Detection and Attribution of Extreme Precipitation and Flood Impacts

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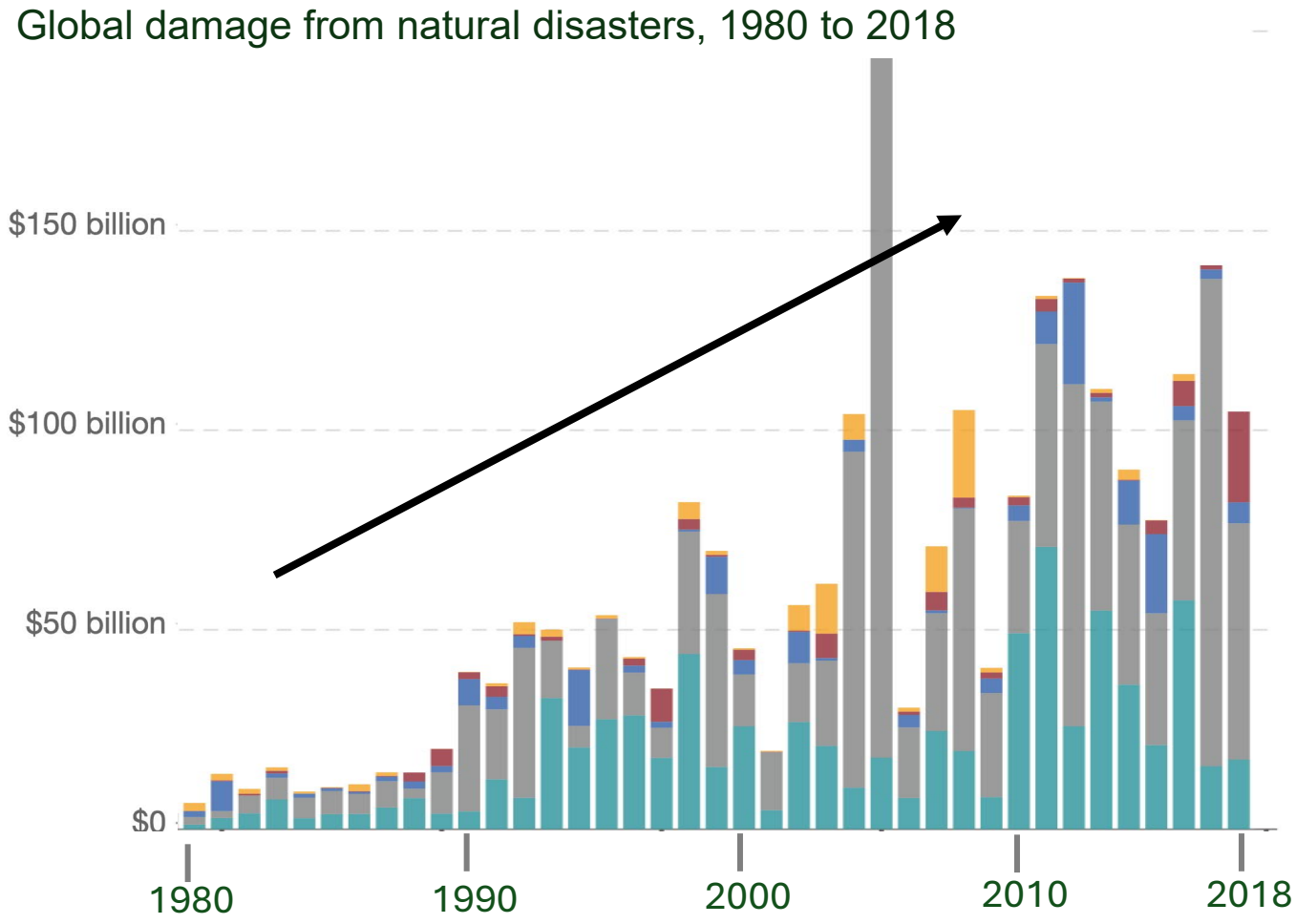
Attributing flood impacts using historical data + causal inference

