Climate Change and Catastrophe Losses

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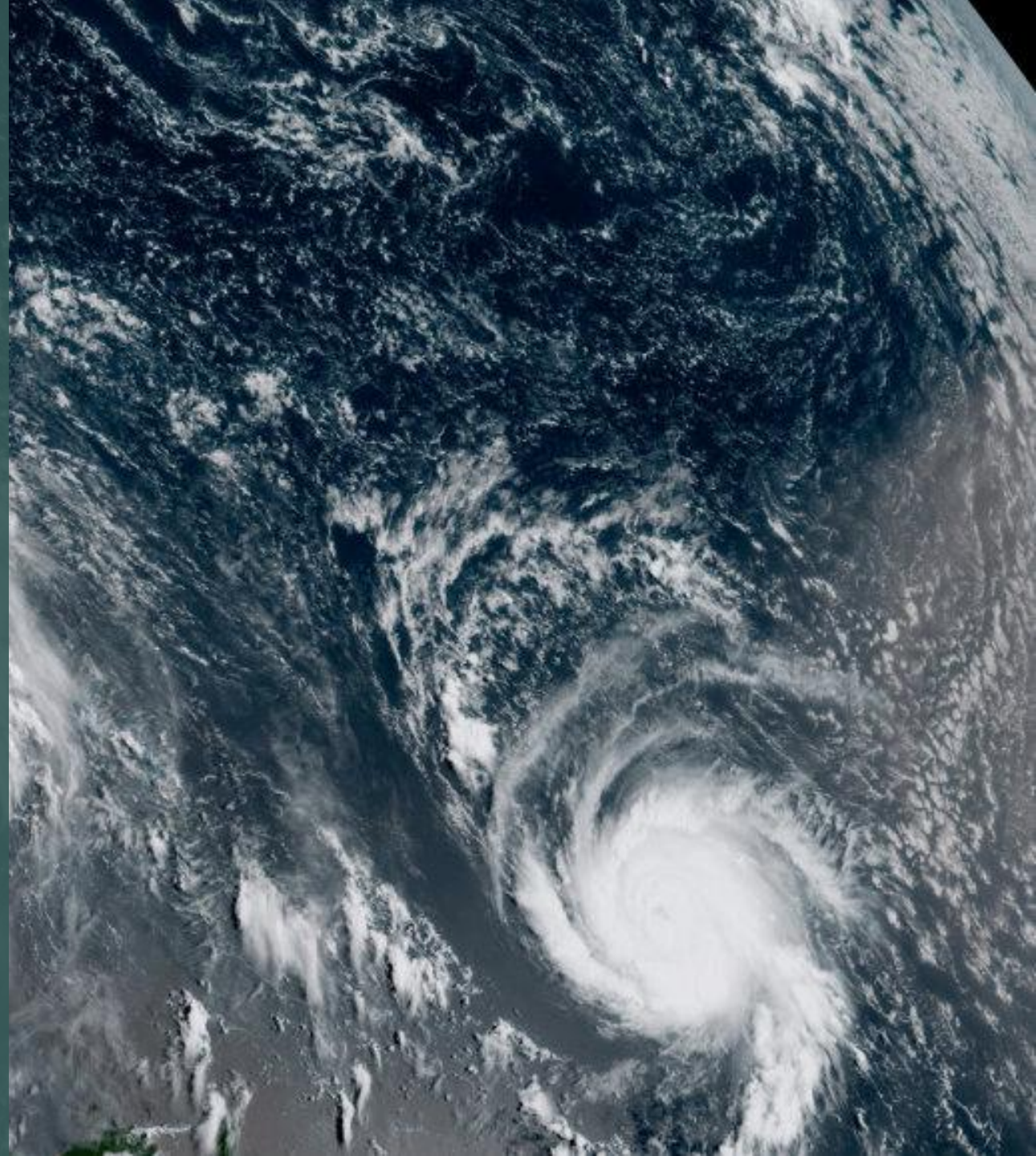
STONYBROOK



