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# Likelihood of back-to-back tropical cyclone hazards is increasing

An integrated Earth system analysis is applied to project the probability of sequential hazards from tropical cyclones along the US East and Gulf coasts. Even a moderate-emissions scenario increases the chances of back-to-back tropical cyclone hazards and, possibly, two extreme tropical cyclone events impacting the United States within a short period of time.

**This is a summary of:**
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## The question

In 2020, Tropical Storm Beta, Hurricane Delta and Hurricane Zeta sequentially impacted the Louisiana coast within 40 days. One year later, Hurricanes Ida and Nicholas both impacted Louisiana within 15 days[1]. These back-to-back hurricanes — or tropical cyclones (TCs) — are more hazardous than individual storms, as the first storm can compromise coastal resistance before the second storm arrives. The sequential hazards induced by back-to-back TCs — involving extreme winds, heavy rainfall and storm surges occurring in close proximity within a short time — represent a compound weather and climate event that is not well understood[2]. Recent events have raised questions regarding whether the probability of sequential hazards caused by TCs is already increasing and how this likelihood will be affected by climate change. Knowing how sequential TC hazards will change in the future is crucial for the development of coastal resilience.

## The discovery

Historically, sequential TC hazards are rare, and thus the historical trend cannot be directly derived from observations. We, therefore, used a probabilistic model that captures the relationship between the occurrence rate of sequential TC hazards and their climatology features to perform Monte Carlo simulations for the period 1949 to 2018 and to obtain estimates of the trend along the US East and Gulf coasts. For future projections, considering both high- and moderate-emissions scenarios, we used a deterministic model to downscale climate models, generating numerous synthetic storms. Physics-based hazard models were applied to the synthetic storms to estimate their wind, rainfall and storm surge hazards, and the effect of sea-level rise (SLR) was accounted for by incorporating a probabilistic SLR projection. Statistical analysis was then applied to the generated hazard database to estimate the occurrence probability of sequential TC hazards along the US East and Gulf coasts.

Our analysis reveals that the occurrence probability of sequential TC hazards has been increasing over the past 70 years in many US East and Gulf coast areas. Moreover, even under the moderate-emissions scenario, SLR and storm climatology change will lead to a drastic increase in the future likelihood of sequential TC hazards. For example, the return period between sequential TC hazards impacting the same location along the US East and Gulf coasts within 15 days decreases from every 10–92 years in the historical climate to every 1–3 (1–2) years by the end of the century under the moderate (high) emissions scenario (Fig. 1a). Climate change could also cause unprecedented compounding of extreme TCs at the regional level. The chance of a Katrina-like hurricane and a Harvey-like hurricane impacting the United States within 15 days is projected to have an annual occurrence probability of more than 1% by the end of the century under the high-emissions scenario (Fig. 1b), whereas such events do not exist in historical observations or simulations.

## The implications

Our findings emphasize the importance of considering the impact of back-to-back TCs in the development of coastal resilience strategies, including reduced timeframes for recovery. Furthermore, TC rainfall and SLR have considerable influence on the occurrence of sequential TC hazard events; thus, coastal resistance to extreme rainfall and prolonged flooding needs to be improved. Finally, temporal compounding between extreme events, even when affecting different locations, will place unprecedented strain on emergency response systems, which should be upgraded accordingly.

Nevertheless, the projection of sequential TC hazards depends on the projected storm frequency, which is uncertain across the literature. Our synthetic model projects an increased TC frequency, whereas several previous studies project a constant or decreased frequency[3]. Although our sensitivity analysis shows that storm intensification (which is quite certain[3]) alone can cause a substantial increase in the probability of sequential TC hazards, the degree of the increase depends on the change in storm frequency. Thus, this study also highlights the necessity of furthering fundamental understanding of the influence of climate change on TC frequency.

Going beyond the temporal and spatial compounding of TC hazards, we now plan to investigate the compounding of TC hazards and other climate hazards, such as hurricane–heatwave compounding[4]. Some of these hazards might intensify together under climate change, leading to compound hazards having greater impact.

**Ning Lin & Dazhi Xi**
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## EXPERT OPINION

"This study indicates that we are increasingly at risk of two hazard-producing (but not necessarily extreme) TC events sequentially impacting the same location, as well as two extreme events impacting multiple locations sequentially. These findings are highly relevant because compound events cause greater damage than individual events and put more strain on resources for preparedness and recovery. Changes in sequential TC hazards have not previously been studied in detail, so this work is timely."
**Allison Wing, Florida State University, Tallahassee, FL, USA.**

## FIGURE

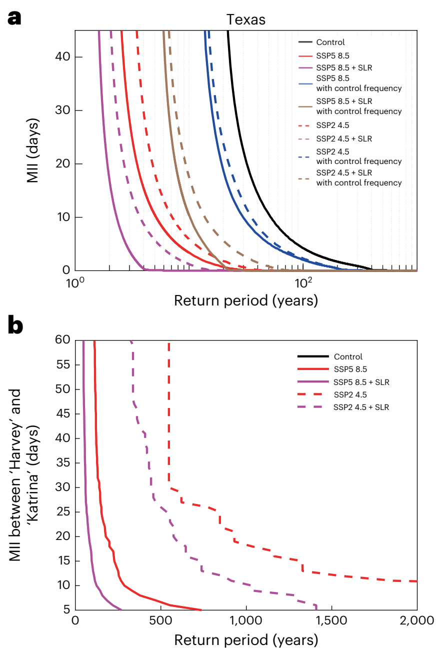


**Fig. 1 | Return period of sequential TC hazards.** We predicted the return period (that is, the reciprocal of the annual exceedance probability) of the minimal impact interval (MII) between two hazard events under control (1984–2005), moderate-emissions (Shared Socio-economic Pathway 2 4.5 (SSP2 4.5); 2070–2100) and high-emissions (SSP5 8.5; 2070–2100) scenarios, and with and without the incorporation of SLR. **a**, Return period of the MII between sequential TC hazards impacting somewhere in Texas. **b**, Return period of the MII between a Katrina-like and Harvey-like storm impacting the US coastline sequentially. There is no control curve because such an event was not identified in the control simulations. 

## BEHIND THE PAPER

In August 2017, Hurricane Harvey (category 4) made multiple landfalls in Texas, causing record-high flooding in the Houston area, many fatalities and huge economic losses. My research group joined a survey team to investigate the damage in Texas. Two weeks later, before we had finished our survey, Hurricane Irma (category 5) made landfall in Florida, causing unprecedented evacuation and destruction. We quickly moved to Florida to survey the damage. Yet, just two weeks after, Hurricane Maria (category 5) impacted Puerto Rico, jeopardizing its power system. By this time, we couldn't conduct a survey in Puerto Rico, but we started questioning the likelihood of back-to-back intense hurricanes impacting the US, whether this likelihood is increasing under climate change and our preparedness to deal with such disasters. We realized that sequential hurricane hazards are an important type of compound weather and climate event[1] of great interest in the context of climate change adaptation. **N.L.**

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## FROM THE EDITOR

"The risks of tropical cyclones are often just assessed for single storms, but the effects of two storms making landfall in the same area in short succession can be even more devastating. This study shows that the likelihood of this understudied type of compound event is increasing, which implies stronger protection could be needed."
**Editorial Team, *Nature Climate Change*.**