- Globally, costs of flood disasters have grown over time
- How do we attribute increases due to climate change vs. changes in exposure or vulnerability?



adapted from Our World in Data, data from EM-DAT (2020)

Attributing flood impacts using historical data + causal inference

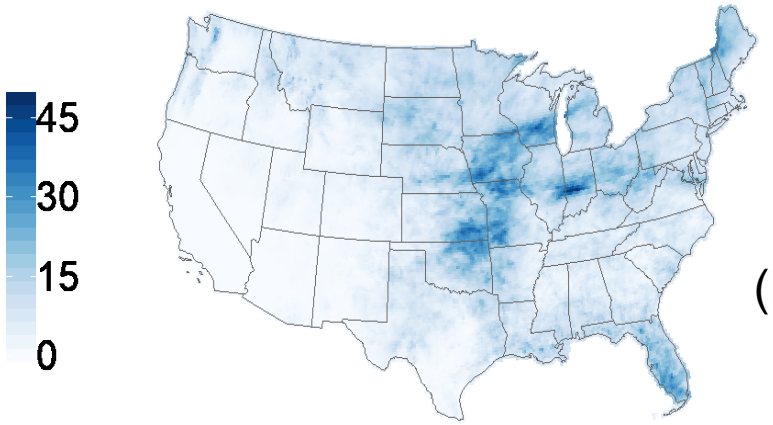
- fixed effects panel regression
- example: historical monthly data on state-level precipitation and flood damage

- $ln(Damage_{it}) = f(P_{it}) + fixed\ effects$

total flood damage

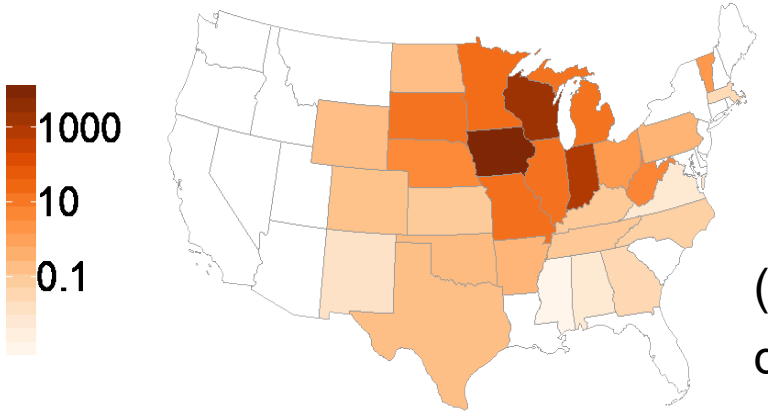
total precipitation

June 2008 Precipitation (cm)



