Illustrating Extreme Weather Across U.S. School Districts Through Data Linking and Visualization

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Increasingly common extreme weather events can impact children's learning and well-being

Extreme weather—that is, high-intensity weather events such as severe storms, floods, fires, and tornadoes[1]—is increasing in frequency and severity and threatens many sectors, including education.[2] One global study showed that a 10-year-old child today will experience twice as many wildfires and tropical cyclones, three times more river floods, four times more crop failures, and five times more droughts over their lifetime compared to a 10-year-old child in 1970.[3] These extreme weather events can severely impact access to school-based learning and services.[4] Schools may be destroyed by a tornado, closed because of extreme heat and cold, or repurposed as emergency centers during hurricanes. Teachers may become absent, displaced, or unavailable. Students may be temporarily relocated to other school districts or move to another area altogether. Together, these effects create disruptions in access to educational services, which—coupled with negative drivers outside of schools like housing instability, food insecurity, parental job loss, and social disconnection[5]—may impact children's learning, executive functioning, and well-being.[6]

To understand how this increase in extreme weather may impact children's learning and well-being, local education system leaders need access to integrated data that link national weather and disaster information from sources such as the Federal Emergency Management Agency (FEMA) or the National Weather Service with data from their own state or district. This integrated data can enable data-informed decision-making to support disaster preparedness and response, program coordination, and post-event resource allocation.

To do this, national weather and disaster data must first be linked to school district boundaries geospatially. Then, states or school districts can link extreme weather data to their own administrative data on key education metrics such as enrollment, attendance, and test scores. Resources from the National Center for Education Statistics (NCES) enable linkage of weather data to district boundaries or individual schools using the Education Demographic and Geographic Estimates (EDGE) geospatial data. To date, these integrated data have primarily been used to track weather events such as active hurricanes or wildfire smoke forecasts in real time through tools like the NCES School Weather Watch dashboard or local emergency management dashboards that display schools in the path of ongoing weather events.

In this brief, we link weather, education, and population data to estimate how extreme weather events affected school districts over an extended period. To do so, we describe the prevalence of extreme weather events—defined as storms, floods, fires, and tornadoes that were so severe that they warranted federal disaster declarations—in school districts across the U.S. geospatially from the 2010–11 to 2019–20 school years. We use this information to address the following research questions about event frequency and geographic distribution.

Research Questions

1. **Over a decade (between 2010 and 2019), what proportion of districts were affected by extreme weather events (storms, floods, fires, tornadoes) each year?**

2. **How were these events distributed across the U.S. in terms of frequency and type of event?**

For each type of extreme weather event, we also provide illustrative examples about how each type of extreme weather has impacted school systems. We conclude with a discussion of what state leaders need for better decision-making and how researchers can support data integration, interpretation, and communication.

Methods

To document how often and what type of extreme weather events affected each district across the U.S. over the course of 10 years, we linked FEMA disaster declaration data,[a] Common Core of Data (CCD) school district data, and EDGE geospatial school district data. We first defined our sample using CCD data to include all public school districts.[b] Next, we spatially analyzed the intersection of school districts in the 2019 EDGE single school district composite shapefile and 2019 county boundaries in ArcGIS to create unique district-county segments. We then linked these segments to county-level FEMA data. Next, we defined a measure of exposure to an event as the share of the population (according to U.S. Census block population centroids) in a district's catchment area that were in a county with a weather event necessitating a FEMA declaration. We considered each FEMA disaster declaration that was a storm, flood, fire, or tornado to be an extreme weather event. We calculated the prevalence of each storm type by district and U.S. Census-defined regions and divisions. We then used ArcGIS to map the extent of extreme weather events across U.S. school districts.

[a] FEMA disaster declarations occur when the President declares that a disaster caused damage so severe it exceeds the capabilities of state and local governments, qualifying the affected area for federal assistance. Governors or tribal chief executives must initiate the request.

[b] For the purpose of this analysis, we define public school districts as public, non-charter, locally governed districts that are responsible for providing free education and do not share superintendent or administrative services with other districts.

Nearly all districts experienced at least one extreme weather event over 10 years

Nine out of 10 school districts experienced at least one extreme weather event over the 10-year period, with half of districts experiencing three or more years in which there was an extreme weather event (storm, flood, fire, or tornado) between the 2010–11 and 2019–20 school years. School districts in New England and the West North Central (Great Plains) region experienced the most years with extreme weather events, averaging four years with an event per district over the 10 years. Districts in the Mountain and East North Central (Great Lakes) regions experienced the fewest years with extreme weather events, averaging just one year with an event per district.

