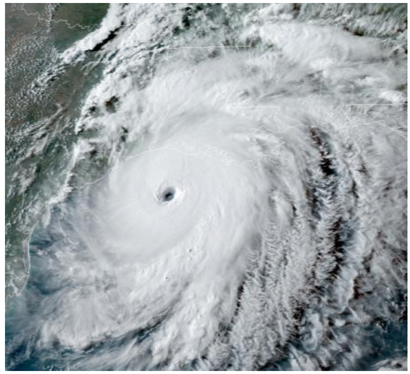
2021 U.S. Billion-dollar Weather and Climate Disasters in Historical Context - Hazard and Socioeconomic Risk Mapping



Better understanding disaster costs, hazard risk and resilience over space and time – integrating U.S. county socioeconomic risk mapping

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Climate Science and Services Division

April 2022

U.S Billion-dollar Weather and Climate Disasters

Outline:

- Context for Measuring Disaster Impact
- Data Sources / What we are Measuring
- 2021 U.S. Disasters in Review
- Historical Cost Comparisons, Maps, Tools
- County Multi-hazard Risk Mapping

NOAA’s National Centers for Environmental Information (NCEI) –

Climate Science and Service Division






Statutory mission to describe the climate of the United States and act as the **"Nation's Scorekeeper" regarding the trends and anomalies** of weather and climate.

- As part of this responsibility we also analyze extreme weather and climate events in the U.S. that have **great economic and societal impacts** known as “**U.S. Billion-dollar Weather & Climate Disasters**”

- NCEI’s U.S. billion-dollar disaster analysis seeks to bring the best public and private disaster loss data together in a systematic approach. To that end, we maintain a consistent record of weather and climate disasters with costs equaling or exceeding $1 billion in damages (adjusting for inflation) using high-quality data sources and peer-reviewed methods.

- **Period of record: 1980-2021 (Quarterly updates)**
- The U.S. has sustained **323** separate weather and climate disasters since 1980 where overall damages/costs reached or exceeded $1 billion.
- **Total, direct costs exceed $2.195 trillion (CPI-adjusted to 2022).**

To capture losses requires a broad array of **public** and **private** data

	Hurricanes/ Tropical Storms	Severe Local Storms	Winter Storms	Crop Freeze	Wildfire	Drought / Heat Wave	Inland / Riverine Flooding
Insurance Service Office - Property Claim Services	x	x	x		x		x
FEMA – Presidential Disaster Declarations	x	x	x	x	x		x
FEMA – National Flood Insurance Program	x						x
USDA – Risk Management Agency	x	x	x	x	x	x	x
National Interagency Fire Center					x		
Energy Information Administration	x	x	x		x	x	
US Army Corps of Engineers							x
State Agencies	x	x	x	x	x	x	x

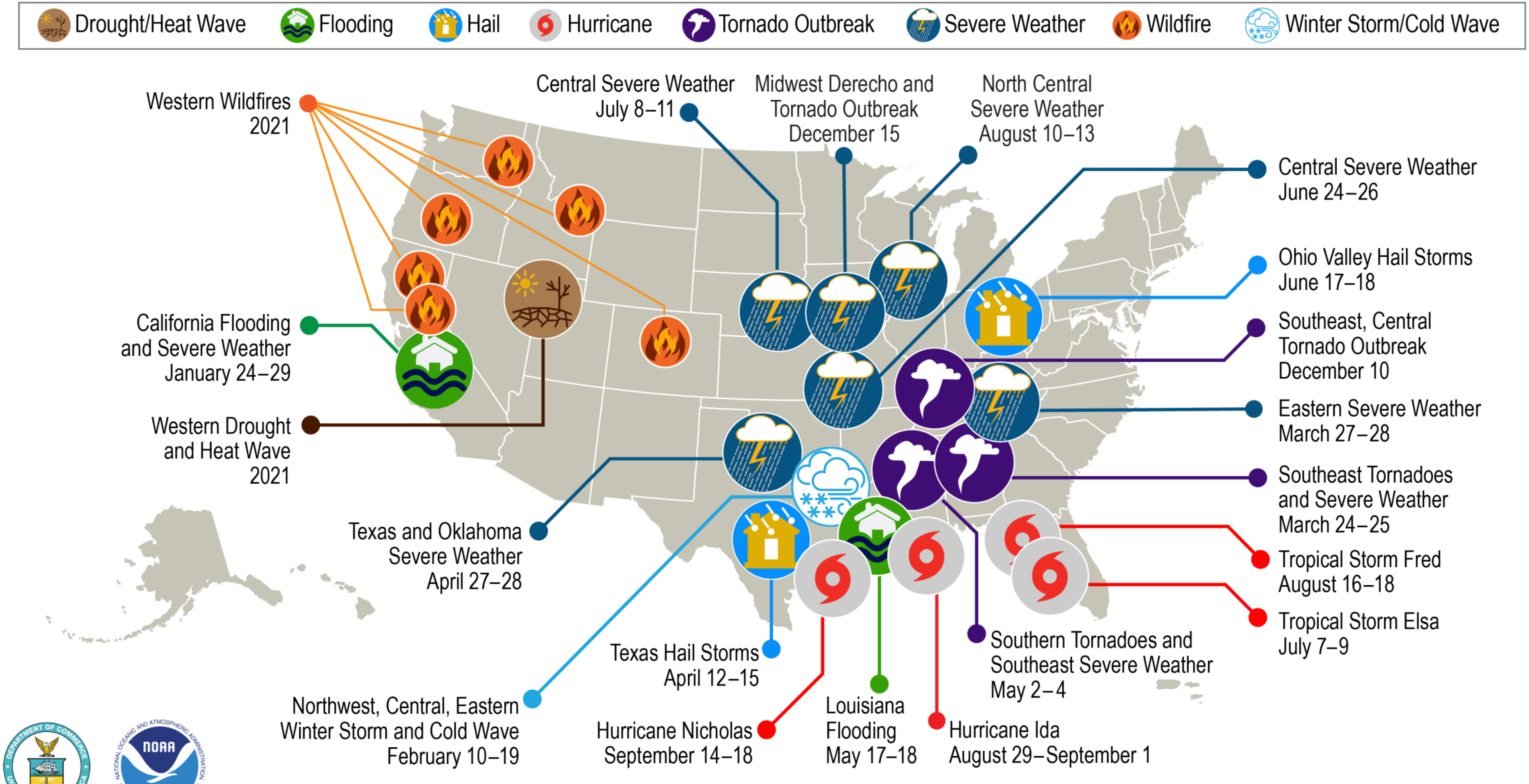
Account for total, direct losses (i.e., **insured** and **uninsured**) for assets including:

- **physical damage** to residential, commercial, and government buildings
- **material assets** (content) within a building
- **time element losses** (i.e., time costs for businesses; hotel costs for loss of living quarters)
- **vehicles, boats, offshore energy platforms**
- **public infrastructure** (i.e., roads, bridges, levees, buildings)
- **Agricultural / forestry assets** (i.e., crops, livestock, commercial timber, wildfire fighting)

We do not account for:

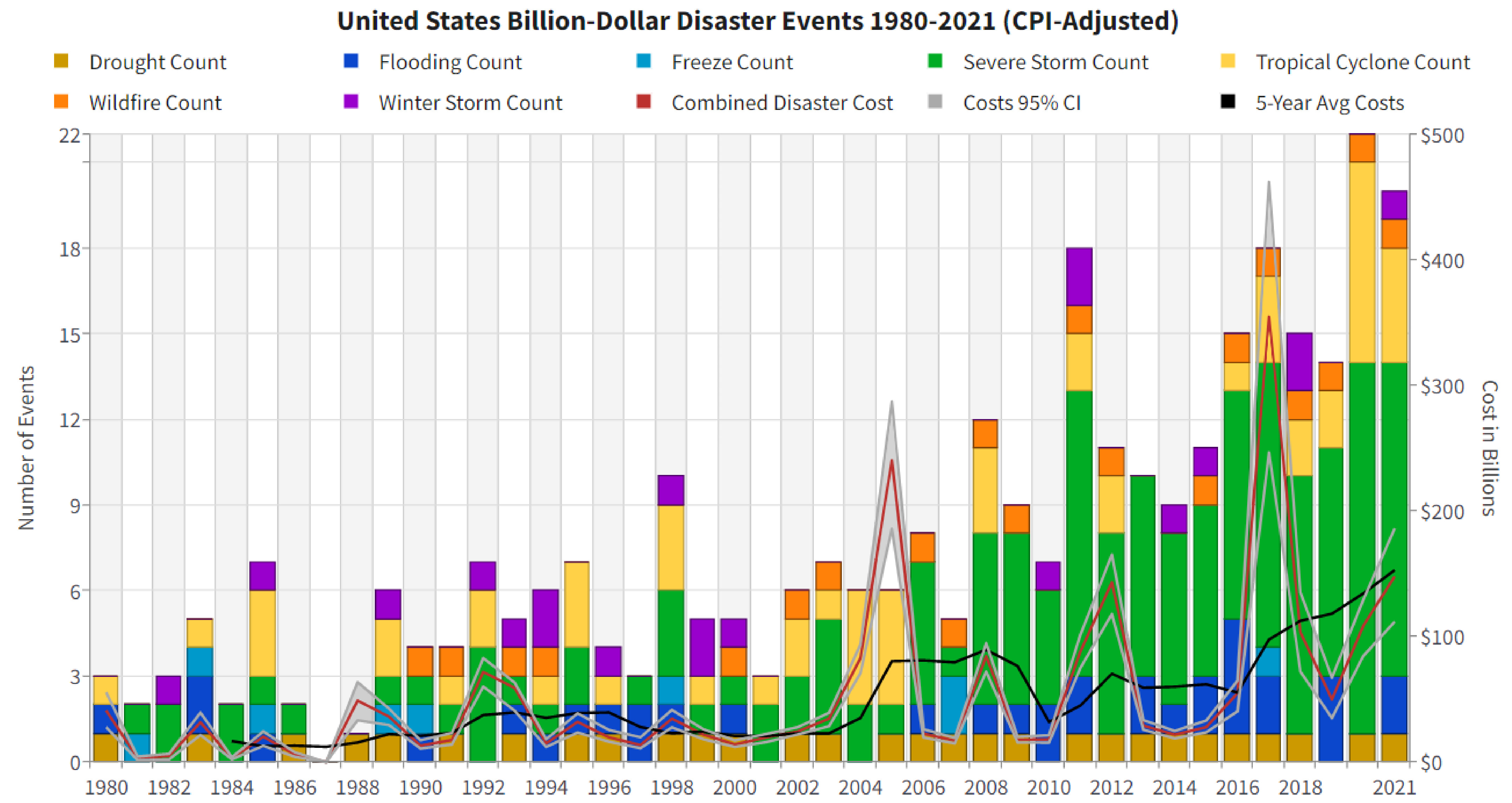
- natural capital/envn. degradation;
- mental or physical healthcare-related costs;
- all downstream (indirect) costs

U.S. 2021 Billion-Dollar Weather and Climate Disasters



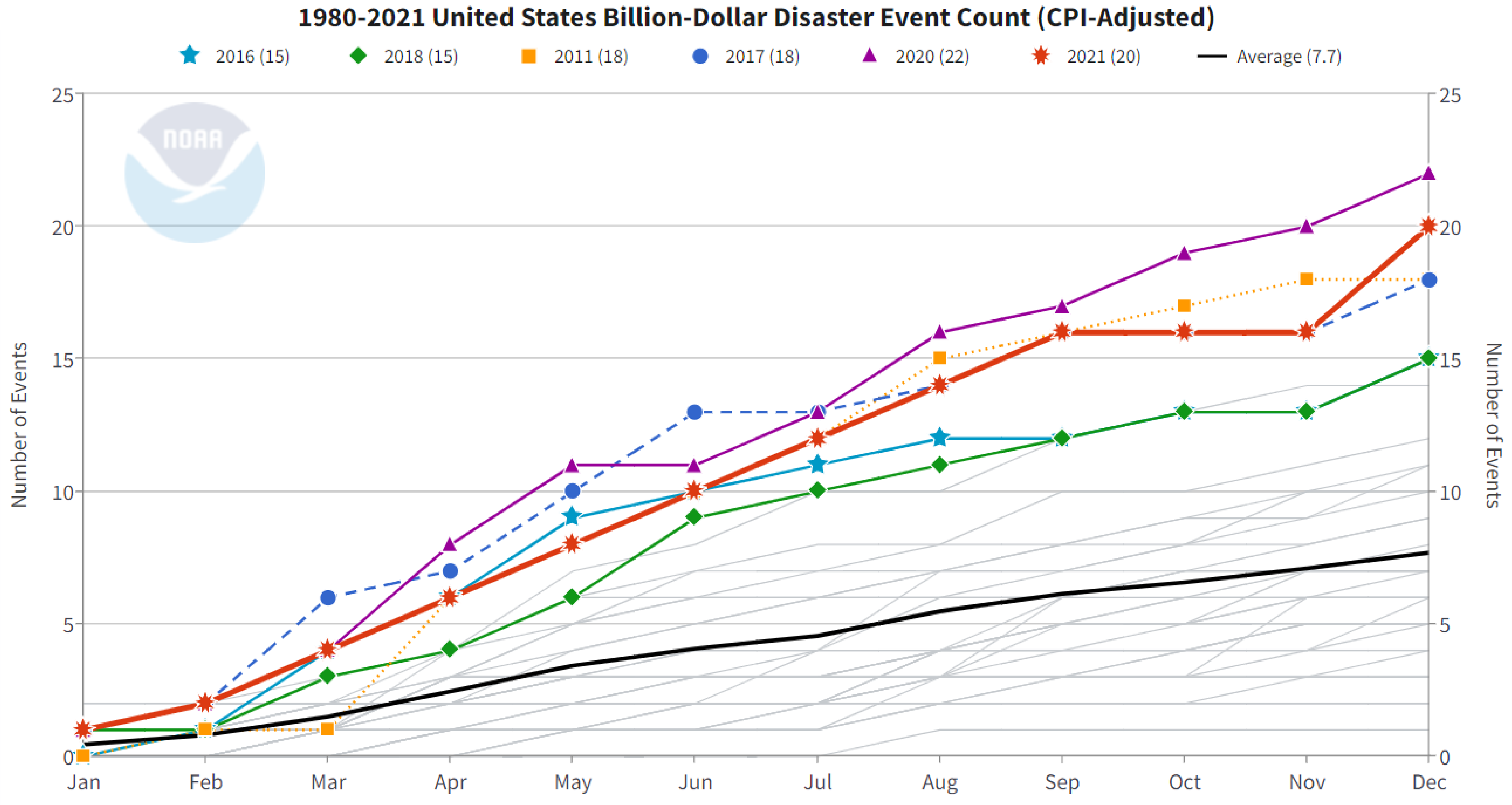
This map denotes the approximate location for each of the ***20 separate billion-dollar weather and climate disasters that impacted the United States in 2021***