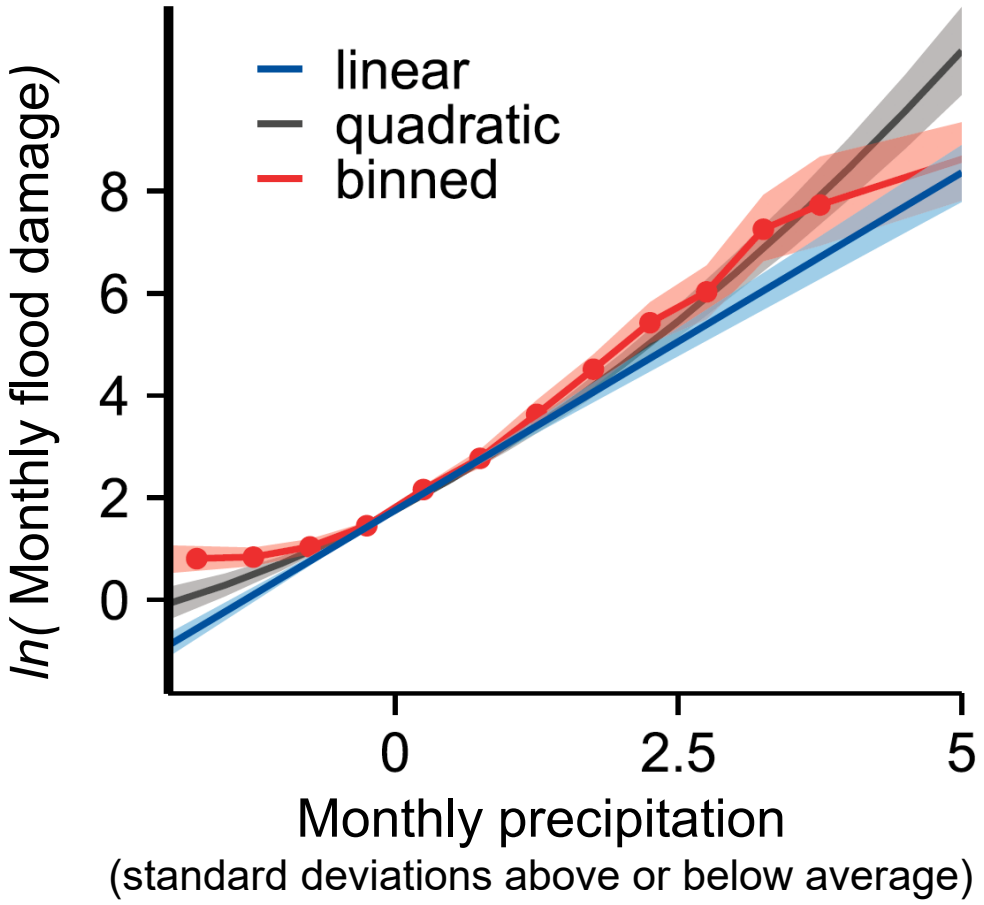
(PRISM)

June 2008 Flood damages ($ millions)



(SHELDUS database)

log-linear effect of precipitation change on flood damages



1 standard deviation increase in precipitation → **>3x increase in flood damages**

based on >6,600 events with flood damage in the U.S. between 1988-2017

Davenport, Burke and Diffenbaugh (2021), *PNAS*

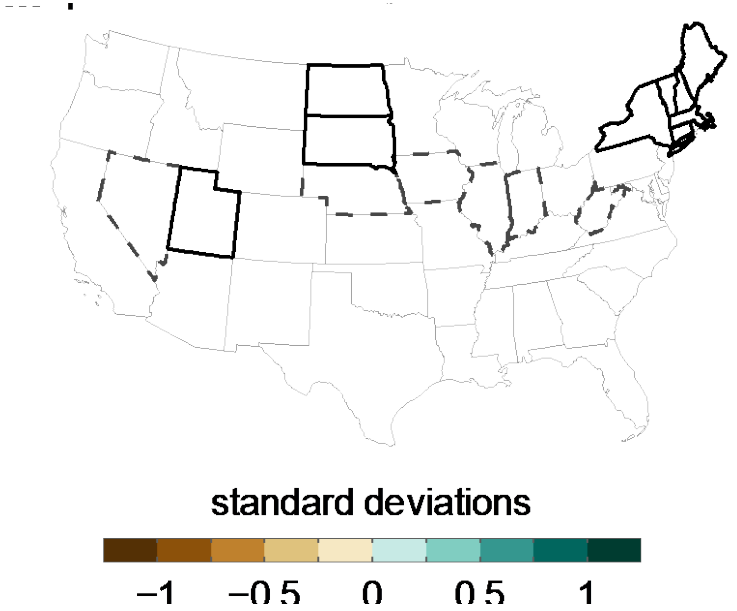
Counterfactual: what would damages have been without climate change*?