## Mapping the extent of extreme weather across U.S. school districts

Number of years with extreme weather events between 2010 and 2019
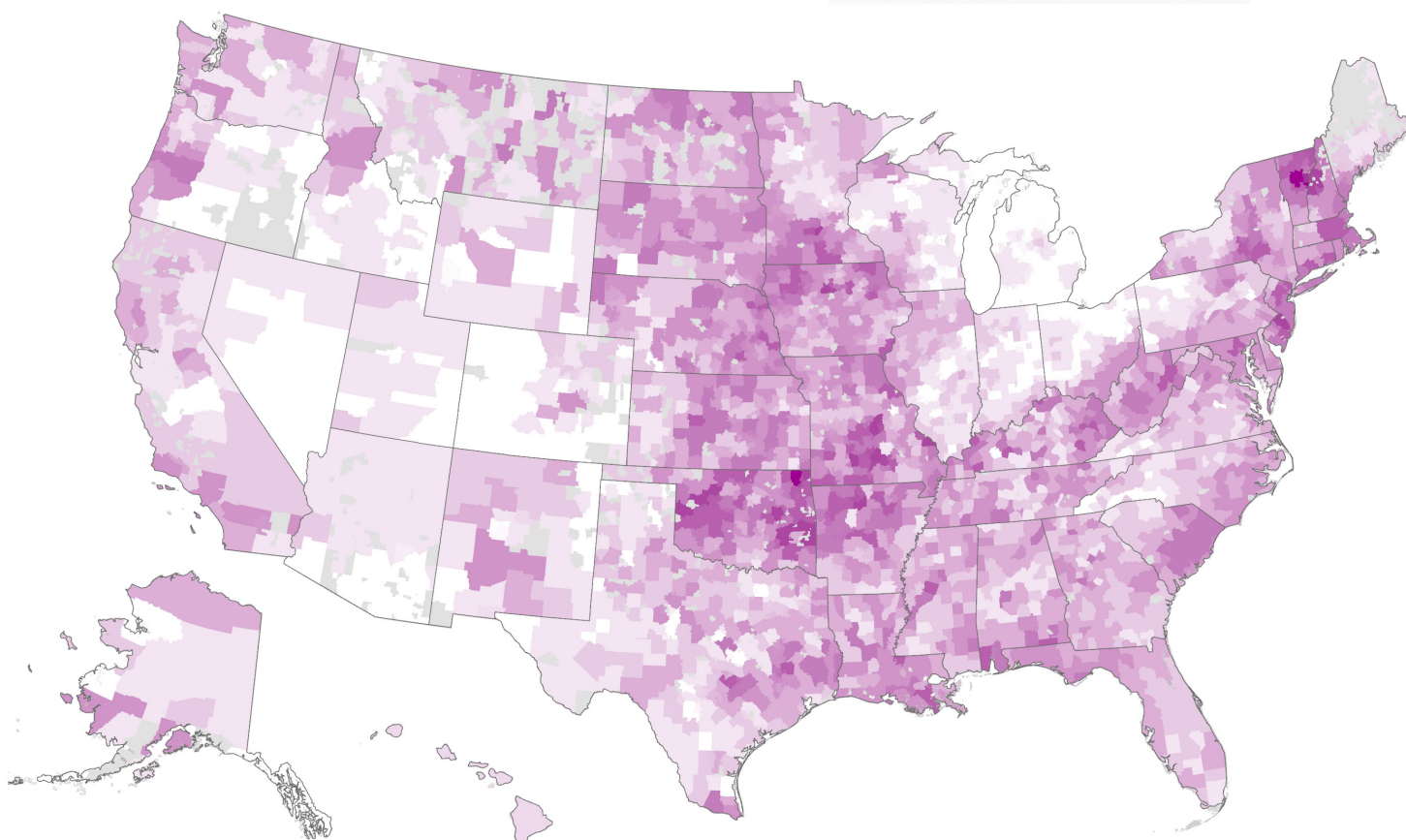
Note: 761 (6%) records in the EDGE shapefiles were not in the CCD. Because EDGE data are a subset of CCD records, our hypothesis is that the missing records are due to the limitations applied to our sample (public school districts only, EDGE 2019 single composite shapefile). These districts were largely concentrated in very rural areas.

