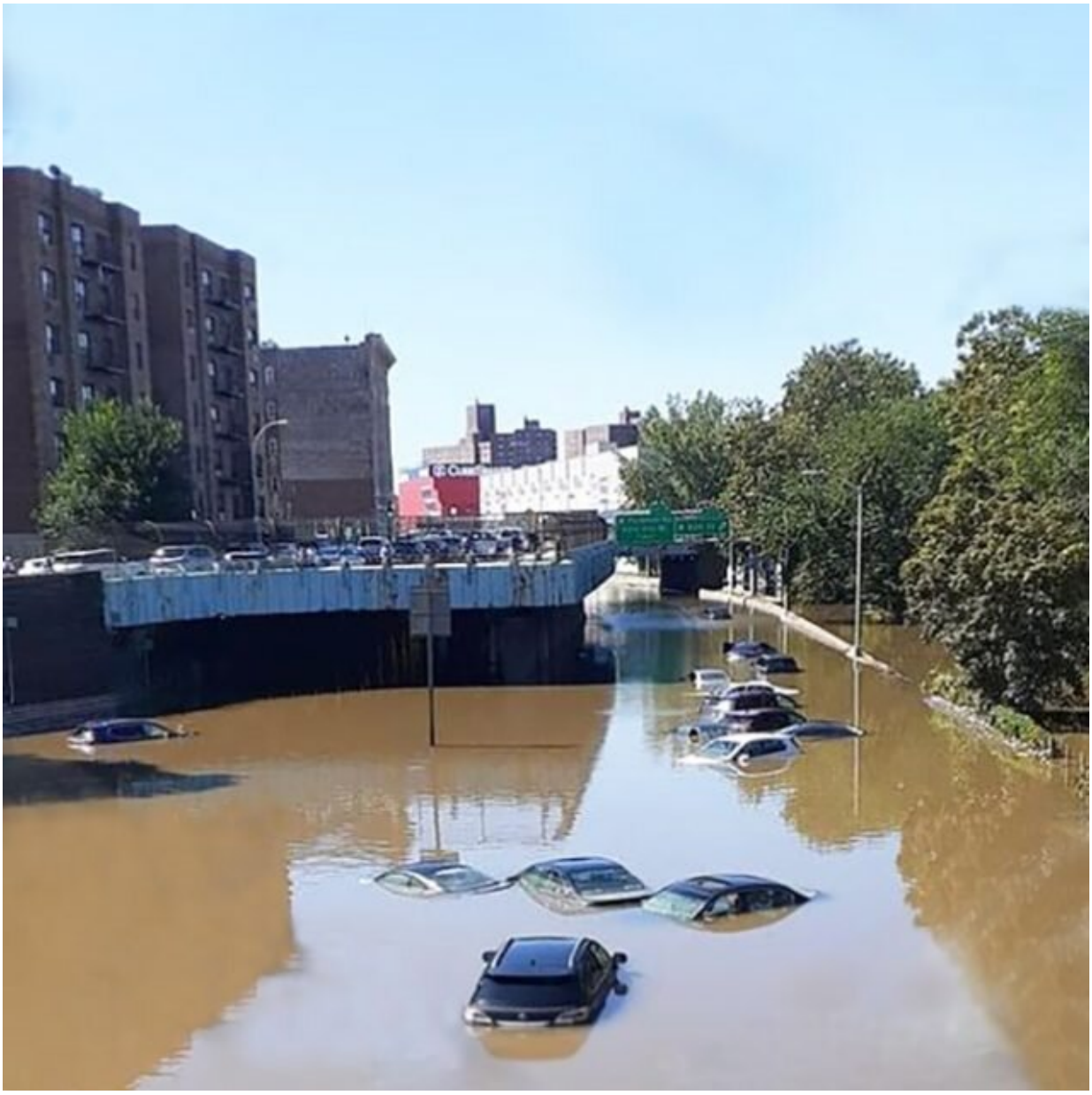
Mitigating the impacts of extreme rainfall events in a changing climate