U.S. Billion-dollar event frequency, annual cost, 5-year cost average (1980–2021)



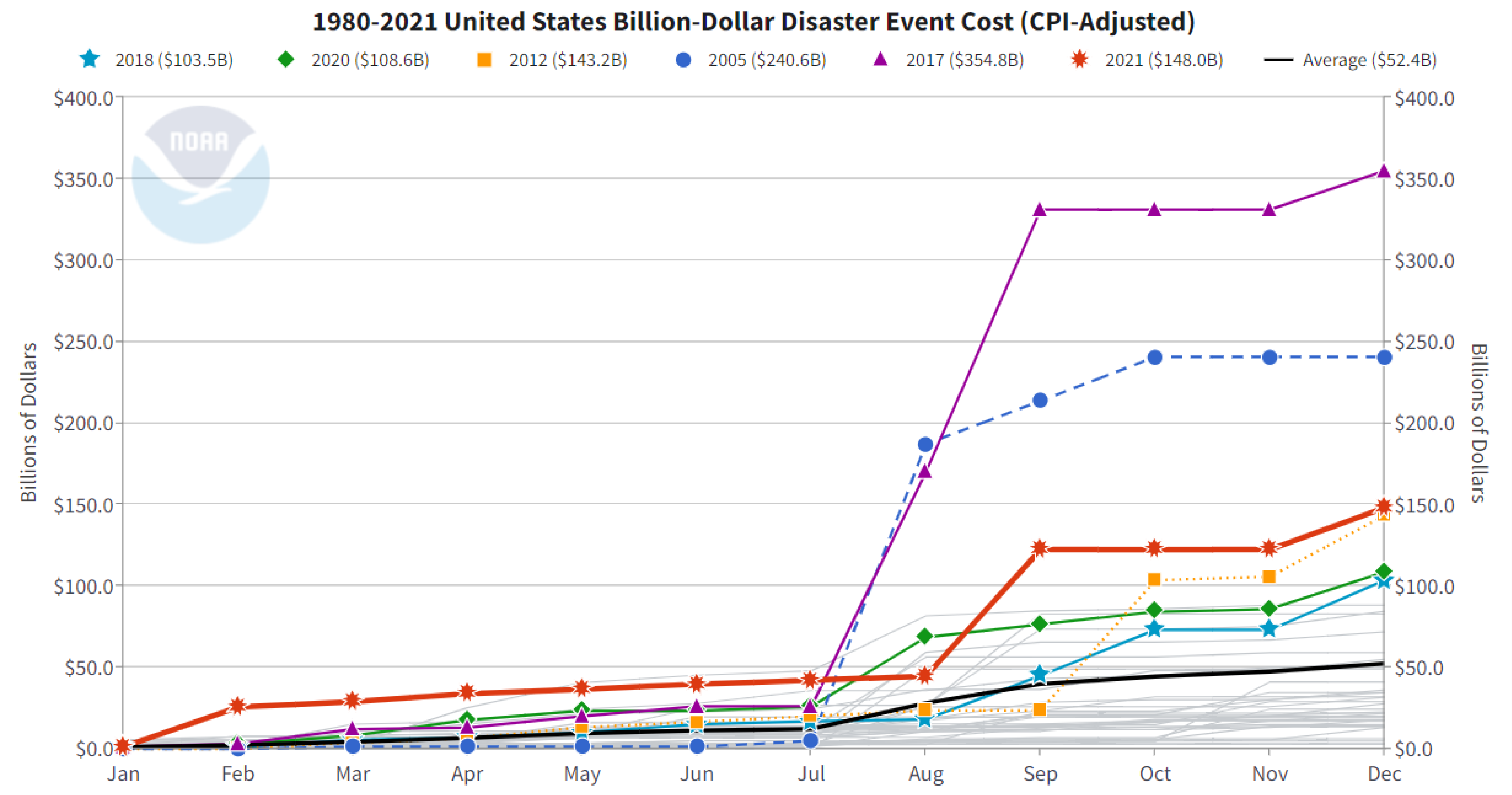
- Western wildfires, severe storms, inland flooding and hurricane costs all on the rise
- <u>**5-year annual cost average**</u> >**$152.9 billion - a record;** costs over **5 years** (2017-2021) **$764.9 billion - a record**

Cumulative U.S. billion-dollar disaster frequency (year-to-date) for years 1980-2021



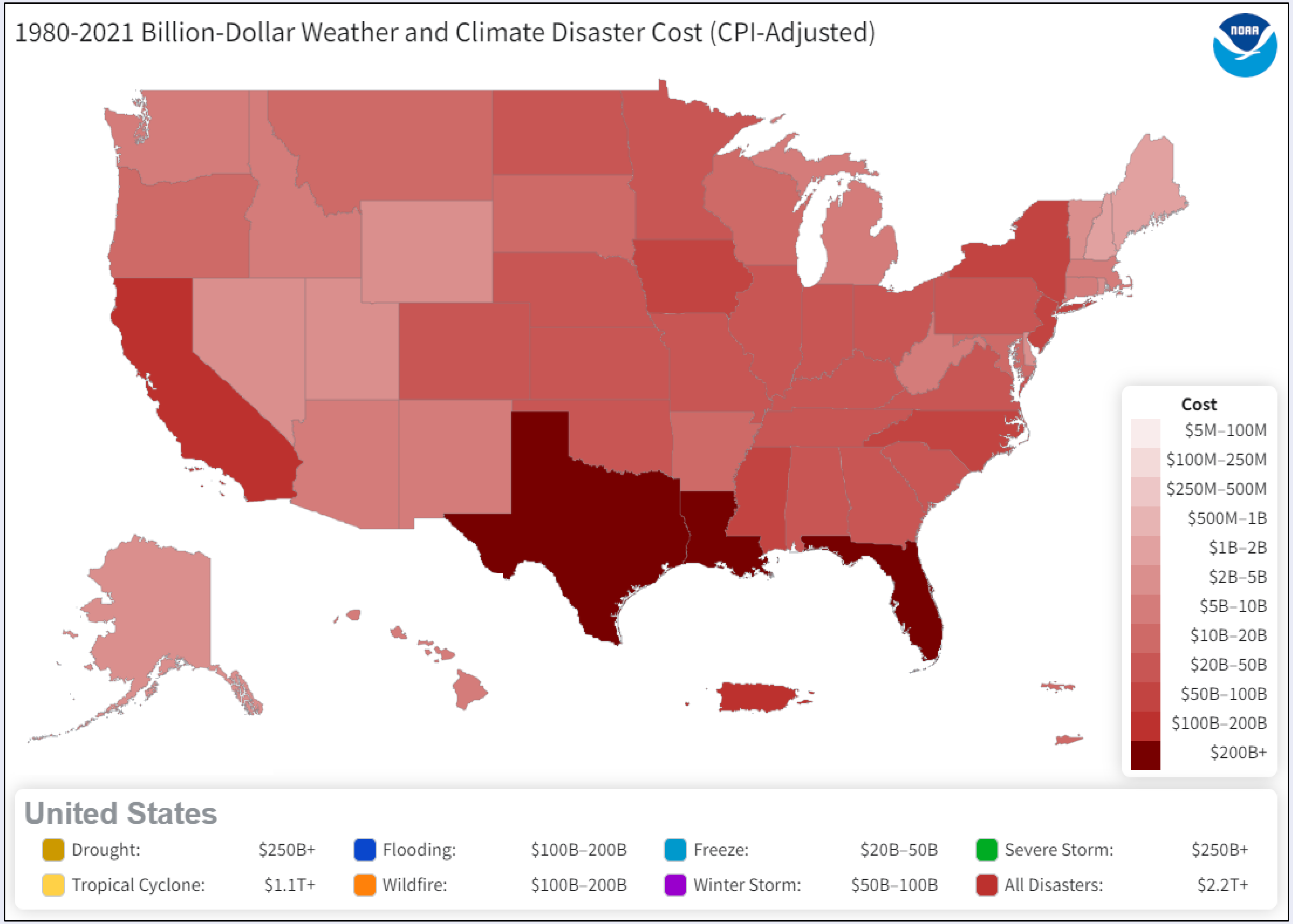
- **1980 – 2021** annual average: **7.7 events** (CPI-adjusted). **2017–2021** 5-year average: **17.8 events** (CPI-adjusted)
- **2021 - 20 events** [11 severe storm events, 4 tropical cyclones, 2 floods, 1 winter storm, drought & wildfire]

Cumulative U.S. billion-dollar disaster cost (year-to-date) for years 1980-2021



- **2021** <u>cost total</u> (**$148.0 billion – 3rd highest**) vs. the 42-year period of record at **$52.4 billion**
- The **top 3 most costly years** for U.S. - **2017** ($354.8 billion); **2005** ($240.6 billion); **2021** ($148.0 billion)

From 1980–2021, the U.S. **South, Central** and **Southeast** regions experienced a higher cost from billion-dollar disaster events. CA, NY, NJ, PR and V.I. as well.



- Reflects the **severity** and **vulnerability** of weather & climate events impacting different regions
- The **top 3 most impacted states:**
  - **Texas** ($349 billion)
  - **Louisiana** ($278 billion)
  - **Florida** ($249 billion)
- The relative costs are more acute in Louisiana, as its population and economic size is much smaller than Texas or Florida.
- Louisiana also has a high frequency of disaster events, which can leads to compounding, cascading socioeconomic impacts.

From **1980-2021**, the U.S. has experienced **323** distinct billion-dollar weather & climate events - each causing at least $1 billion in direct losses

- **Total, direct losses** from these **323 events** exceeds **$2.195 trillion** (CPI-adjusted, 2022)

Disaster Type	Events	Events/Year	Percent Frequency	Total Costs	Percent of Total Costs	Cost/Event	Cost/Year	Deaths	Deaths/Year
Drought	29	0.7	9.0%	$291.1B CI	13.2%	$10.0B	$6.9B	4,139†	99†
Flooding	36	0.9	11.1%	$168.4B CI	7.7%	$4.7B	$4.0B	634	15
Freeze	9	0.2	2.8%	$33.7B CI	1.5%	$3.7B	$0.8B	162	4
Severe Storm	152	3.6	47.1%	$344.8B CI	15.7%	$2.3B	$8.2B	1,975	47
Tropical Cyclone	57	1.4	17.6%	$1,157.1B CI	52.6%	$20.3B	$27.6B	6,708	160
Wildfire	20	0.5	6.2%	$123.6B CI	5.6%	$6.2B	$2.9B	418	10
Winter Storm	20	0.5	6.2%	$81.0B CI	3.7%	$4.1B	$1.9B	1,313	31
All Disasters	**323**	**7.7**	**100.0%**	**$2,199.7B** CI	**100.0%**	**$6.8B**	**$52.4B**	**15,349**	**365**

†Deaths associated with drought are the result of heat waves. (Not all droughts are accompanied by extreme heat waves.)