Storms

Storms—a broad category that includes hurricanes, snow storms, severe storms, and severe ice storms—were the extreme weather event experienced by the largest number of school districts, affecting all regions. Most districts (79%) experienced a storm of sufficient strength and destructive power to receive a federal disaster declaration at some point between the 2010–11 and 2019–20 school years. Each year on average, one in five districts were affected by a storm disaster. Storms were most common in New England, where every district experienced at least one storm, with an average of four years of exposure to storms throughout the decade. Storms were also frequent in the Middle Atlantic, with an average of three years of exposure per district. Storms were least common in the Mountain region, where fewer than half of districts (45%) experienced a storm emergency throughout the decade.

Number of years with storms

0 · · · · · · 7 · No data

Superstorm Sandy
landfall (2012)
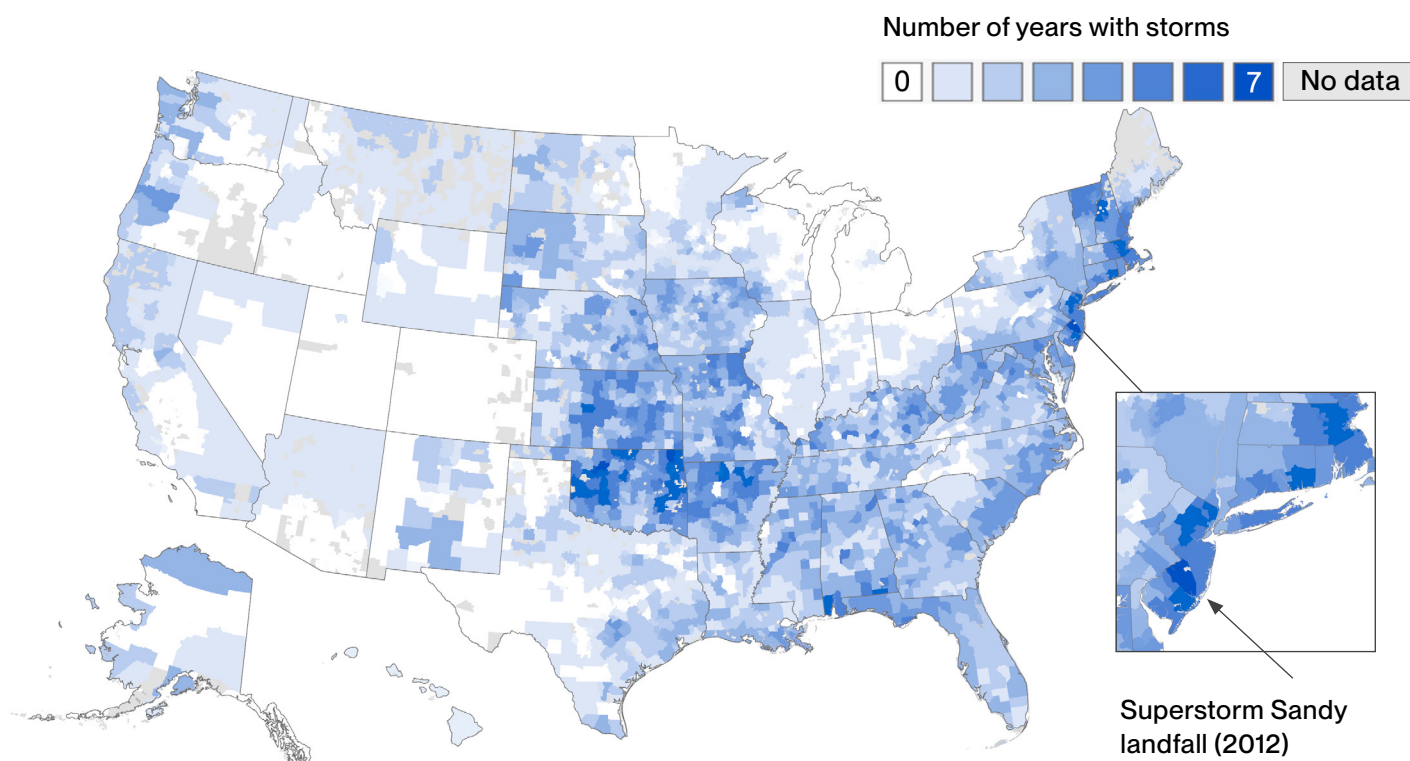
Spotlight on the Northeast:
2012 Superstorm Sandy