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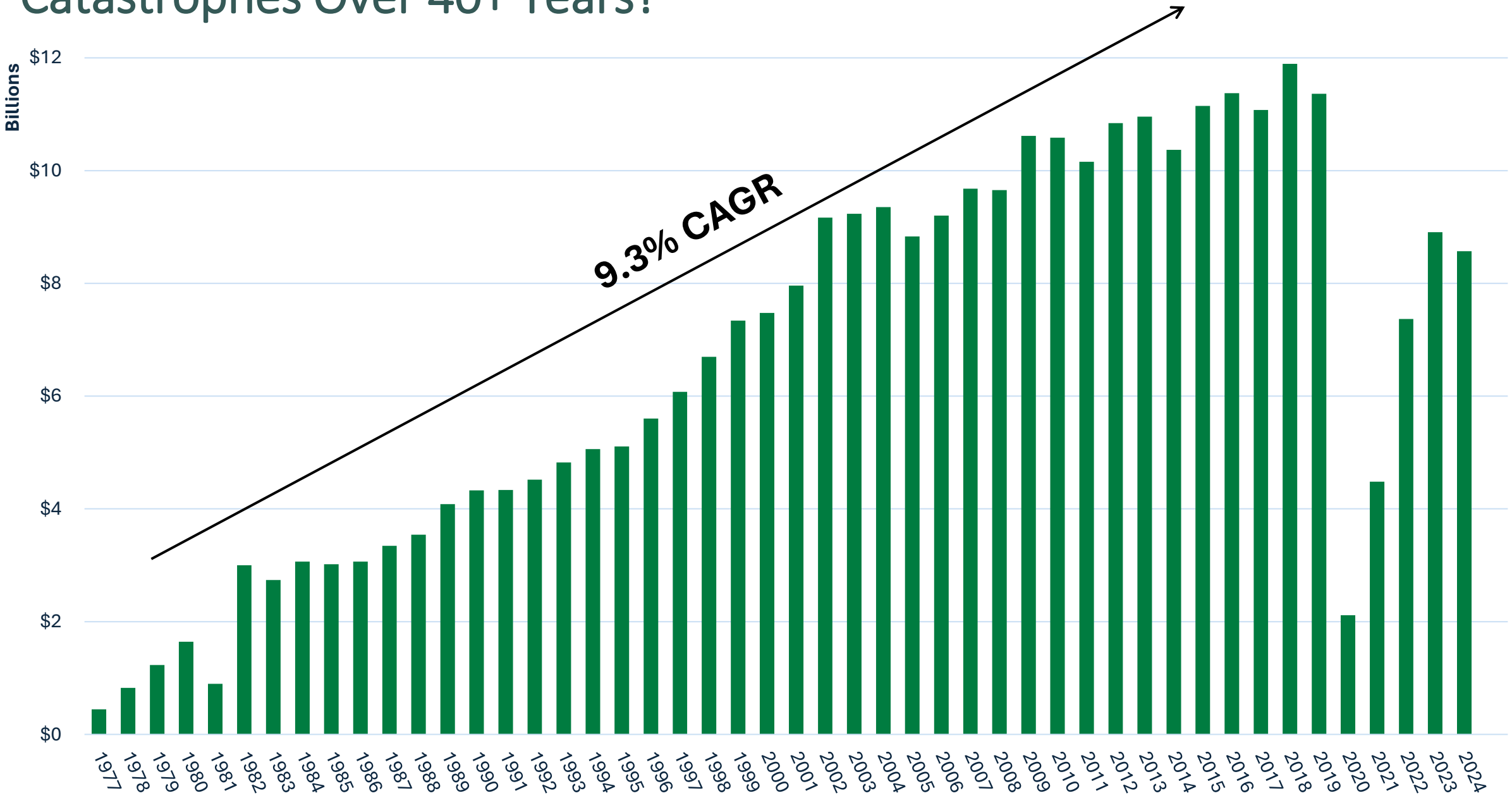