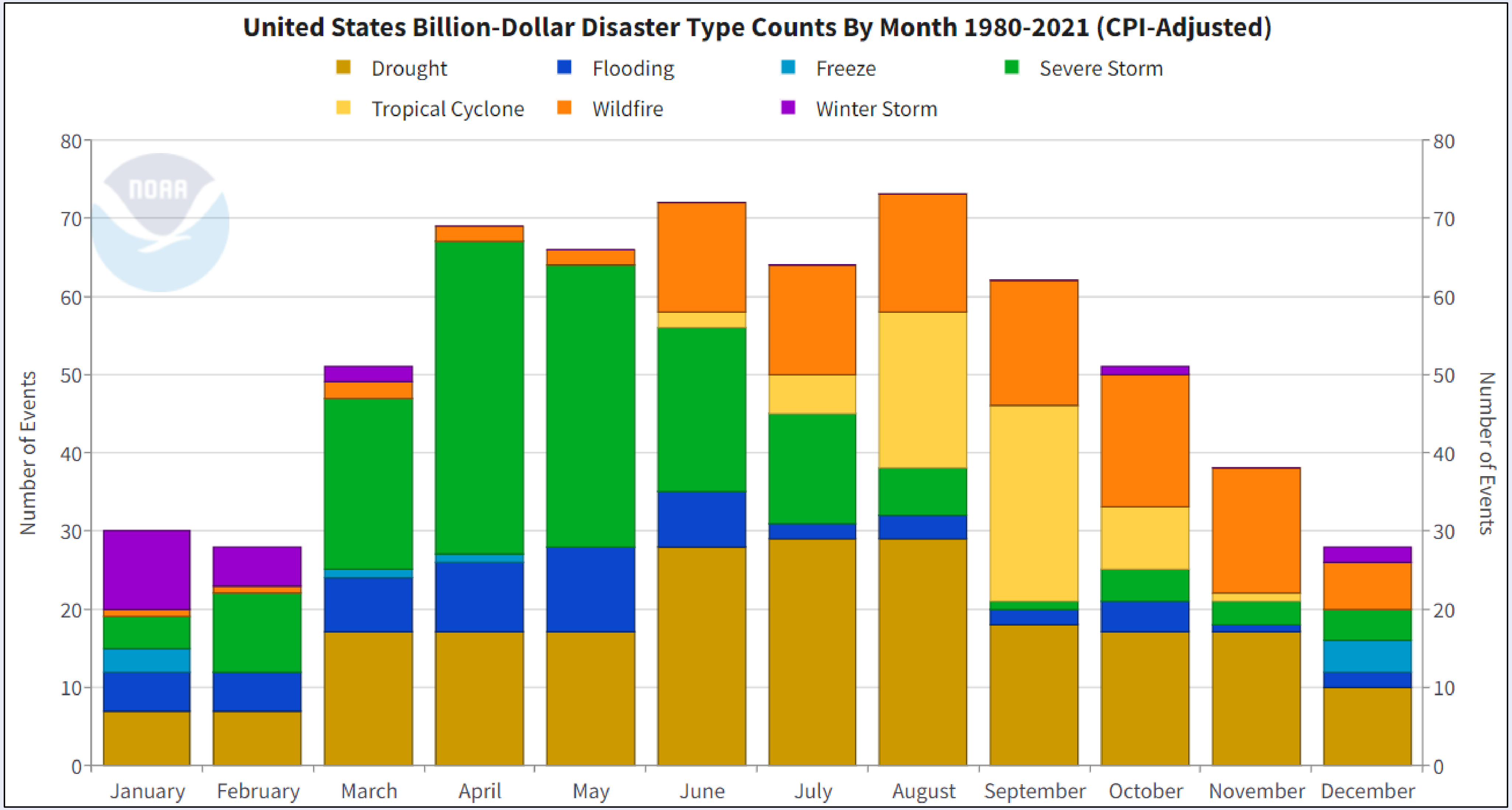
Flooding events (river basin or urban flooding from excessive rainfall) are separate from inland flood damage caused by tropical cyclone events.

Comparison of U.S. Billion-dollar disaster stats over time

Time Period	Billion-Dollar Disasters	Events/Year	Cost	Percent of Total Cost	Cost/Year	Deaths	Deaths/Year
1980s (1980-1989)	31	3.1	$195.2B	8.9%	$19.5B	2,975	298
1990s (1990-1999)	55	5.5	$298.4B	13.6%	$29.8B	3,062	306
2000s (2000-2009)	67	6.7	$558.0B	25.4%	$55.8B	3,102	310
2010s (2010-2019)	128	12.8	$891.5B	40.5%	$89.2B	5,224	522
Last 5 Years (2017-2021)	89	17.8	$764.9B	34.8%	$153.0B	4,555	911
Last 3 Years (2019-2021)	56	18.7	$306.6B	13.9%	$102.2B	1,030	343
Last Year (2021)	20	20.0	$148.0B	6.7%	$148.0B	724	724
All Years (1980-2021)	**323**	**7.7**	**$2,199.7B**	**100.0%**	**$52.4B**	**15,349**	**365**

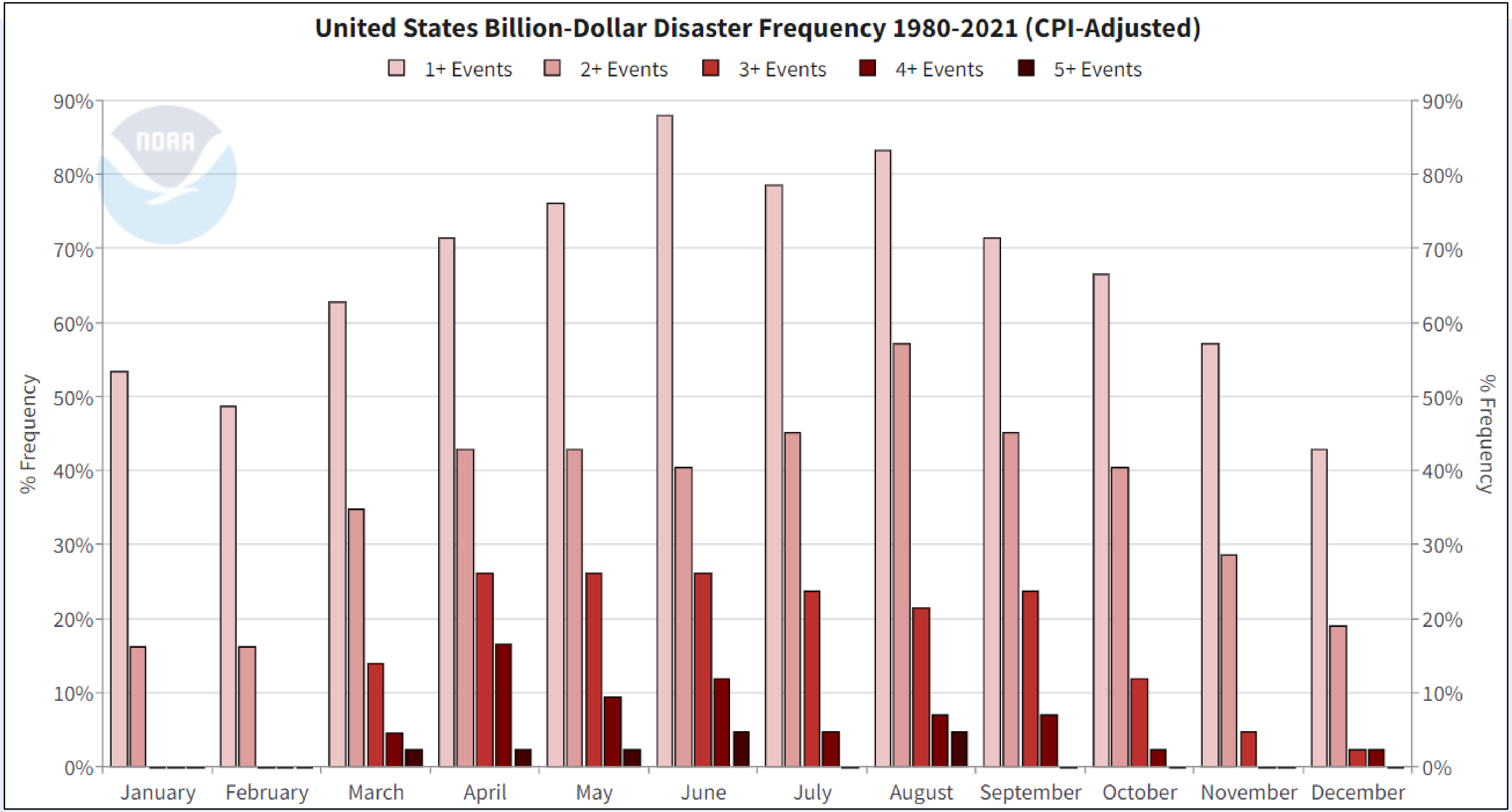
The **number and cost of disasters are increasing over time** due to a **combination of** increased exposure (i.e., values at risk of possible loss), vulnerability (i.e., where we build; how we build) and that climate change is increasing the frequency of some types of extremes that lead to billion-dollar disasters (NCA 2018, Chapter 2)

Severe storm and **inland flooding events** frequent during **Spring** and **Summer**
Wildfires and **hurricanes** most frequent during **Fall** months.



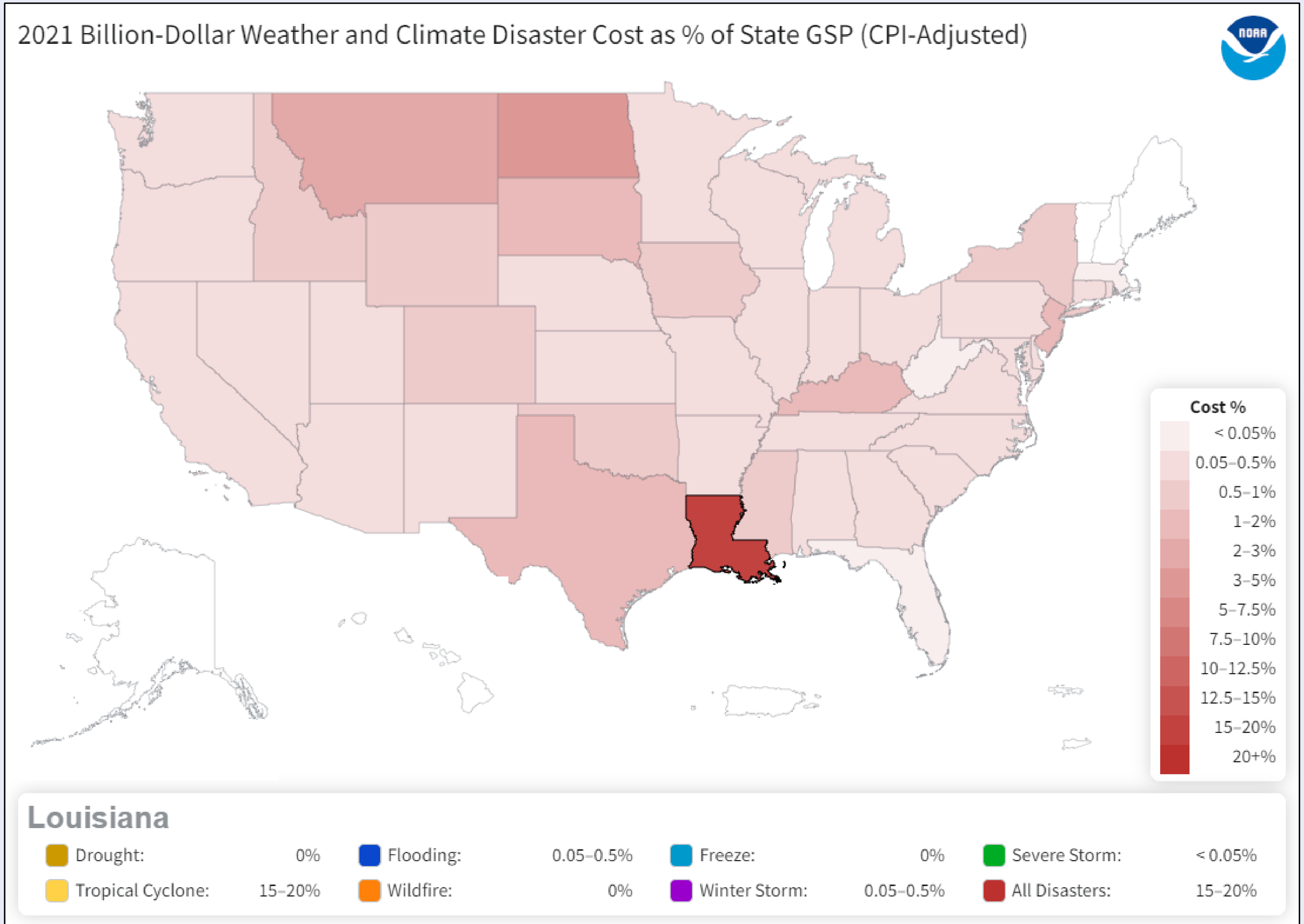
- Visualizing the 42-year **frequency of climatology of extreme**, damaging events across the Nation.
- A way for decision-makers to understand which types of large events typically occur at what times of year, by region.