On October 29, 2012, remnants of Hurricane Sandy (nicknamed "Superstorm Sandy") made landfall a few miles from Atlantic City, New Jersey, disrupting school systems in multiple states up and down the Atlantic seaboard. In New York City, all public schools closed for at least a week following the storm, and attendance rates suffered. For example, schools that had to relocate had just 33% attendance nearly two weeks after the storm.[7] Further, districts often faced the dual challenge of supporting their students in the face of disruptions both at school and at home. For example, one New York City school reported that 60% of students and 30% of its staff were displaced from their homes in the aftermath of the storm.[8]


Aerial views of the damage to the New Jersey coast from Superstorm Sandy, October 30, 2012.

Floods

Floods were the second most common extreme weather event, affecting districts across all U.S. regions. About half of school districts (47%) experienced a flood at some point between the 2010–11 and 2019–20 school years, with 7% experiencing a flood each year. Floods were most common in the Pacific and West North Central (Great Plains) regions, where 77% and 75% of districts, respectively, experienced a flood throughout the decade. Flooding was least common in New England, where 9% of districts experienced a flood.

Number of years with floods

0 ☐☐☐☐☐☐ 6   No data

Baton Rouge
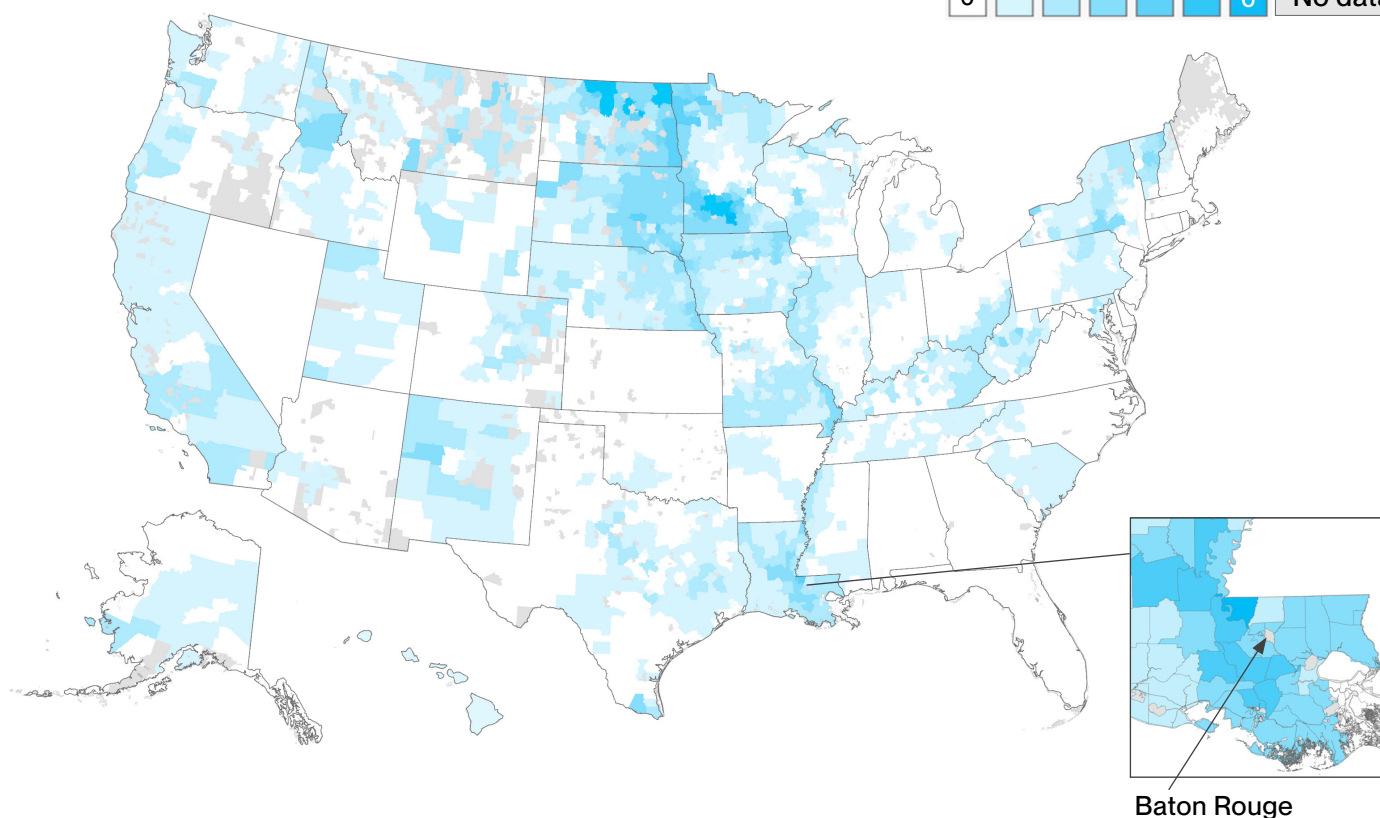
## Spotlight on Louisiana: 2016 "No-Name Floods"