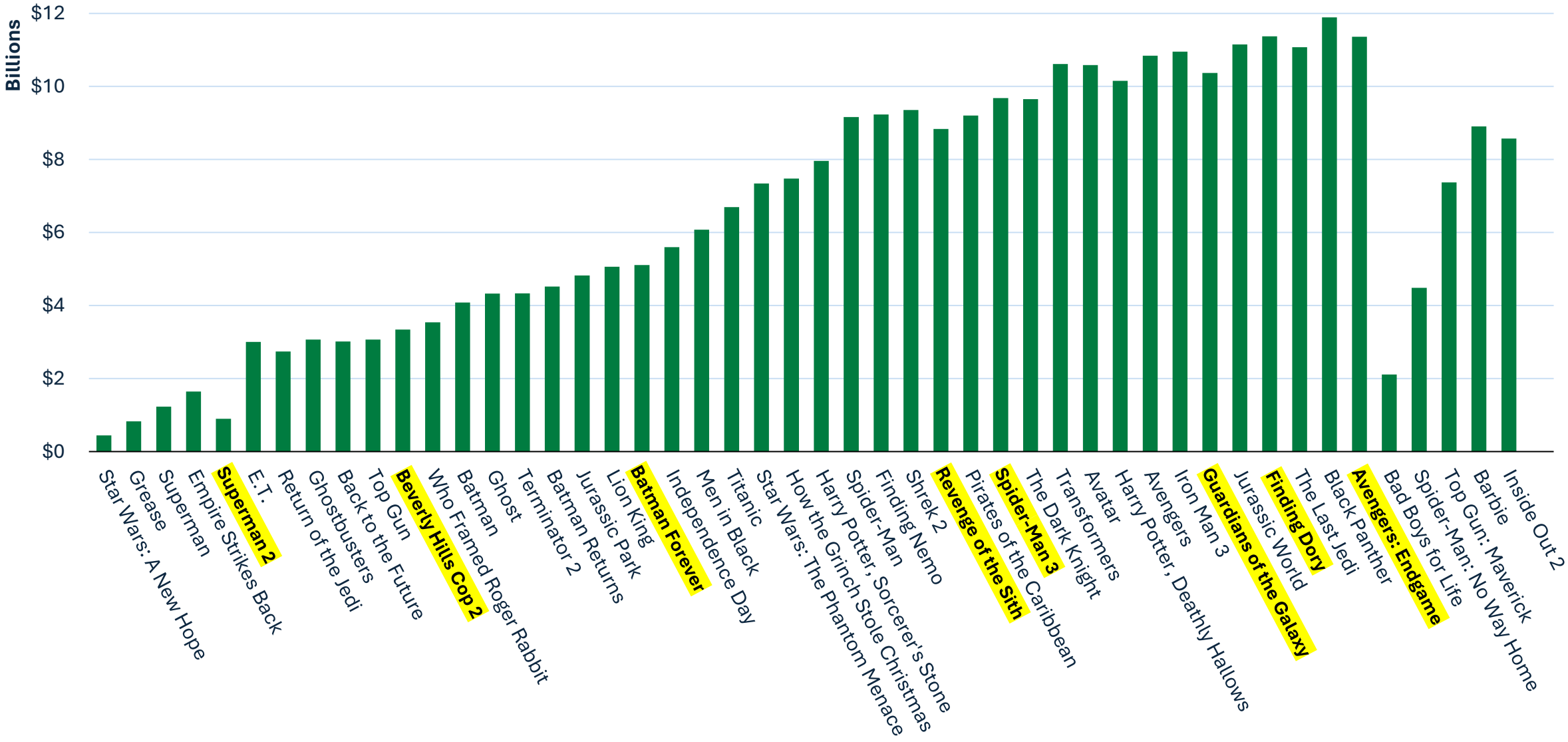
Catastrophes Over 40+ Years?