Historic record for multiple, billion-dollar events, by month



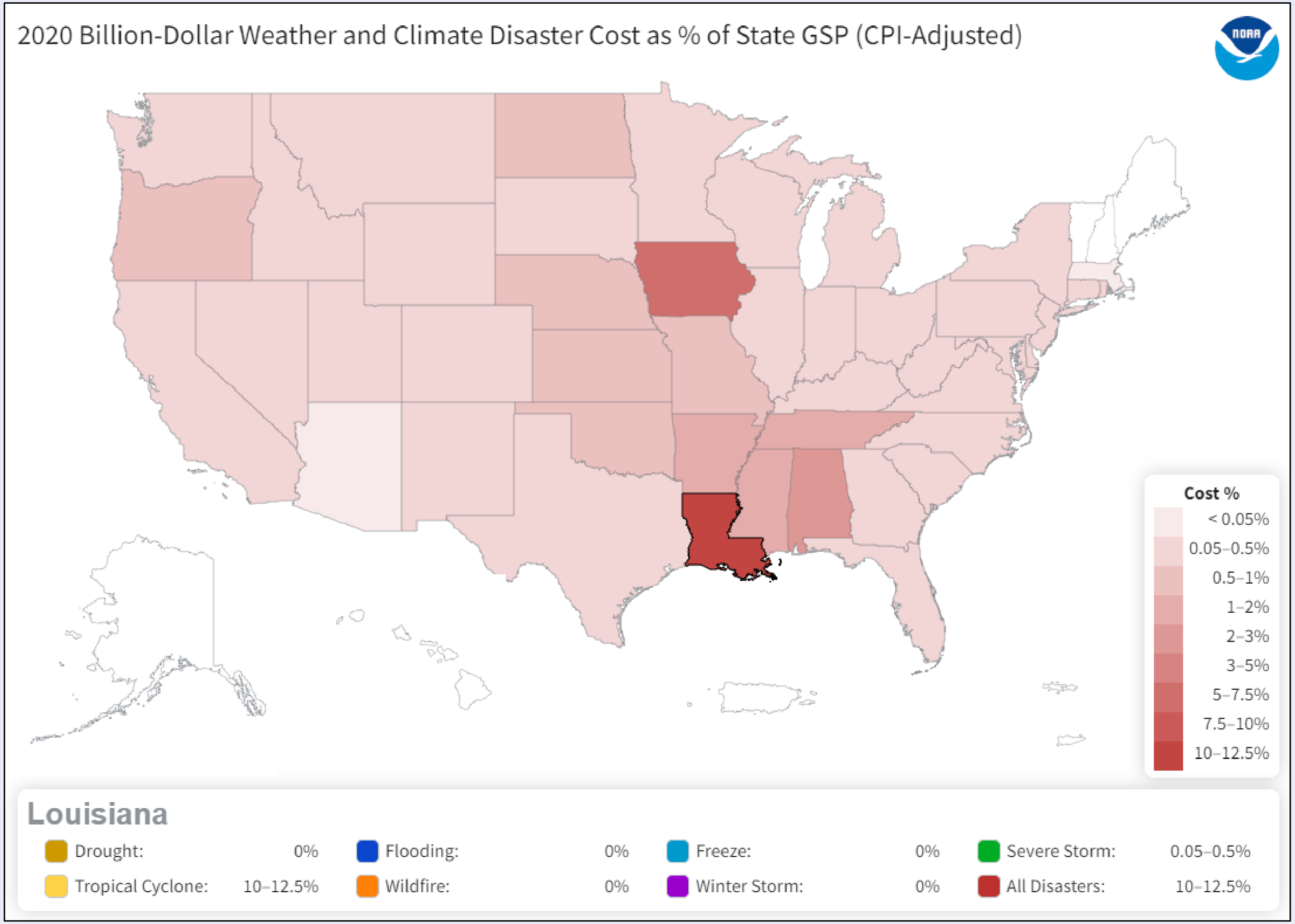
As noted in the *Climate Science Special Report* of the *Fourth National Climate Assessment*, "The physical and socioeconomic impacts of **compound extreme events** (such as simultaneous heat and drought, wildfires associated with hot and dry conditions, or flooding associated with high precipitation on top of snow or waterlogged ground) can be **greater than the sum of the parts**."

The **2021 disaster costs** for each state as a **% of that state's 2021 GDP** (economic output)... clear impact from billion-dollar disaster events.



- Reflects the **severity** & **vulnerability** of weather & climate events vs. scale of each state’s economy

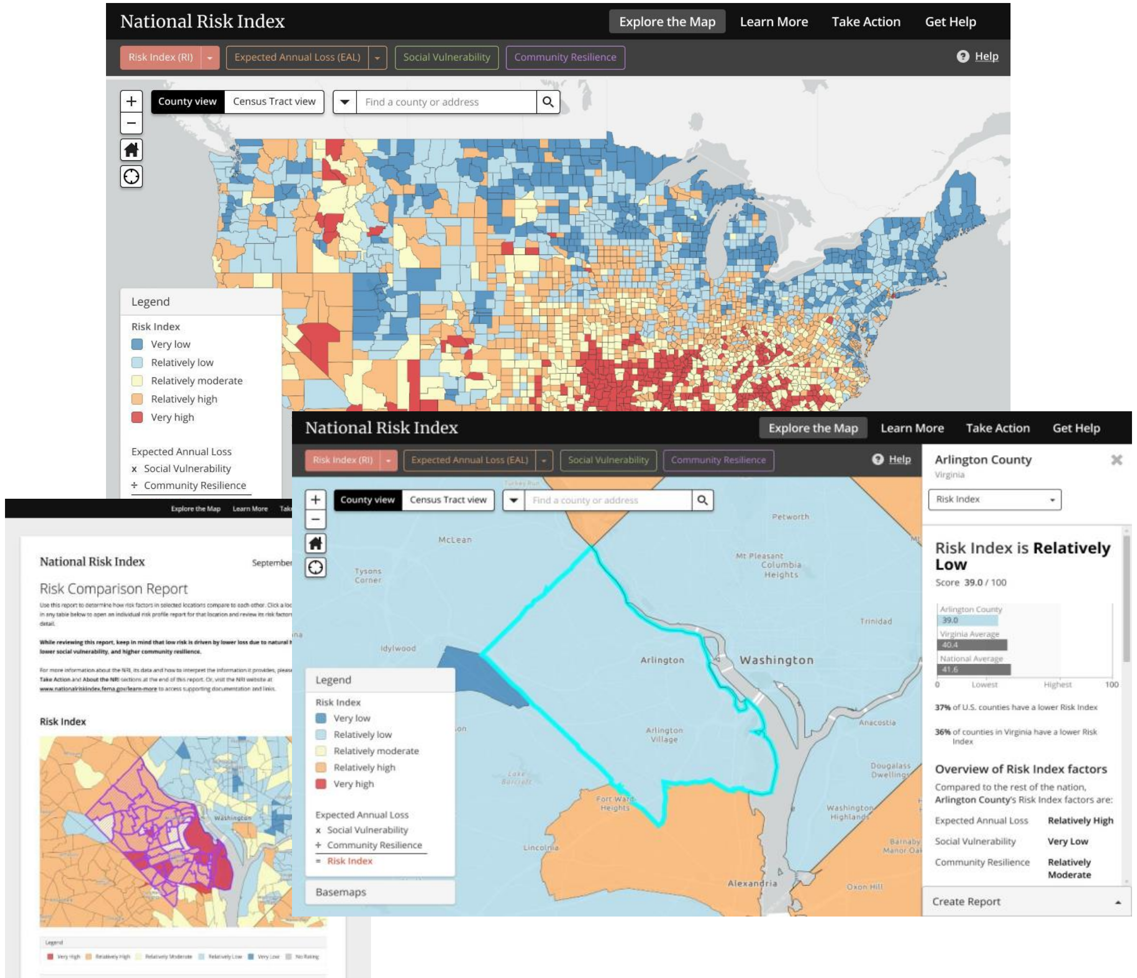
The **2020 disaster costs** for each state as a **% of that state's 2020 GDP** (economic output)… clear impact from billion-dollar disaster events.



- Reflects the **severity** & **vulnerability** of weather & climate events vs. scale of each state's economy
- Compound hazards and cascading impacts slow down recover and increase the cost

New: Integration & expansion of FEMA National Risk Index within the Billion-dollar disasters platform

- A strategy for reducing cost and eliminating inconsistent risk assessments in planning
- Identifies areas that offer high return on mitigation investment
- Reduces the cost of risk assessment allowing community planners to prioritize action
- Provides pre-calculated, top- down national baseline risk assessment



Multi-hazard county weather and climate risk mapping

- NCEI worked with & expanded upon FEMA's NRI to enhance the NOAA Billion-dollar disaster website producing **127 new, interactive U.S. county hazard risk maps** for <u>any combination of county-level hazard risk for</u>:

  hurricanes, severe storms (tornado, hail, damaging winds), inland/urban flooding, drought/heat wave, wildfire, winter storms and freeze/cold wave events.

- Importantly, these maps offer more <u>granular information</u> in relation to <u>**exposure, vulnerability and resilience**</u> to weather & climate hazards, at a <u>county scale</u>.

- These new hazard combination maps are useful as we see more focus on <u>**cascading hazard impacts**</u>

  For example: drought-enhanced wildfires produce mountain-side burn scars, which often enhance debris flows from flooding. This is a compound hazard with cascading impacts that we see in California.

Calculating Risk

Risk = Expected Annual Loss x Social Vulnerability ÷ Community Resilience

where Expected Annual Loss (EAL) =

Annual Frequency		Exposure		Historic Loss Ratio
Rate of occurrence	**X**	**• Property Value • People • Agriculture**	**X**	**Percentage of property/people/crop losses**
How likely is hazard to occur?		How many people & how much property are potentially at risk?		What percent of property/people have historically been lost from hazard in a given area?

Estimating Annualized Frequency: Rate of hazard occurrence

SOURCE DATA

HISTORICAL EVENT DATA

Strong Wind | Tornado | Winter Weather | Cold Wave | Hail | Heat Wave | Riverine Flooding

- Storm Events Database
- Severe Weather Database
- Weather Alerts

Hurricane | Lightning | Tsunami | Drought | Ice Storm | Landslide

- HURDAT2 Best Track
- Cloud-to-Ground Lightning
- Tsunami Runup Data

NDMC | CRREL | NASA

PROBABILISTIC MODELS

Earthquake | Wildfire

USGS science for a changing world | Forest Service

HIGH THREAT AREAS

Avalanche | Volcano | Coastal Flooding

Forest Service | Smithsonian Institution | National Flood Insurance Program | NOAA

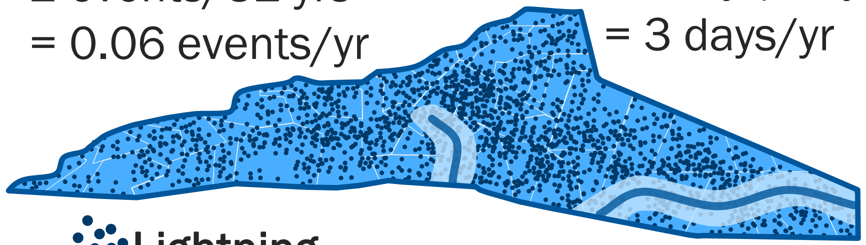
- HURDAT2
- Sea level rise
- High tide

CENSUS TRACT FREQUENCY ESTIMATES

of historical events or event days depending on hazard

Tornado
2 events/32 yrs
= 0.06 events/yr

Heat Wave
36 days/12yrs
= 3 days/yr



Lightning
2200 events/22 yrs = 100 events/yr

Establishing Hazard Exposure: People/property/ag at risk

Many hazards impact the entire county/census tract while some are limited to susceptible zones

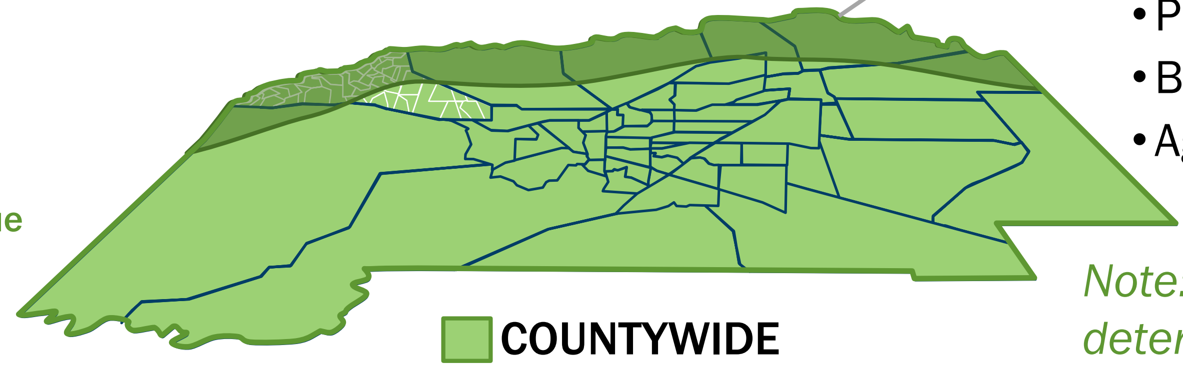
SOURCE DATA

HAZUS®
EARTHQUAKE • WIND • FLOOD • TSUNAMI

- Population
- Building Value

2017 CENSUS OF AGRICULTURE

- Agriculture



HAZARD SUSCEPTIBLE ZONE

- Population: 300K
- Building Value: $90B
- Agriculture: $120M

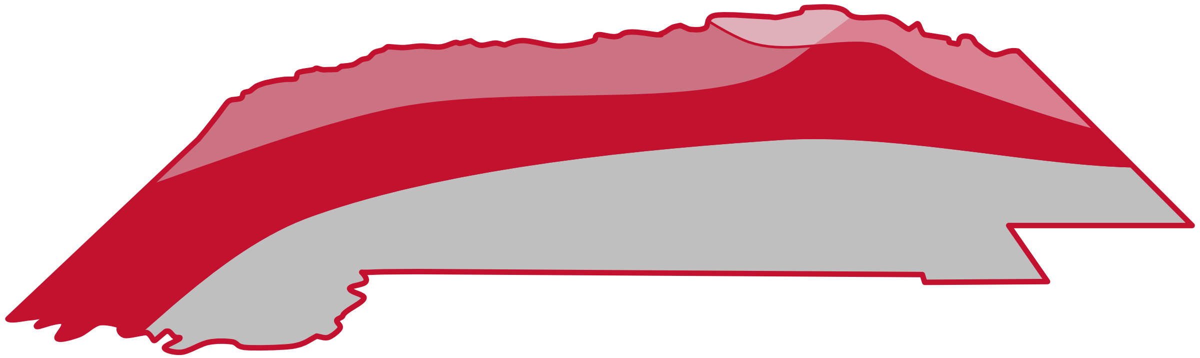
COUNTYWIDE

- Population: 1.3M
- Building Value: $250B
- Agriculture: $720M

Note: Susceptible areas determined by hazard-specific source data polygons

Characterizing Historic Loss Ratios: % of exposure lost in historic events

To address variance & lack of enough events for statistical significance, **county ratios are calculating using Bayesian adjustments informed by averages from multiple geographic levels**