In August 2016, prolonged rainfall led to catastrophic flooding in southern Louisiana, dumping three times as much rain as Hurricane Katrina.[9] The Red Cross called these "no-name" floods the worst U.S. disaster event since Hurricane Sandy.[10] During the peak of flooding, at least 22 school districts closed and nearly 250,000 children—about a third of the state's school-aged population—were out of school. The flooding strained school infrastructure, with some schools under several feet of water and a third of the state's bus fleet lost.[11] As a result of the prolonged school closures, districts extended the school day or school year to make up for lost time.[12]

Flooding and devastation in Baton Rouge, LA, on August 15, 2016.

Fires

Fires were concentrated in the East South Central, West South Central, Mountain, and Pacific regions. Only 8% of school districts across the U.S. experienced a fire of sufficient strength to warrant a federal disaster declaration at some point between the 2010–11 and 2019–20 school years. Fires were most common by far in the Pacific and West South Central regions, though the average incidence for each district was still quite low, with about a third of districts experiencing a fire (32% in West South Central and 29% in Pacific).

Number of years with fires

0   [ ]   2   No data

Paradise

San Francisco
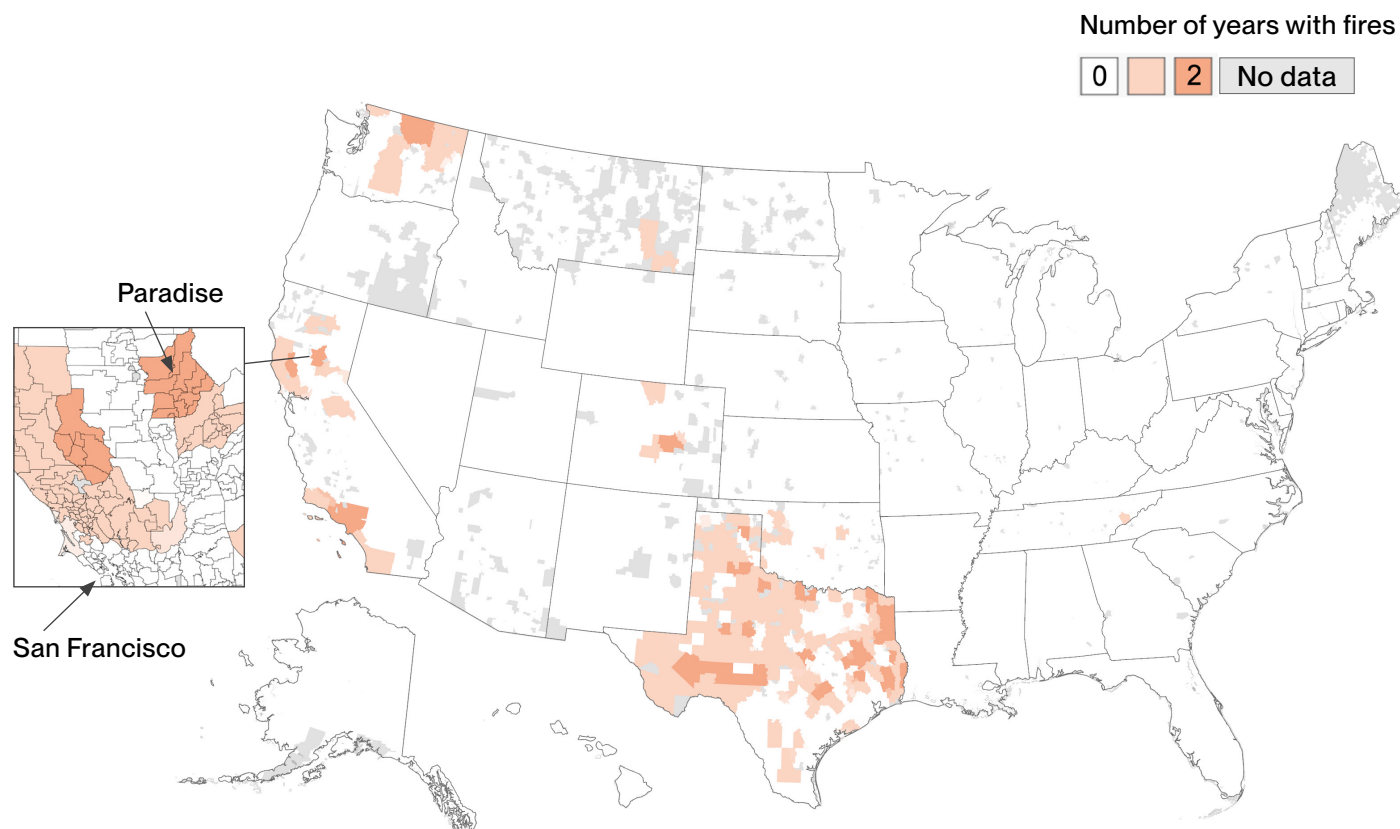
Spotlight on California: 2018 Camp Fire