Catastrophes: An Analogy

Inflation, population, and structure sizes drive growth in dollars



History of Temperature and CO2 Changes

Magnitude of Differences

- The industrializing economy's 170+ years of carbon emissions have led to a significant increase in CO2 levels (50% relatively more parts per million).
- The accumulation of CO2 emissions has likely caused global temperatures to rise by approximately two degrees Fahrenheit.
- This temperature increase is roughly equivalent to the average individual moving 200 miles south.
- The number of extremely hot days (relative to local norms for the average of the 20th century) has increased: We estimate an increase from six to ten days per summer in this timespan.

Drivers of Climate Differences

Year	World Population (Ms)	World GDP (Bns. Of $ 2024's)	Emissions (Bn tonnes / yr.)	CO2 in Atmos (ppm)	Temp diff (F) vs 20th Cty Avg.
1850	1,258	2,105	0.25	280	0.00
1900	1,653	4,752	2.90	274	-0.14
1950	2,478	11,487	5.90	313	-0.23
2000	6,144	71,569	25.50	363	0.77
2023	8,045	104,700	37.60	420	2.10

Major US Landfalling Hurricanes 1825 to 2024

Data Review

- "Major" indicates Cat 3 and up; can be easy to miss tropical storms, Cat 1, and Cat 2 in old records
- Category at strongest US landfall
- Current US state boundaries, TX to ME only
- 1851 to 2024: NHC public data; 1825 to 1850: backfilled
- Summarized by half decade to make trends more credible, most individual years have zero events

What is Knowable?

- Pre-1851 records existed, but were lost in a fire
- UK government compiled at least back to 1837
- Telegraphs, canals, coastal steamships introduced in 1830s
- 1825 is the earliest cut-off, as Florida data is less certain from any earlier for the following reasons: Low population in peninsula; not a US territory until 1822; no overland road; likely missed events from 1825-1835

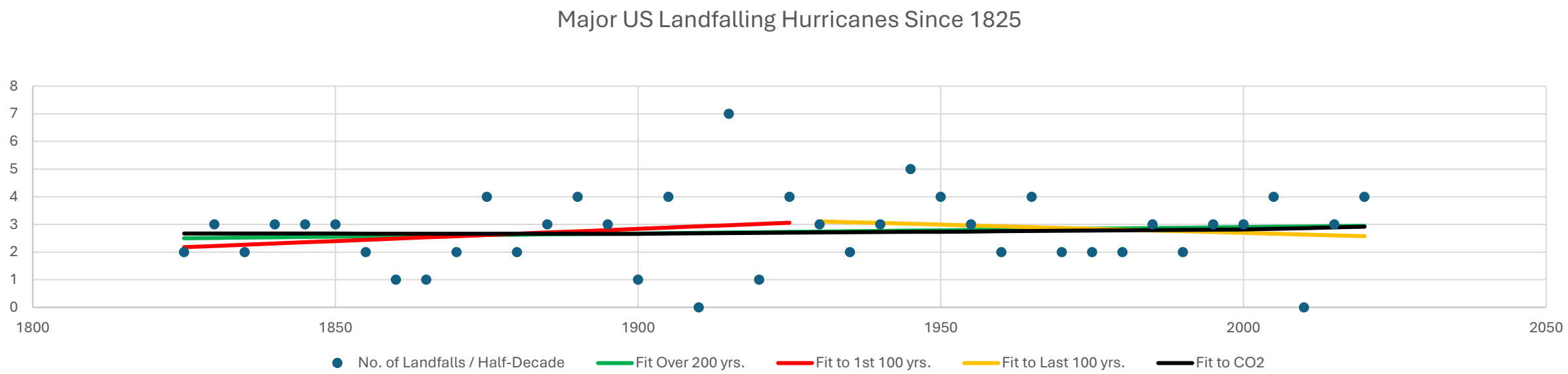
Backfill Process

- Wikipedia season summary pages
- Storm detail pages often provide damage descriptions
- Googled by storm name for local histories or news reports
- Included if reported damage aligns with Cat 3 definition of "major damage"
- Also included if barometer readings below 965mb
- Excluded vaguer reports, likely missed some relevant events