SOURCE DATA

Spatial Hazard Events & Losses Database for the U.S. (SHELDUS)

Arizona State University

DATA

Historic Loss Events

Event	Loss / Exposure
9/91	$50M/$250B = 0.02%
6/07	$300M/$250B = 0.1%
8/14	$15B/$250B = 6%

County Historic Loss Ratio

Simple	Adjusted
2.1%	1.3%

BAYESIAN CREDIBILITY ADJUSTMENTS

- U.S.
- Region
- Area
- County

Social **Vulnerability** and Community **Resilience**

Social Vulnerability Index: SoVI 2010-2014

- Grouped into **7 components with 29 variables** (SoVI 2010):
  - **Race and class (7 variables), Wealth (5 variables), Elderly residents (6 variables), Hispanic ethnicity (5 variables), Special needs individuals (2 variables), Native American ethnicity (1 variables), and Service industry employment (2 variables)**
- Comparative index at the county & census tract levels
- Positive and negative component loading

Baseline Resilience Indicators for Communities: BRIC 2010-2014

- **6 resilience category scores**, plus total score
  - **Social, Economic, Community Capital, Institutional, Infrastructural, Environmental**
- Comparative indicators at the county level
- Indicators analyze the relationship between resilience, vulnerability, and the relative impact of disasters on rural and urban places

FEMA **NRI's "Social Vulnerability and Community Resilience Working Group reviewed multiple top-down and bottom-up indices** and chose to recommend the University of South Carolina's Hazards and Vulnerability Research Institute (HVRI) Social Vulnerability Index (SoVI)."

HVRI HAZARDS & VULNERABILITY RESEARCH INSTITUTE

UNIVERSITY OF SOUTH CAROLINA

$$\text{Risk} = \frac{\text{Expected Annual Loss} \times \text{Social Vulnerability}}{\text{Community Resilience}}$$

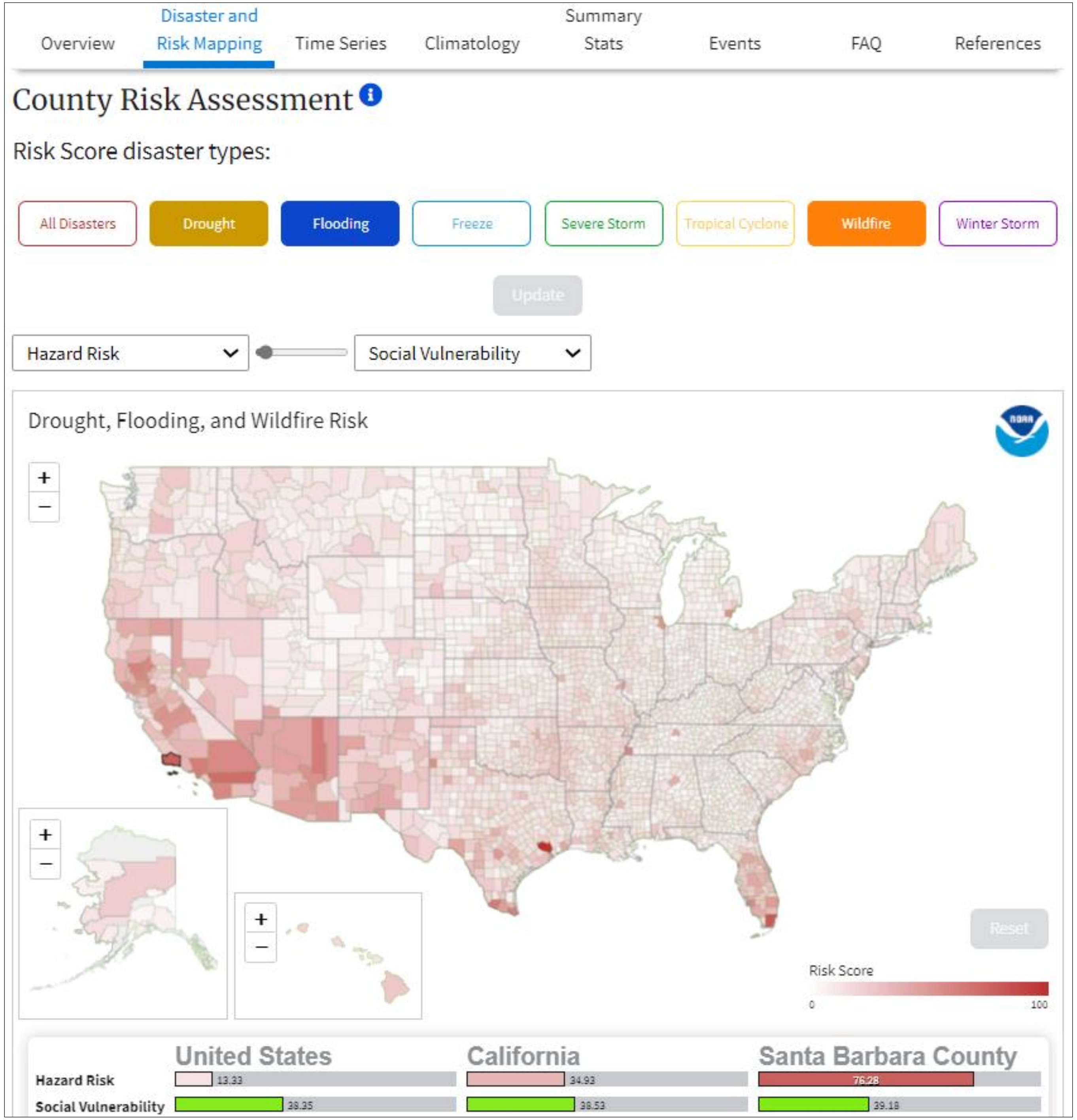
Expected Annual Loss / Social Vulnerability	Rating Category	Community Resilience
Higher Expected Annual Loss & Social Vulnerability = Higher Risk ↑	Very High	↓ Lower Community Resilience = Higher Risk
	Relatively High	
	Relatively Moderate	
	Relatively Low	
	Very Low	

Illustration of Risk Component Scores

County	Expected Annual Loss	Social Vulnerability	Community Resilience	Risk
County 1	100	45	52	100
County 2	26	94	58	55
County 3	54	48	35	51
County 4	16	92	56	37
County 5	32	36	44	24
County 6	22	45	43	22
County 7	9	69	59	15
County 8	25	21	57	13
County 9	10	44	45	9
County 10	16	4	39	1

All scores are constrained to a range of 0 (lowest possible value) to 100 (highest possible value). To achieve this range, **the values of each component are rescaled using min-max normalization, which preserves their distribution** while making them easier to understand. EAL values are heavily skewed by an extreme range of population and building value densities between urban and rural communities. **To account for this, a cube root transformation is applied before min-max normalization.**

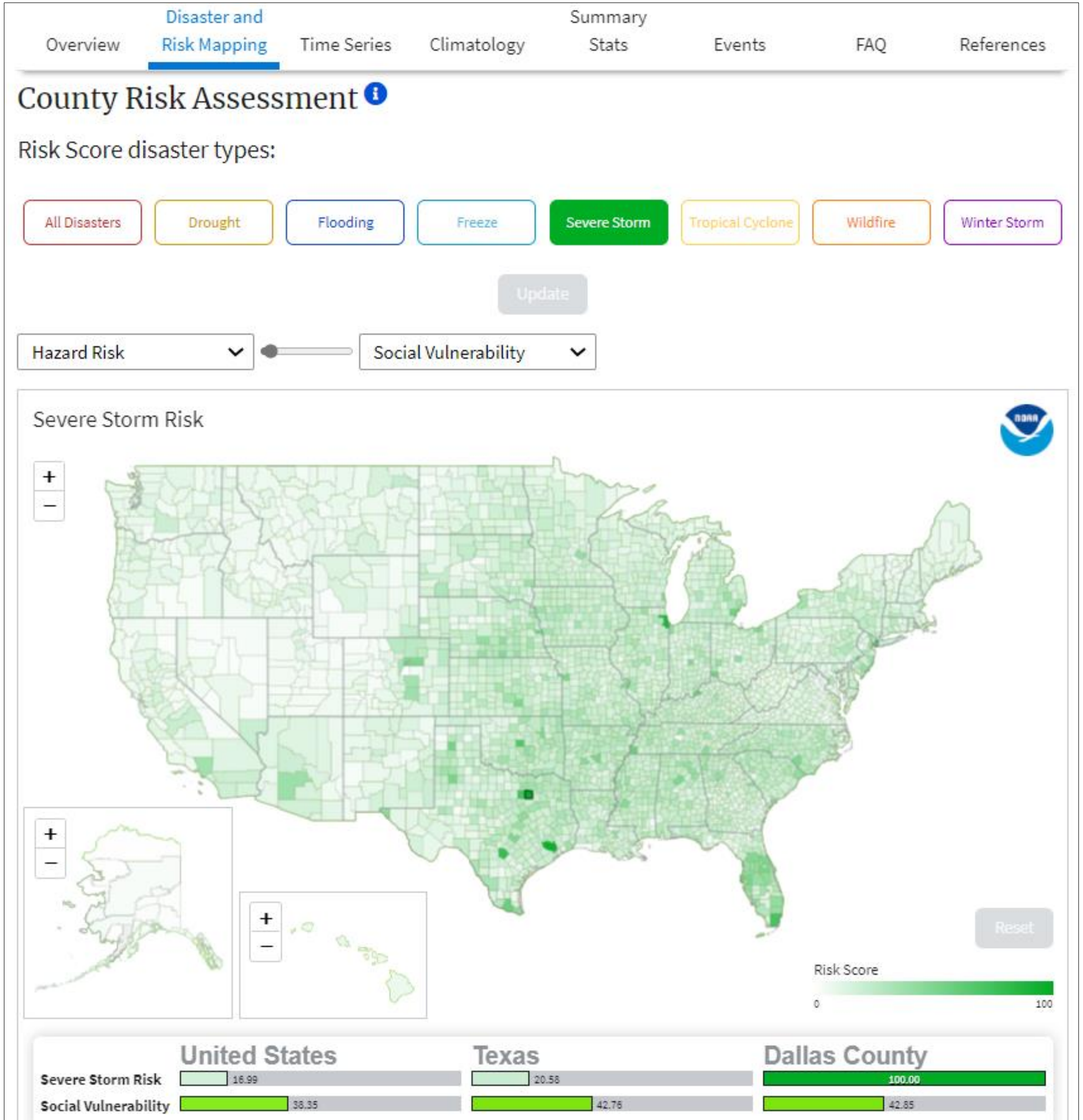
By applying cube root transformation, the National Risk Index controls for this characteristic and <u>provides scores with greater differentiation and usefulness</u>. If the minimum value of the EAL is a nonzero number before normalization, an artificial minimum is set to 99% of that value so that communities expected to experience loss do not receive a 0 EAL score



Compound hazard county risk (Drought, Wildfire and Flooding)

Each region faces **unique hazard combinations, which are useful in <u>a new era of more likely cascading hazard impacts</u>** (i.e., drought-enhanced wildfires produce mountain-side burn scars, which often enhance debris flows from flooding.