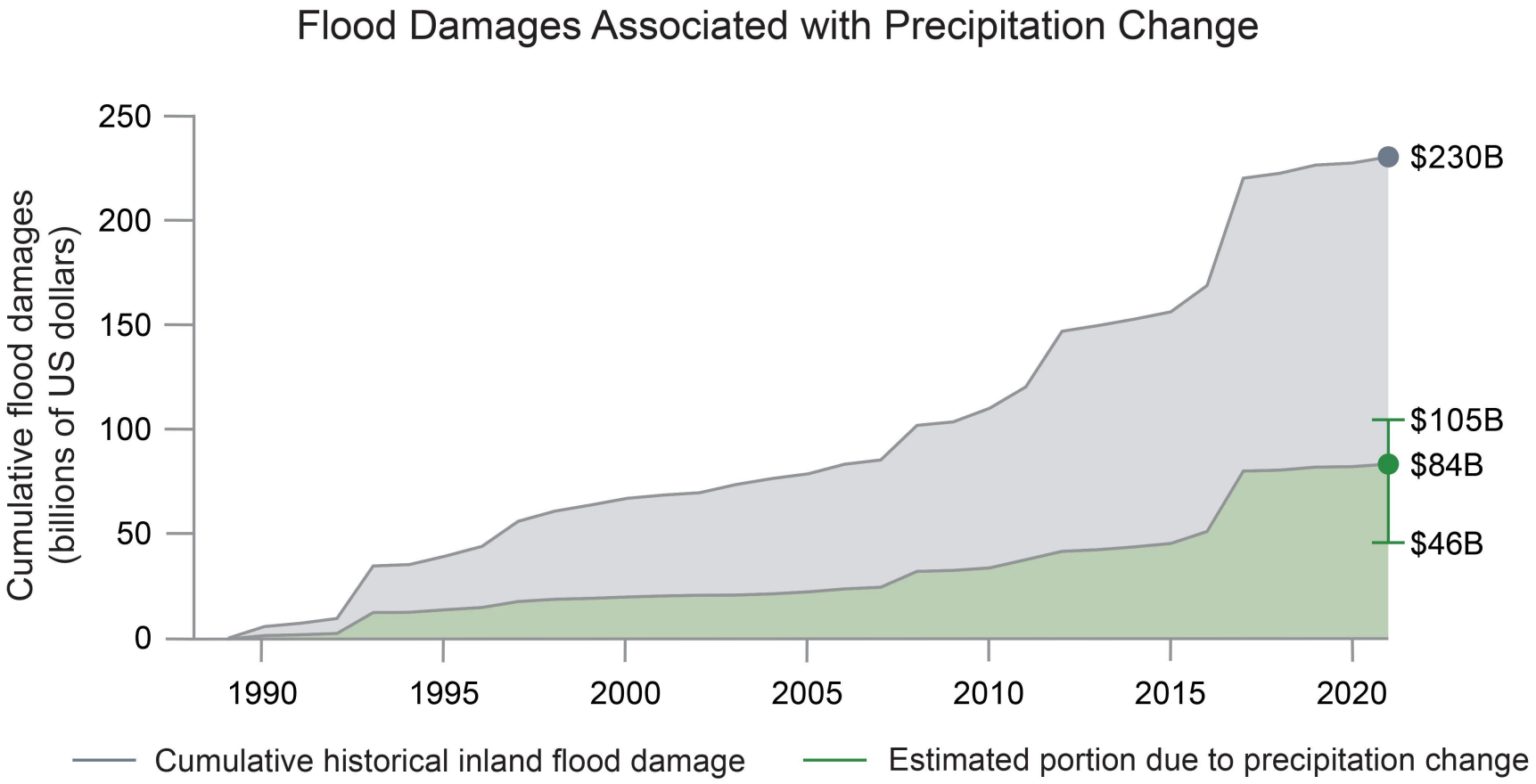
- 30 years of flood events across the US - do not have attribution studies for all of these events

- detrend the historical precipitation time series over **90 years** (1928-2017), accounting for non-uniform changes across the distribution
- calculate counterfactual damages for each event based on counterfactual precipitation

- *only attributing impacts due to precipitation amount (not changes in rain/snow fraction or antecedent conditions)

trend in 95th percentile of monthly precipitation (1928-2017)