Backfill: US Mainland Major Hurricane Landfalls from 1825-1850

Year	Storm	Damage Reported
1827	Great North Carolina hurricane	“One of the worst in the history of coastal Carolina,” multiple ships lost and villages heavily damaged, modern summaries list it as “perhaps Category 4”
1829	Hurricane at the mouth of the Rio Grande	Texas coastal hurricane histories note a hurricane struck the mouth of the Rio Grande with widespread coastal inundation; Port Isabel and Brazos Santiagos destroyed
1831	Great Barbados / Louisiana hurricane	“Cataclysmic damage” across Caribbean and Louisiana, ~1,500-2,500 total fatalities, reports of up to ~17 ft storm surge in Barbados, monetary damage reported in the millions (19th century USD)
1834	Galveston	Heavy damage to early Galveston settlement, major disruption to commerce, buildings damaged & destroyed, streets & wharfs flooded, and ships driven ashore or wrecked
1834	South Carolina	“Devastating destruction of property” along South Carolina and Outer Banks, structures damaged or unroofed, wharves & shipping damaged, flood & tide impacts on coastal plantations, 37 deaths reported
1835	Key West	Likely hurricane-force at Key West; severely floods several islands, damage around Tampa totals $200K (1835 USD), destroys lighthouse at Ponce de Leon inlet on East Coast
1837	“Racer’s Storm”	“One of the most famous and destructive hurricanes of the century,” named after Royal Navy ship HMS Racer which first encountered the storm in the Caribbean, 8 ft storm surge in New Orleans
1842	North Carolina hurricane	Early season hurricane severely impacting coastal North Carolina and making landfall in Norfolk, Virginia, described as “a severe hurricane” with “many houses wrecked”
1842	St. Marks	Reports of up to ~20 ft storm surge at Cedar Key and Big Bend in Florida panhandle, reported ~$500K losses in 1842 USD in Tallahassee
1843	Port Leon	Reports of up to ~10 ft storm surge that obliterated the town of Port Leon, residents abandoned town and moved inland
1844	Matamoros	“Did not leave a house standing” at the mouth of the Rio Grande and Brazos Santiago, reports of ~70 deaths in the area
1846	Havana and Keys	Recorded as a Cat 5 over Havana, 902 mB in Key West, of the approx. 600 homes in Key West only 6 endured the storm successfully, over 50 killed
1848	Tampa Bay	Pressure and storm surge consistent with at least a Cat 4, the strongest hurricane to make landfall on Florida’s west coast, reshaped parts of coastline
1849	New England	~143 deaths reported, Martha’s Vineyard newspaper stated storm “has rarely, if ever, been surpassed in violence”

200 Year Trend in Hurricane Activity



Commentary

- The history of major US hurricane landfalls since the pre-industrial period shows a minimal rate of change. It shows a steeper trend in the earlier century, perhaps due to events not recorded in the earliest decades.
- There is only a statistically insignificant relationship to CO2 levels in the atmosphere (R-squared of 3.5%).
- There are other recognized volatility factors, including regular cycles of El Niño – La Niña, Atlantic sea current patterns, and solar activity.
- Storms do seem to becoming “wetter”, at least anecdotally, Helene in the Carolinas, Ida in NY, Harvey in Houston. Although there were also damaging river floods caused by hurricanes in the early 20th century.

Largest Global Insured Weather Occurrences from 1950 to 2024

Events Considered

- "Occurrence" is well defined in both time and space
- Includes Windstorms, Floods, Blizzards, and damaging Freezes; excludes Droughts and Heat Waves
- Fires attributed to utilities are not considered to be weather
- "Large" event threshold: Losses >0.005% of Global GDP (~$5.5B today)
- Attempted to include all insured loss and expense, broader than PCI, PERILS, and modelers; loss expenses a major addition; covers off-premises BI, offshore marine, event and trip cancellation, AD&D; includes private flood (especially <1968)
- Also broader than insurers' financial disclosures: Gross of tax, reinstatement premiums, commission swings

Loss Data Sources

- Holborn whitepapers for 1960 through 2022, supplemented PCS, etc. with retrocessional data, insurer financial disclosure summaries and underwriters' estimates
- Some paired weather patterns treated as one reinsurance event were divided as two occurrences here
- Published estimates >2012 adjusted to consistent definitions
- 1950s based on Wikipedia reports supplemented with news reports; period news reports generally assumed to be Coverage A only and exclude LAE
- Vague events excluded
- Counts summarized by half decade

GDP Data Sources

- OECD when available
- Trended back into 1950s using 1960s rates
- WWII years and immediate recovery too disorienting
- Cold War / Iron Curtain held back both insurance take up and global GDP – understatement?