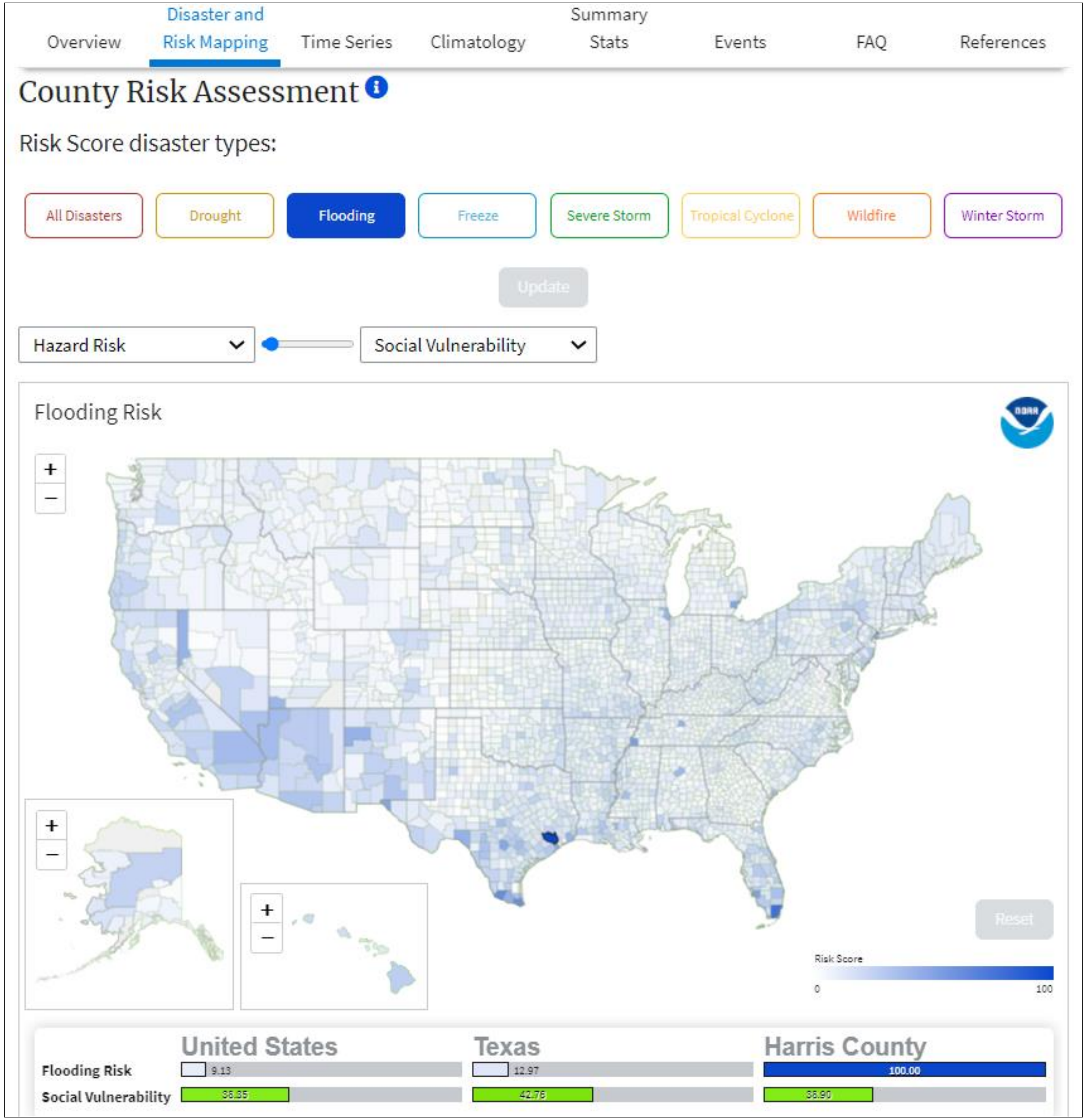
As noted in National Climate Assessment (2017) **"the physical and socioeconomic impacts of compound extreme events (such as simultaneous heat and drought, wildfires associated with hot and dry conditions, or flooding associated with high precipitation on top of snow or waterlogged ground) can be greater than the sum of the parts."**



This map provides county risk scores for combined **severe storm events (i.e., tornado, hail, high wind damage)** reflecting a county's annualized hazard frequency; its potential hazard cost related to building value, crop value and population exposure; and its social vulnerability and resilience to recover from hazard impacts based on dozens of socioeconomic variables.

The map highlights that **Dallas County, Texas has a very high score for severe storm risk** due to its historic frequency of being impacted by these events in addition to having a large urban population and valuable exposure, which further increases the damage potential for severe storm impacts and costs.

Dallas County's SOVI score (42.85) is also near the Texas average but is higher than the U.S. county-average score (38.35). A higher SOVI score indicates lower resilience.



Harris County, Texas - home to **Houston** as America's 4th most populous city - has a very high overall risk from <u>damaging urban flood events.</u>

The Houston area has been **<u>impacted by several 100-year urban flood events</u>** since the year 2015, in addition to **Hurricane Harvey in 2017.**

Harris County's SOVI score (38.90) is **below** (more resilient) than the **Texas county SOVI score average.**

Harris County, TX
Risk Assessment

Historic Risk	Harris County	Texas	U.S.
Drought Risk	20.36	14.32	11.61
Flooding Risk	100.00	12.97	9.13
Freeze Risk	12.05	13.09	15.72
Severe Storm Risk	94.56	20.58	16.99
Tropical Cyclone Risk	100.00	8.63	5.74
Wildfire Risk	11.81	11.28	6.30
Winter Storm Risk	65.33	15.99	13.71
Weather and Climate Combined Risk	100.00	17.19	13.25
Social Vulnerability Index (SoVI®) Score	38.90	42.76	38.35

Harris County, Texas - home to Houston as America's 4th most populous city - has a **very high** overall **risk from damaging urban flood events, severe storm and hurricane impacts**.

The **Houston** area has been impacted by several **100-year urban flood** events since the year 2015, in addition to **Hurricane Harvey in 2017**.

Houston's large population and valuable infrastructure were also damaged from hazards such as the **mid-February 2021 winter storm / cold wave**, which crippled the regional power grid causing widespread damage and disruption.

Harris County, TX
Risk Assessment

Historic Risk	Harris County	Texas	U.S.
Drought Risk	20.36	14.32	11.61
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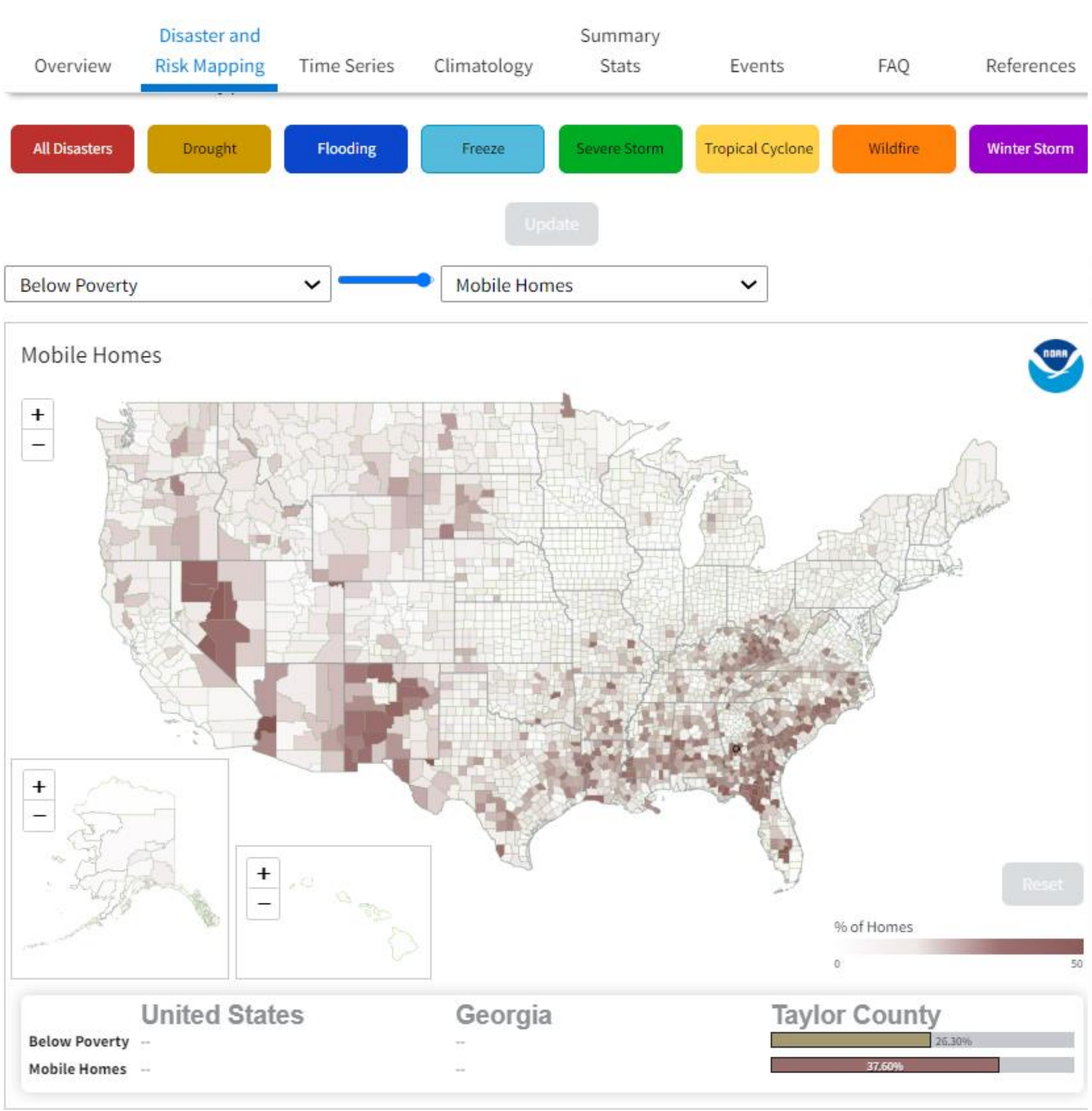
Winter Storm Risk	65.33	15.99	13.71
Weather and Climate Combined Risk	100.00	17.19	13.25
Social Vulnerability Index (SoVI®) Score	38.90	42.76	38.35

Socioeconomic Vulnerabilities	Harris County
Below Poverty (% of Population)	16.20%
Income (Per Capita Income)	$31,901.00
No High School Diploma (% of Population)	19.10%
Age 65+ (% of Population)	9.80%
Age < 18 (% of Population)	26.90%
Disabled Population (% of Population)	9.20%
Single Parent Households (% of Population)	11.40%
Minority Population (% of Population)	69.90%
English Spoken "Less Than Well" (% of Population)	11.70%
Mobile Homes (% of Homes)	2.50%
No Vehicle (% of Households)	6.00%



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Disaster and Risk Mapping
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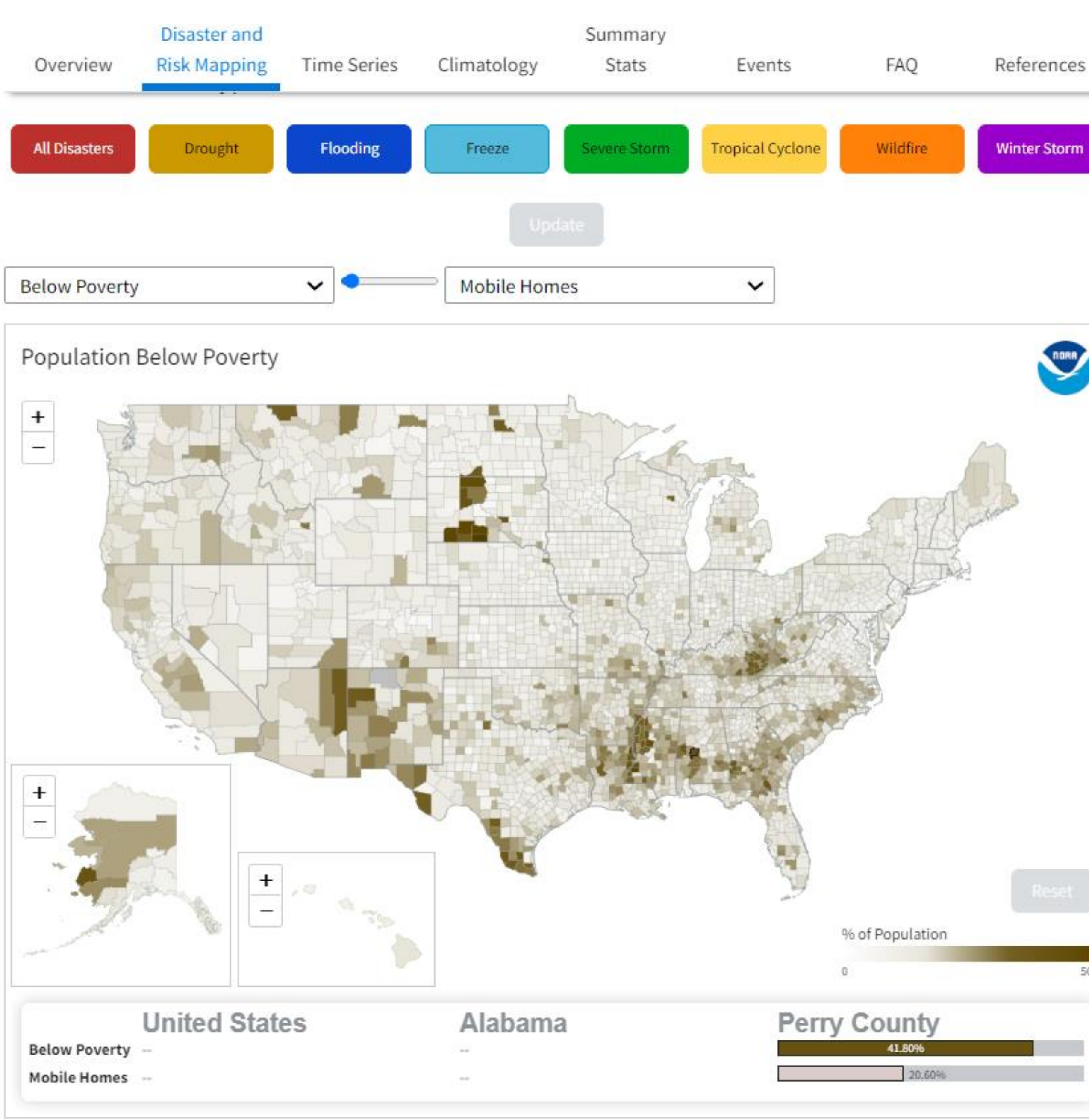
All Disasters
Drought
Flooding
Freeze
Severe Storm
Tropical Cyclone
Wildfire
Winter Storm
Update
Below Poverty
Mobile Homes
Mobile Homes
Reset
% of Homes
0
50
United States
Georgia
Taylor County
Below Poverty
Mobile Homes
26.30%
37.60%