September 22 2021, by Kai Kornhuber, Mona Hemmati, Andrew Kruczkiewicz



Flooding in the Bronx the day after Ida passed through New York City. Credit: Jim Griffin

Torrential rainfall quickly transformed New York City's streets and expressways into rivers and lakes on Wednesday night September 2, 2021, shutting down the entire metro system (the first time since Hurricane Sandy) and forcing traffic throughout the city to come to a halt. Air traffic was interrupted, and businesses had to close, causing an estimated 16 billion to 24 billion dollars in flood damage to the Northeast. At least 13 people died that night in New York, and at least 44 throughout the Northeast—more than the total in the southern US from Ida's initial landfall as a strong Category 4 storm. With a total damage of approximately 98 billion dollars, Ida might become the seventh most expensive hurricane in recent US history. In a nonstationary climate due to ongoing anthropogenic climate change, we will see more events like this. Mitigation measures must be prioritized to address the rising risk from ever increasing frequency and magnitude of rainfall extremes.

Similar to past extreme flooding events, the rainfall was brought by the remains of a tropical storm, Ida, which prior caused widespread flooding and devastation to Louisiana. Next to the record-breaking precipitation levels witnessed in New York it is remarkable, however, that the past NYC record was set just two weeks before when Hurricane Henri brought hourly rainfall of more than two inches, leading to widespread floods and disruption of daily life. The events constitute the third major flooding event in NYC within just a few months, after remnants of tropical storm Elsa brought strong winds and unusual rainfall to the city in early July. What used to be rare occurrences in the city—subway flooding, for example—occurred regularly this summer.

From a global perspective these citywide disasters didn't happen in isolation, but were part of a series of high impact flood events that made 'record-breaking' the norm of 2021. Just after Elsa brought anomalous rain to NYC, a major storm system stalled over Western Europe on July 14–15, causing record-setting rainfall over the Low countries, Germany, Switzerland, and France. Some parts of Germany received two months of rain in one to two days, which caused rivers to overtop their banks and flash flooding through communities. This extreme event resulted in severe insured losses of around 4.7 to 5.9 billion euros from the floods in Western Germany alone.

Just a week later, on July 19 and 20, severe flooding occurred in the central Chinese Province Henan after record breaking rainfall of more than seven inches was measured in the provincial capital Zhengzhou. The floods that affected large parts of central China caused at least 300 casualties and forced more than 800,000 people to evacuate.

Then in August, a series of thunderstorms caused severe rainfall in Turkey that resulted in several floods and landslides. During the course of the week that featured unprecedented local water rises by four meters, at least 81 people lost their lives, and more than 1,800 were evacuated.

Extreme rainfall and stagnating weather in a changing climate

Record breaking rainfall extremes in general and short duration rainfall events in particular are increasing in frequency in a warming climate as the rate of evaporation and the atmosphere's capacity to hold water both increase. Physically, these relationships are well understood and an increase in regional rainfall extremes can be found in observations globally and at a local scale leading to an increase in flood damages within the historic datasets and under future high emission projections.

To express the Germany flooding event from a climate change perspective, the rapid attribution study from the World Weather Attribution Project found that the event was made 1.9 to nine times more likely by climate change.

In addition to thermodynamic factors that increase the likelihood of record-breaking rainfall extremes, atmospheric dynamics often contribute in making an extreme weather event more severe. For example, when slow moving weather systems cause associated rainfall to occur over the same region for a longer duration, local flood risk can amplify. One of the most prominent examples of recent years is Hurricane Harvey, which remained stationary over Texas, guided by a persistent meander in the jet stream, thereby leading to extreme flooding in Houston mid-August 2017. Similarly, the low-pressure system associated with the German flood in 2021 remained stationary. Evidence suggests that climate change is one of various factors in shifts in atmospheric dynamics, such as the weakening of the mid-latitude circulation over the past four decades, leading to slower storms and intense precipitation events more frequently. Although the 2021 record rainfall events in New York were not due to a particular slow moving weather system, the large-scale circulation played a critical role by providing additional moisture to Tropical Cyclone Ida through the interaction with an extratropical front when it made its way to the northeast.