Global Insured Weather Events as % of GDP

"Large" events are defined as >0.005% of Global GDP (currently ~$5.5B)

Top 5 Events by %

Rank	Year	Event	Direct Loss / World GDP (Current $)
1	2005	Hurricane Katrina	0.2131%
2	1992	Hurricane Andrew	0.1366%
3	1965	Hurricane Betsy	0.0754%
4	1951	Gt. Flood Kansas Missouri	0.0598%
5	1969	Hurricane Camille	0.0545%

Middle 5 Events by %

Rank	Year	Event	Direct Loss / World GDP (Current $)
46	2011	Joplin, MO Tornado Outbreak	0.0128%
47	1995	Texas Hail (Cat 38)	0.0128%
48	1998	Hurricane Georges	0.0126%
49	1983	Hurricane Alicia	0.0125%
50	1956	March Nor'easter	0.0125%

Bottom 5 Events by %

Rank	Year	Event	Direct Loss / World GDP (Current $)
91	1974	Hurricane Carmen	0.0056%
92	2013	2013 European Floods	0.0054%
93	1955	Great Plains Tornado	0.0054%
94	2018	Hurricane Florence	0.0052%
95	1950	Eastern US Blizzard	0.0050%

Global Insured Weather Events by Location & Frequency

Number of Events by Region

North American & the Caribbean: 77

Europe: 12

Asia-Pac: 6

Number of Years with Multiple Events

Events	Actual	Poisson
5 events	1 year	0.7
4 events	2 years	2.3
3 events	7 years	7.2
2 events	12 years	17.0
1 event	44 years	26.8
None	9 years	21.1

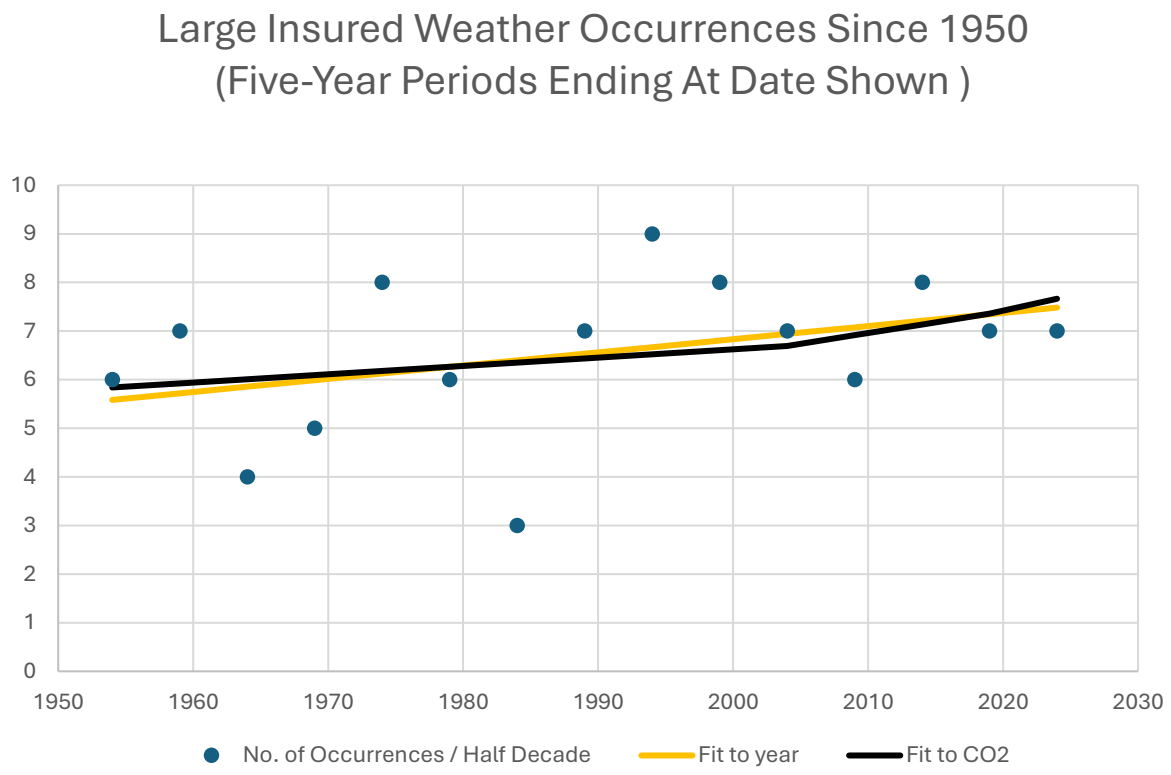
75-Year Trend of Large Insured Weather Losses Relative to Global GDP