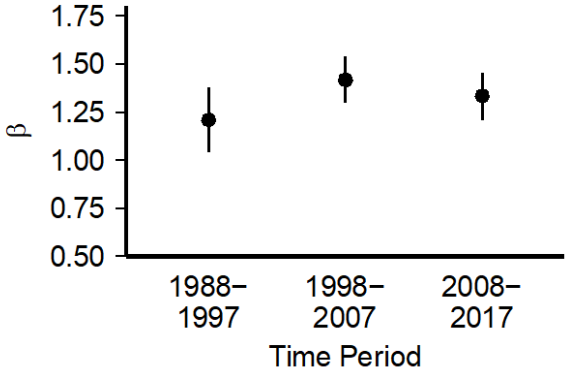
historical changes in precipitation account for ~30% of recent U.S. flood damages

Fifth National Climate Assessment, Ch. 4 (2023)
(adapted from Davenport, Burke and Diffenbaugh, PNAS, 2021)

advantages of causal inference for attributing flood impacts

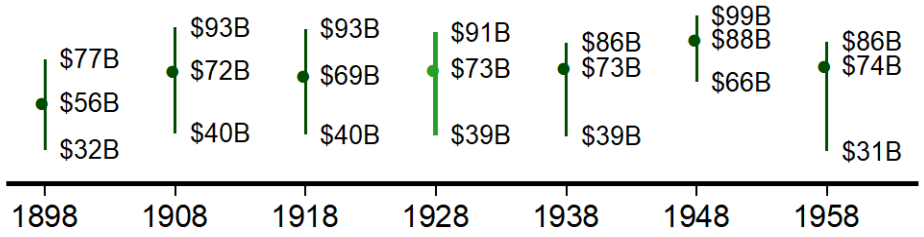
- minimal need for data or assumptions about exposure and vulnerability or about damage function

relationship between precipitation and flood damage over time:

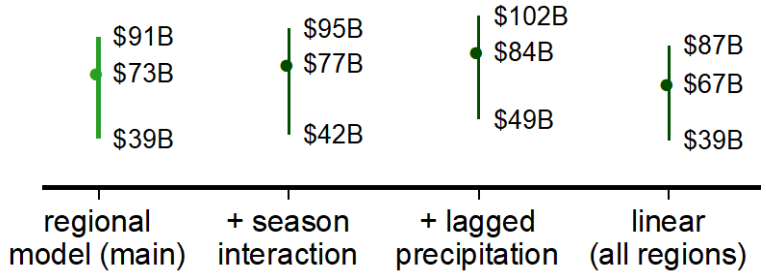


- computationally efficient:
  - practical to apply across large regions and many events
  - easily test model sensitivity/uncertainty