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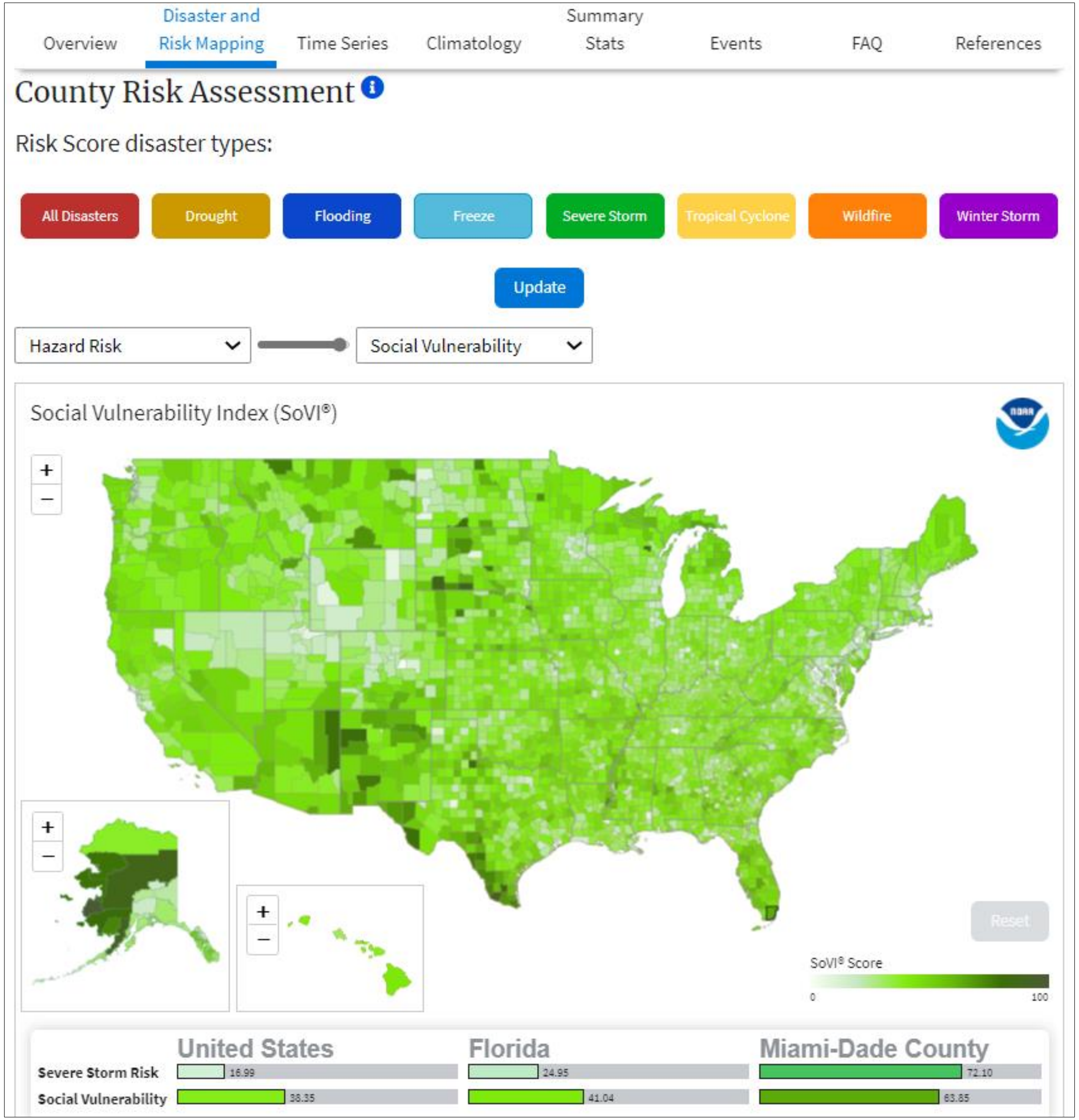
Mobile Homes
Population Below Poverty
Reset
% of Population
0
United States
Alabama
Perry County
Below Poverty
Mobile Homes
41.80%
20.60%



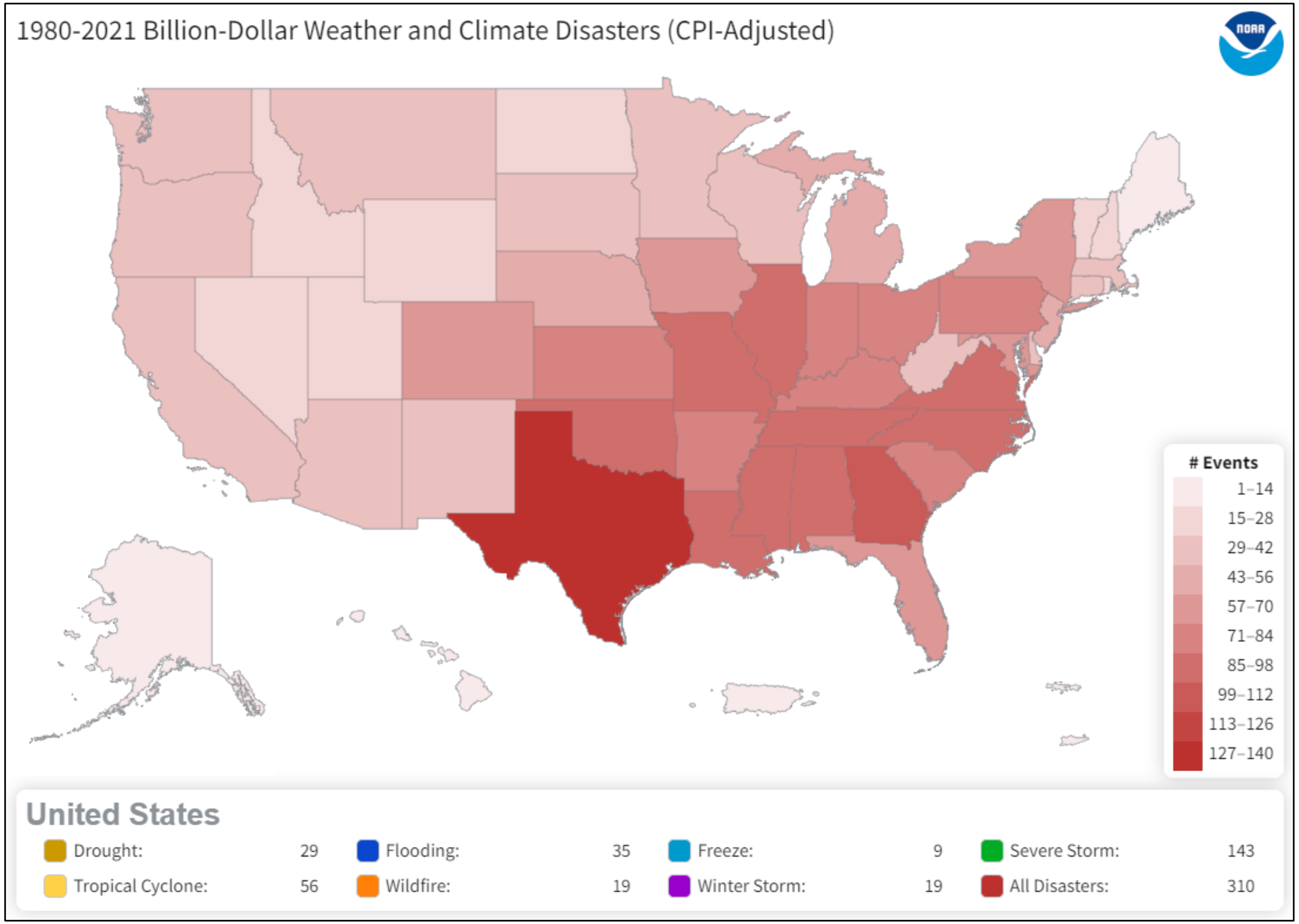
The **new mapping interface also provides an interactive control slider** that allows users to compare county hazard risks with county-level vulnerability “to prepare for, respond to, and recover from hazards," via the Social Vulnerability Index (SoVI).

The SoVI is a widely referenced data set that is "a location-specific assessment of social vulnerability that utilizes 29 socioeconomic variables deemed to contribute to a community's reduced ability to prepare for, respond to, and recover from hazards."

The darker colors represent counties with higher scores of socioeconomic vulnerability. The dataset was developed by and is referenced to the University of South Carolina's Hazards and Vulnerability Research Institute (HVRI).

From 1980–2021, the U.S. **South, Central** and **Southeast** regions experienced a **<u>higher frequency</u>** from billion-dollar disaster events. CA, NY, NJ, PR and V.I. as well.

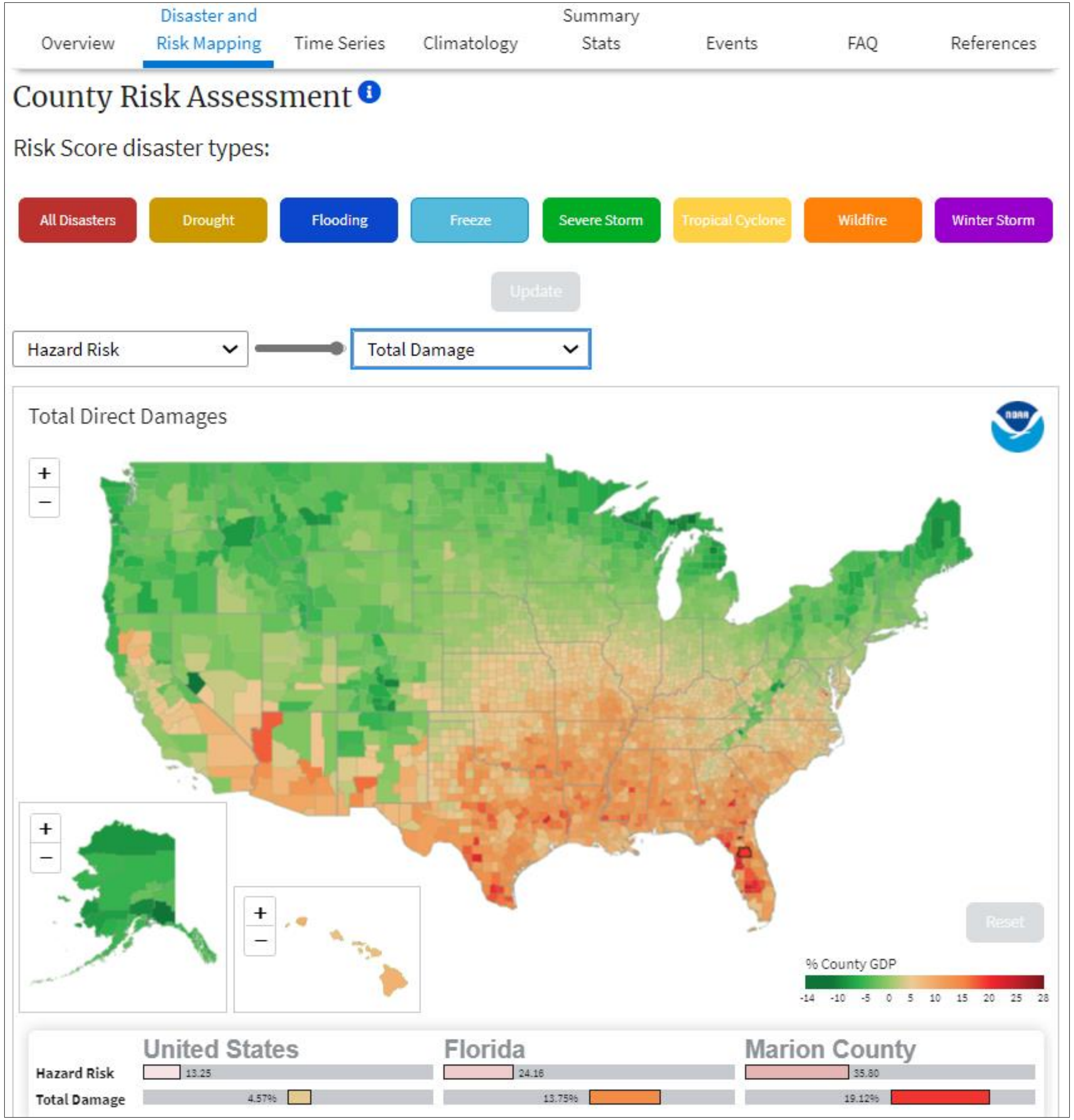
Cumulative Event Frequency (1980-2021) for each state (combined perils)



Historically, the U.S. **<u>South, Central & Southeast regions</u>** have experienced the highest frequency and cost from billion-dollar disaster events (see state / event maps on billion-dollar disasters).