Commentary

- Some observers suggest that climate change has raised the frequency of large weather catastrophe losses above previous hazard levels.
- We reviewed the last 75 years of large global insured weather losses to examine any potential changes in the impact on insurers.
- The graph shows the worldwide number of individual loss occurrences that produced insured loss and expenses greater than 0.005% of world GDP in the year of loss, summarized by half decade.
- The fitted rate of change indicates a 0.4% compound annual rate of growth in event frequency, but was not statistically significant.
- The relationship between event frequency and CO2 levels was also not significant (R-squared of 11.3%).
- Increased use of insurance in economies that have developed over this period may be another, potentially larger, contributing factor, apart from the climate.

Fitted and Actual Large Weather Events

(> .005% of Global GDP = ~$5.5B today)



Conclusions

Frequency Trends Not Significant

- No significant relationships to CO2 levels
- If older years were understated, then trends are actually overstated

By Type of Event

- Major hurricane frequency stable
- Damaging tornado frequency stable (in insured and NOAA records
- Wildfire damage by acres burned stable
- Large US flood losses becoming rarer

Possible Climate Concerns

- Are hurricanes getting “wetter”? Are inland flood hazards higher?
- If rapid intensification of storms is increasing, what effect does it have on surge levels?
- Are large derechos becoming more common or just better identified?

Other (Bigger?) Concerns

- Economic inflation outpaces TIV and deductibles
- Population movements (now tax driven)
- Building codes and new tech raises replacement costs
- Increasing wealth raise contents faster than structures?
- And: social inflation

Big Picture

- $150B global annual insured Cat losses
- $2 Trillion+ global industry capital and annual premiums
- Isn’t a 7% Cat load sellable? If not, why not?