Mitigating flood risks in a changing climate

Impacts from climate extremes don't occur in isolation to other non-climate related societal challenges and often act as an amplifying force. COVID-19 hospitalizations in Louisiana were close to their all-time high just before Ida struck, making evacuations and potential health support more challenging. Many of those that died in NYC drowned in illegal subterranean apartments, a last refuge to avoid displacement from the

city's high rents. The record-setting hourly rainfall rates of three inches or more made the waters rise at speeds impossible to escape.

In addition, urbanization as a result of population growth and economic development adds more impervious surfaces to the region resulting in increasing runoff and changing the characteristics of floodplains, flood depth, and flood extent. Urban growth and informal development leads to not only increased exposure, but increased exposure to already underserved populations with lower coping capacities.

For protection of current and future generations, and to decrease the chances of future events leading to devastating consequences, two types of mitigation measures can be adopted. These can be categorized as structural and nonstructural measures. Structural measures typically involve engineered systems, such as dams, levees and floodwalls aimed at controlling the hazard. A practical example of such measures is the new levee system in New Orleans that was constructed after Hurricane Katrina. Ida tested the reliability of the system, and reports demonstrated that it performed adequately, reducing the destructive consequences of the hurricane considerably. However, every storm is different and while a success for Ida, questions remain: are these measures enough considering the changing nature of the hazard?

As the frequency and intensity of flood events are increasing due to climate change, protective structures—known as structural mitigation measures—that are designed based on contemporary flood threats, may experience future extreme events that cause overtopping or failure of the structure. Such strategies may also create an illusion of safety, further promoting growth in or near 'flood-protected' areas, as well as promoting a lack of proper risk perception at the individual, institutional and government levels.

Nonstructural flood mitigation measures rely on public policy planning,

such as zoning, acquisition and land-use regulation, and socioeconomic incentives that focus on controlling the exposure. These policies are most effective in urbanizing communities, however, they are not as successful as expected in reversing the tendency of people to choose to live in flood-prone areas.

Important questions in that context are: what level and combination of structural and nonstructural measures should be implemented to help future communities be more resilient to devastating floods and extreme events like the one that happened September 2, 2021 in NYC? And further, to what extent are these measures supporting one group of people more than others? Is this disproportionate benefit leading to the disadvantaged populations becoming relatively more disadvantaged?

In some regions, the amplified frequency of extreme weather events makes it increasingly difficult to recover, let alone to adequately prepare for the next extreme, making retreat the only viable option. But this is easier said than done as many questions around which communities are prioritized, and around mandatory vs. optional retreat must be addressed. And lastly, we must know not only what we are retreating from, but what hazards (current and future) may be encountered there when we arrive.

Moving inland to a certain degree will mitigate coastal storm surge and sea level rise risks. Flash flood risk is much more complex to delineate, and we must communicate if, and to what extent, people are retreating from one hazard into another one. This tension, both with flash floods, other individual hazards, and compound risks, will be one of the elements that must be addressed. The opportunity now is that we have the privilege to assess and manage options in a structured approach, rather than waiting and being forced to address them under immense cognitive, emotional, and technical strain.

With Climate Week happening in New York City at the moment, we

have an opportunity and the responsibility to ensure a connection is re-established with the most vulnerable populations, especially in urban areas such as NYC where gradients of wealth and privilege exist. This week is an opportunity to ensure the activities/discussions/policies are developed at an appropriate granularity that address disproportionate impacts, such as what we saw in NYC only a short couple of weeks ago.

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