In November 2018, high winds downed a powerline, which ignited the Camp Fire, the deadliest and most destructive wildfire in California's history. The high winds and dry, dead biomass amplified the fire, tearing through the town of Paradise.[13] Five Paradise public schools were destroyed, and about 800 students lost their homes.[14] Air pollution from smoke forced numerous school district closures,[15] including many outside the FEMA disaster declaration area more than 100 miles away. Nearly seven years later, recovery is still in progress. "We'll get there, but we have not yet recovered," said former Paradise Unified School District Superintendent Tom Taylor before he retired in May 2025. "We're not yet where we want to be."[16]


Rubble from a home in Paradise, CA the month after the November 2018 Camp Fire.

Tornadoes

Tornadoes were the least common extreme weather event, though they were more distributed across regions than fires, with all but the Pacific region experiencing at least one tornado. Only 6% of districts experienced a tornado at any point between the 2010–11 and 2019–20 school years. Each year, approximately 1% of school districts were affected by a tornado-related disaster. Tornadoes were most common in the West South Central region, which includes part of the area known as Tornado Alley, followed closely by New England. However, tornadoes were quite rare even in these regions, with just 13% of districts experiencing a tornado throughout the decade.

Number of years with tornadoes

0 | | 6 | No data

Oklahoma City
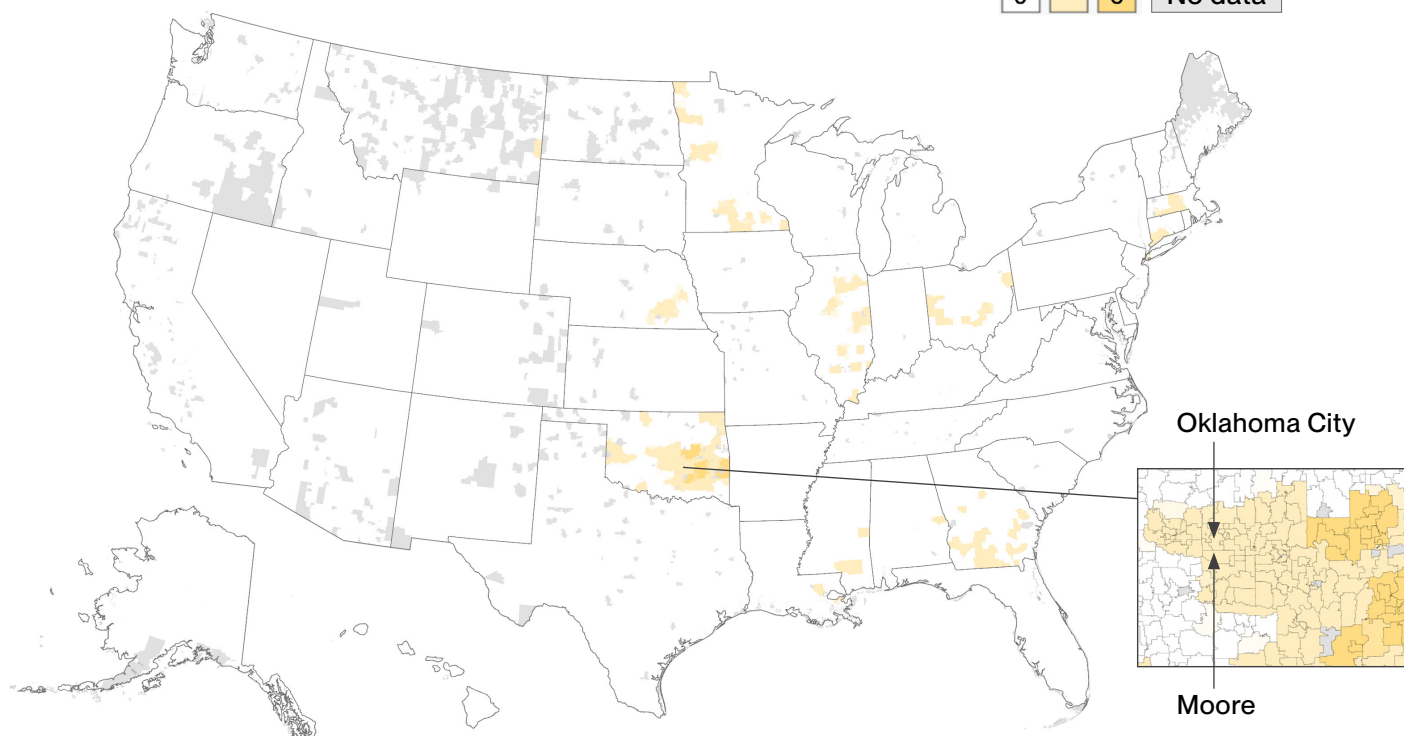
Moore

Spotlight on Oklahoma: 2013 Moore Tornado

On May 20, 2013, a two-mile wide EF5 tornado struck the town of Moore, Oklahoma, resulting in severe localized devastation to children and schools. Plaza Towers Elementary School was leveled, resulting in loss of life after a wall collapsed in the gymnasium.[17] Other nearby schools were also destroyed or badly damaged. In response, the community passed a local bond measures funding construction of storm shelters in every school building in the district.

Classroom damaged at Plaza Towers Elementary School, Moore, OK, during an EF5 tornado on May 20, 2013.

Implications and future directions