Year	Event	Cat. at loss date	Direct Loss ($Ms)	Direct Loss / World GDP (Current $)
1950	Eastern US Blizzard		$67	0.0050%
1951	Gt. Flood Kansas Missiouri		340-950	0.0598%
1953	North Sea Flood		220 – 600	0.0279%
1954	Hurricane Carol	3	$135	0.0158%
1954	Hurricane Hazel	4	115	0.0135%
1955	Connecticut Flood		70	0.0076%
1955	Great Plains Tornado	F5	50	0.0054%
1955	Hurricane Diane	3	275	0.0297%
1956	March Nor'easter		125	0.0125%
1957	Hurricane Audrey	4	75	0.0069%
1957	Valencia Floods		65	0.0060%
1959	Typhoon Vera		350-1000	0.0226%
1960	Hurricane Donna	4	$400	0.0290%
1961	Hurricane Carla	4	350	0.0241%
1962	North Sea Flood		500	0.0323%
1962	Columbus Day Storm	Equiv. of 4	250	0.0161%
1965	Palm Sunday Tornados	F4	$350	0.0176%
1965	Hurricane Betsy	4	1,500	0.0754%
1967	Oaklawn Tornado Outbreak	F5	200	0.0087%
1967	Hurricane Beulah	3	200	0.0087%
1969	Hurricane Camille	5	$1,500	0.0545%
1970	Lubbock Tornado	F5	350	0.0116%
1970	Hurricane Celia	3	300	0.0100%
1971	Mississippi Valley Tornado Outbreak	F5	300	0.0090%
1972	Hurricane Agnes	1	2,000	0.0521%
1973	Mississippi River Flood		500	0.0107%
1974	Xenia Tornado Outbreak (Cat 74)	F5	$1,000	0.0188%
1974	Hurricane Carmen	4	300	0.0056%
1974	Cyclone Tracy	3	550	0.0103%
1975	Omaha Tornado	F4	1,000	0.0168%
1975	Hurricane Eloise	3	375	0.0063%
1976	Hurricane Belle	3	450	0.0069%
1978	U.S. Blizzard		800	0.0092%
1979	Red River Valley Tornado Outbreak	F4	$650	0.0064%
1979	Hurricane Frederic	3	2,000	0.0197%
1980	Hurricane Allen	5	750	0.0065%
1983	Hurricane Alicia	3	1,500	0.0125%
1984	Carolinas Tornado Outbreak	F4	$750	0.0060%
1985	Hurricane Elena	4	1,500	0.0116%
1985	Hurricane Gloria	2	1,300	0.0100%
1985	Hurricane Juan	1	750	0.0058%
1987	European Floods		4,000	0.0228%
1987	U.K. Winter Storm (87J)	Equiv. of 1	5,000	0.0285%
1988	Hurricane Gilbert	4	6,000	0.0305%
1989	Hurricane Hugo	4	$7,000	0.0343%
1990	Winter Storm Daria (Burns' Day)	Equiv. of 1	7,000	0.0305%
1990	Winter Storm Vivian	Equiv. of 1	5,000	0.0218%
1991	Typhoon Mireille	4	5,000	0.0209%
1991	Hurricane Bob	2	1,750	0.0073%
1992	Hurricane Andrew	5	35,000	0.1366%
1992	Hurricane Iniki	4	1,500	0.0059%
1992	Nor'easter		2,000	0.0078%
1993	"White Hurricane"		4,500	0.0171%
1993	Mississippi and Missouri Flood		3,000	0.0114%
1995	Texas Hail (Cat 38)		$4,000	0.0128%
1995	Hurricane Opal	4	3,000	0.0096%
1996	Hurricane Fran	3	3,500	0.0110%
1998	Hurricane Georges	3	4,000	0.0126%
1999	Hurricane Floyd	4	$5,000	0.0153%
1999	Winter Storm Lothar	Equiv. of 2	9,000	0.0275%
1999	Winter Storm Martin	Equiv. of 3	6,000	0.0183%
1999	Typhoon Bart	5	4,000	0.0122%
2001	Hurricane Allison	TS	3,500	0.0104%
2002	Central European Floods		4,000	0.0114%
2003	St. Louis Tornadoes	F4	3,500	0.0089%
2004	Hurricane Charley	4	$12,500	0.0283%
2004	Hurricane Frances	2	7,000	0.0158%
2004	Hurricane Ivan	3	13,000	0.0294%
2004	Hurricane Jeanne	3	5,000	0.0113%
2005	Hurricane Katrina	3	65,000	0.2131%
2005	Hurricane Rita	3	9,000	0.0188%
2005	Hurricane Wilma	2	18,500	0.0387%
2006	Northeast US Blizzard		3,000	0.0058%
2008	Hurricane Gustav	2	7,000	0.0109%
2008	Hurricane Ike	4	26,000	0.0405%
2011	Northeast U.S. Ice and Snow		$5,000	0.0068%
2011	Alabama Super Outbreak	F3	7,700	0.0104%
2011	Joplin, MO Tornado Outbreak	F5	9,500	0.0128%
2011	Hurricane Irene	1	6,000	0.0081%
2011	Queensland Flood		5,000	0.0068%
2011	Thai Floods		15,000 - 20,000	0.0237%
2012	"Superstorm" Sandy	Equiv. of 1	40,000	0.0529%
2013	2013 European Floods		3,300 - 5,300	0.0054%
2017	Hurricane Irma	5	$42,000	0.0516%
2017	Hurricane Maria	5	37,000	0.0455%
2017	Hurricane Harvey	4	38,000	0.0467%
2018	Hurricane Michael	5	6,800 - 10,000	0.0114%
2018	Hurricane Florence	4	2,800 - 5,000	0.0052%
2019	Hurricane Dorian	5	$7,000	0.0080%
2019	Typhoon Hagibis	5	6,000 - 10,000	0.0088%
2020	Hurricane Laura	4	10,000 - 15,000	0.0172%
2021	Eur. Floods (Germany, Belgium)		12,000	0.0124%
2021	Hurricane Ida	4	41,000	0.0422%
2021	Texas Winter Storm Uri		18,000	0.0185%
2022	Hurricane Ian	4	45,000	0.0446%
2024	Hurricane Helene	4	12,000	0.0109%
2024	Hurricane Milton	3	40,000	0.0364%
2025 (prelim.)	Palisades Fire		~30,000	~0.0265%