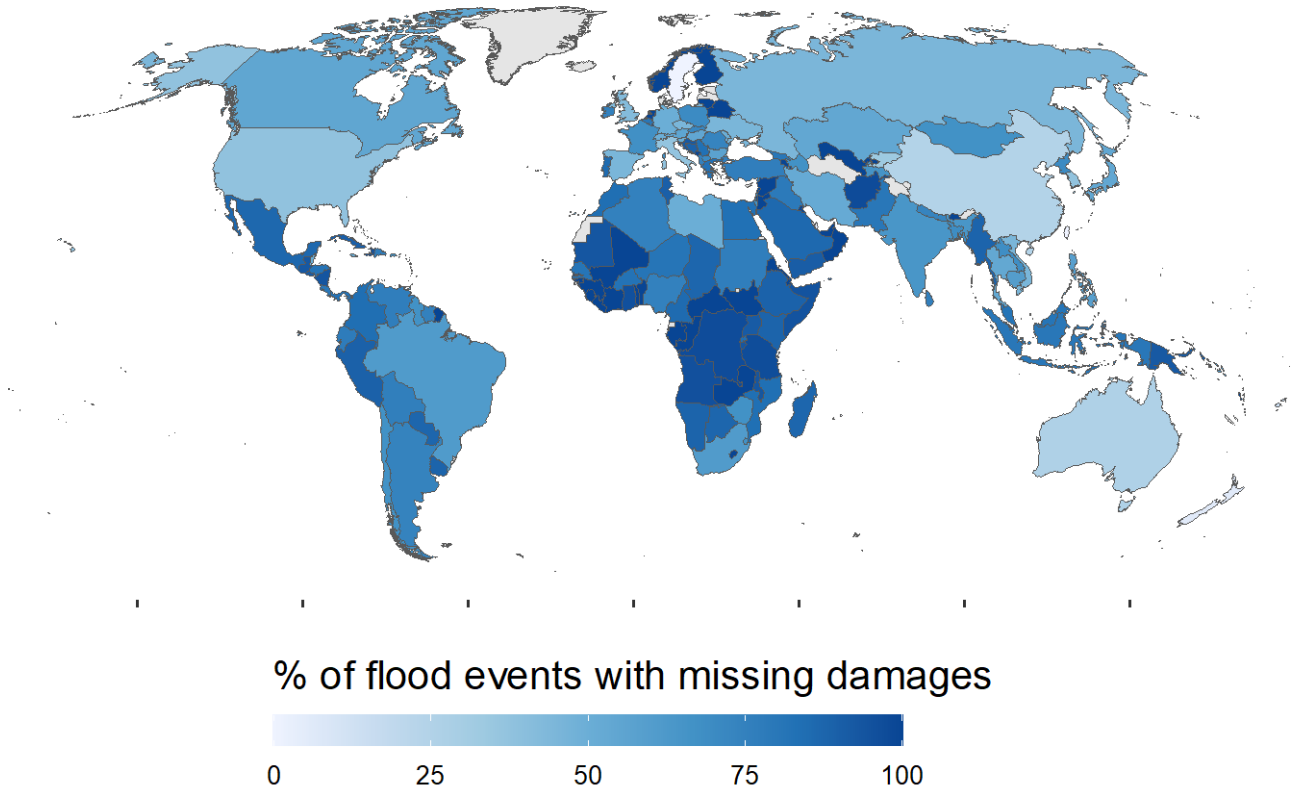
Sensitivity to precipitation trend star ting year:



Sensitivity to regression model specification:



global damage data for natural disasters is incomplete



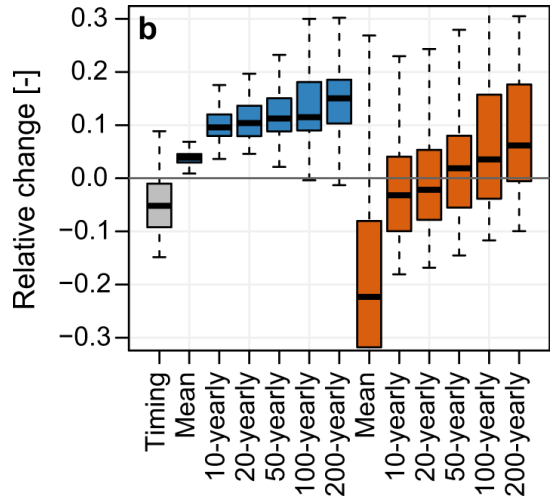
available data has high uncertainty, and is likely an *underestimate* of true damages

→ still more that we can study with current data, but there is an opportunity for better data on natural disaster impacts

some final thoughts on attributing (flood) impacts

- attribution of the physical event is still challenging
  - focus has often been on precipitation amount
  - many factors (rain/snow fraction, snowmelt, soil moisture, etc) can determine whether or not a flood occurs
  - in all likelihood, climate change is not making all floods worse everywhere

Precipitation and flood projections in Bavaria



Manuela Brunner et al., 2021,
Communications Earth & Environment

some final thoughts on attributing (flood) impacts

- attribution of the physical event is still challenging
- impacts can occur from conditions that don’t meet traditional meteorological definitions of extremes
  - e.g. moderately-high precipitation over area with high vulnerability
  - two consecutive moderate precipitation events

some final thoughts on attributing (flood) impacts

- attribution of the physical event is still challenging
- impacts can occur from conditions that don't meet traditional meteorological definitions of extremes
- local infrastructure can create very complex patterns of damage → very hard to model these factors in a counterfactual scenario

Spencer Dam Failure, Niobrara River Nebraska 2019

Pajaro River Levee Failure, California 2023

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