The **<u>same U.S. regions</u>** are **projected** to have the **most negative future impacts** across **several socioeconomic metrics**

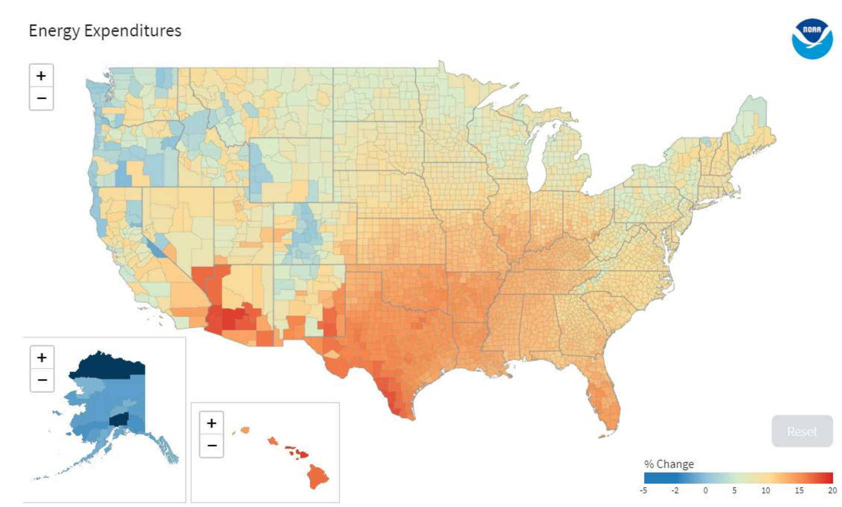
→ Reflects the **severity** & **vulnerability** of weather & climate events impacting different regions



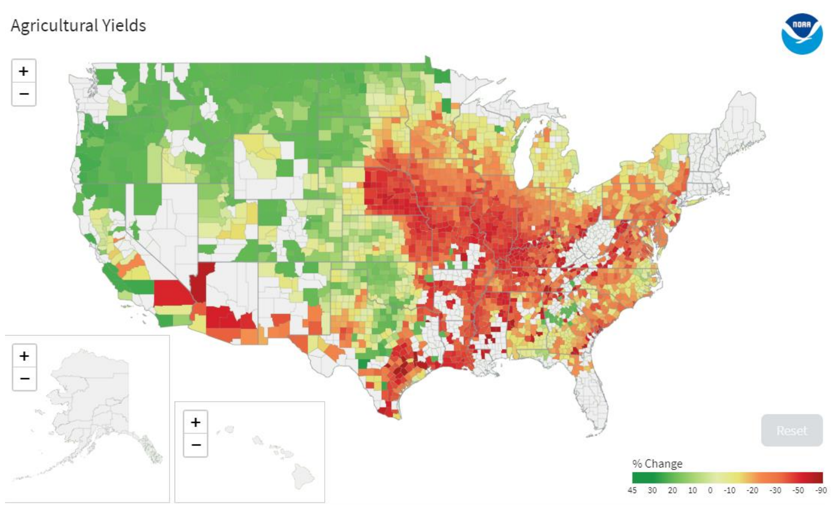
County-level median total direct economic damage across all sectors as a **% of county GDP** for the combined variables (A)-(H) using a future (2080-2099) high-emission scenario (RCP 8.5). This represents:

(A) Percent change in yields, area-weighted average for corn, wheat, soybeans, and cotton. (B) Changes in all cause mortality rates, across all age groups. (C) Change in electricity demand. (D) Change in labor supply of full-time equivalent workers for low risk jobs where workers are minimally exposed to outdoor temperature. (E) Same as (D) except for high risk jobs where workers are heavily exposed to outdoor temperatures. (F) Change in damages from coastal storms. (G) Changes in violent crime rates. (H) Changes in property crime rates. Source: **"Estimating economic damage from climate change in the United States" (Hsiang et al., 2017)**

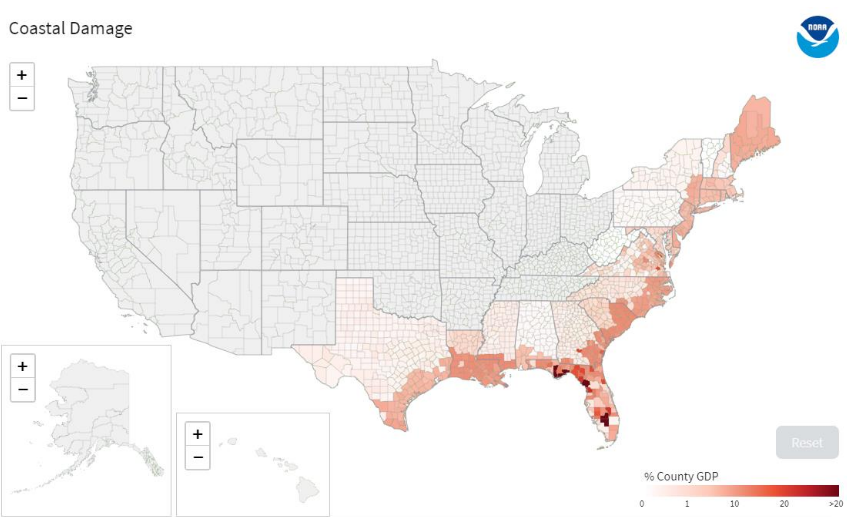
Spatial distributions of projected damages. County-level median values for average 2080 to 2099 RCP8.5 impacts. Impacts are changes relative to counterfactual “no additional climate change” trajectories. County socio-economic risk potential (RCP8.5 projections)



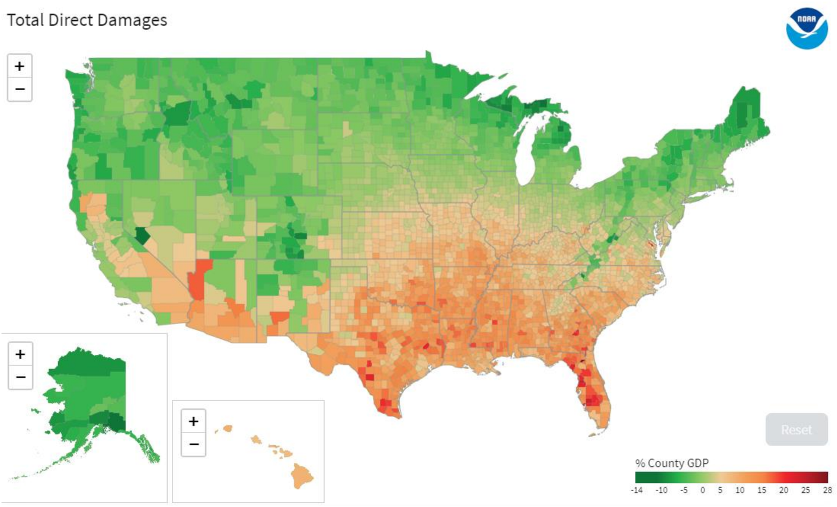
Energy expenditures (% change)



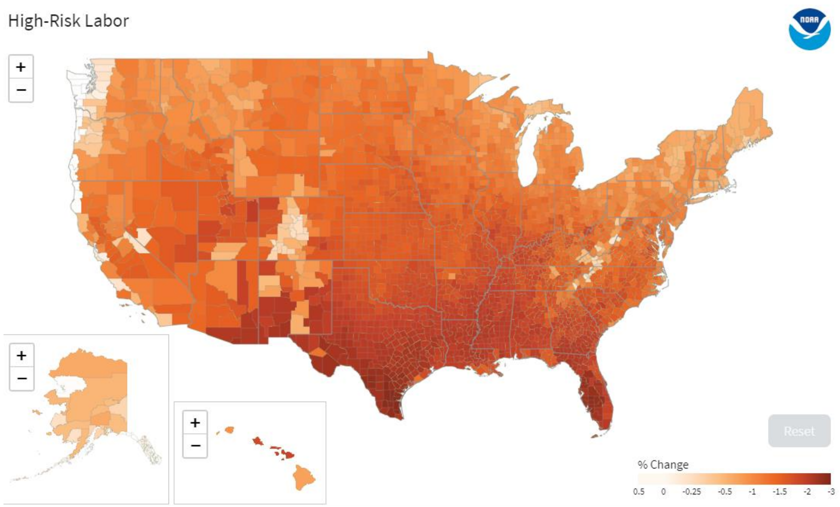
Agricultural yield (% change)



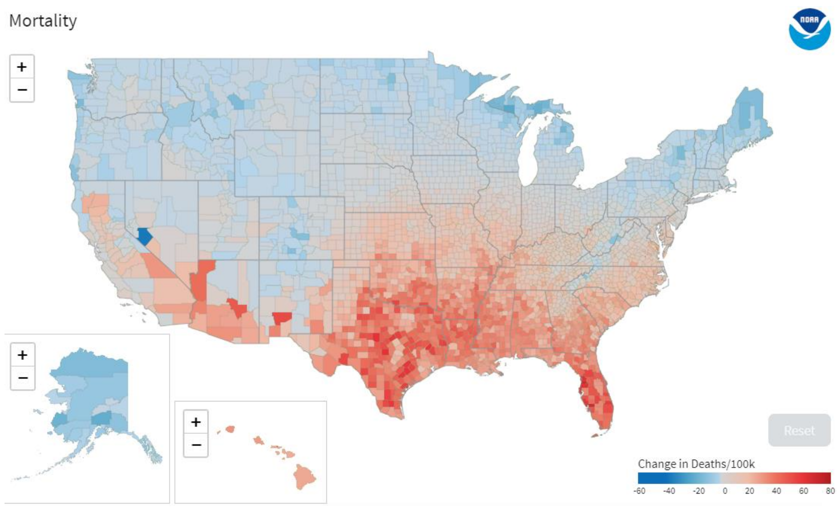
Coastal damage (% county GDP)



Total direct damage (% county GDP)



High-risk labor (% change)



Mortality (change in deaths per 100k)

Source: Hsiang, S., Kopp, R.E., Jina, A., Rising, J., Delgado M., Mohan, S., Rasmussen, D.J., Muir-Wood, R., Wilson, P., Oppenheimer, M., Larsen, K., and T. Houser. 2017. **Estimating economic damage from climate change in the United States**. *Science*, 356, 1362-1369

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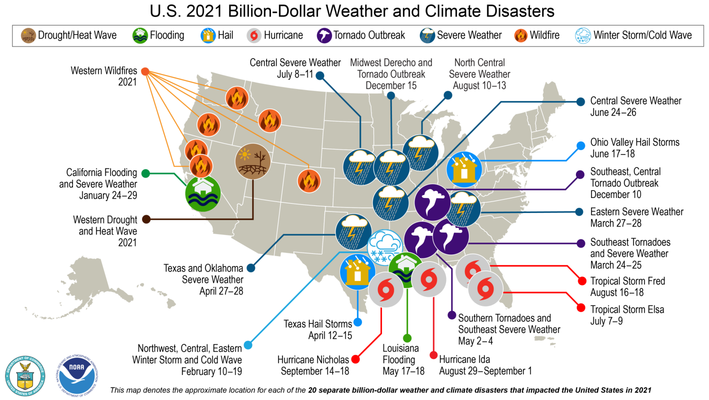
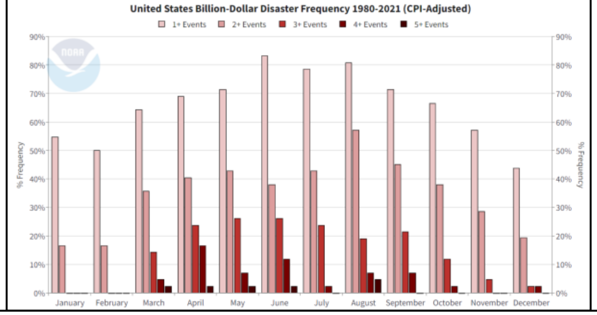
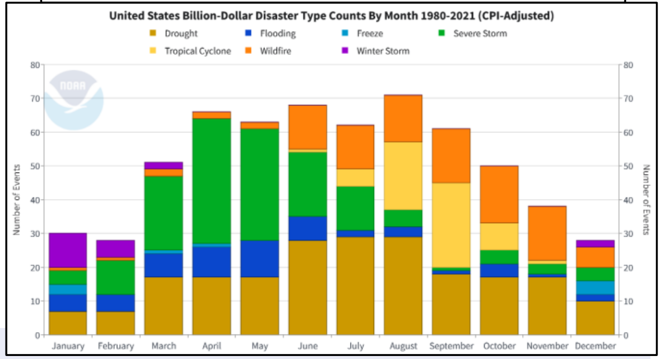
For interactive data, charts, mapping, and disaster summaries (1980-2021):

www.ncdc.noaa.gov/billions







New county hazard risk mapping:

www.ncdc.noaa.gov/billions/mapping

For more detail on disasters, county data, methodology, and uncertainty, see:

NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2022). https://www.ncdc.noaa.gov/billions/, DOI: 10.25921/stkw-7w73

Smith, A., and R. Katz, 2013: U.S. Billion-dollar Weather and Climate Disasters: Data Sources, Trends, Accuracy and Biases. Natural Hazards., DOI: 10.1007/s11069-013-0566-5

Smith, A., and J. Matthews, 2015: Quantifying Uncertainty and Variable Sensitivity within the U.S. Billion-dollar Weather and Climate Disaster Cost Estimates. Natural Hazards., DOI: 10.1007/s11069-015-1678-x

Zuzak, C., E. Goodenough, C. Stanton, M. Mowrer, N. Ranalli, D. Kealey, and J. Rozelle. 2021. National Risk Index Technical Documentation (fema.gov). Federal Emergency Management Agency, Washington, DC.

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