Extreme weather disasters are a common occurrence in the lives of U.S school children. Over the decade between 2010 and 2019, an overwhelming majority of school districts were impacted by an extreme weather disaster. These events severely damaged school facilities, forced families from their homes, and in some cases resulted in loss of life.

School districts and state education agencies across the country must plan for the inevitability of these events. Additionally, resources like transportation, nutrition, and infrastructure mitigation may need to be strategically distributed to high-risk districts and to the most vulnerable students. Resource distribution may also vary depending on type of extreme weather event.

Currently, schools and districts receive emergency supports from the U.S. Department of Education (ED) and FEMA and to prepare for and respond to extreme weather events. These supports include emergency operations plans, trainings, emergency public assistance grants (ED, FEMA), and other technical assistance. Other recently developed tools, such as Undaunted K–12's Extreme Weather and School Closures map, provide useful geospatial visuals of the impacts of extreme weather on schools.

While these resources are helpful, state and local school leaders need (1) resources to integrate data for real-time local monitoring and planning, (2) additional capacity for data storytelling, and (3) ways to identify impacts on their own student outcomes.

Integrate data for real-time monitoring and planning

This brief—like much of the literature on weather and schools—presents a snapshot of the extreme weather events across U.S. school districts. However, real-time monitoring of weather events and relevant education metrics is critical to responding to extreme weather events in ways that support student learning and well-being. Partnerships that leverage the analytic expertise and capacity of research and

technical assistance teams with the policy and contextual expertise of state or district staff can support monitoring and planning through data integrations that connect real-time school or district education data (e.g., attendance, transportation, nutrition) to real-time weather data. Tools such as data dashboards can display these integrated data and facilitate quick local decision-making in the face of a weather event. Districts could also benefit from data models that predict how different types of extreme weather may impact certain localities and certain outcomes differently.

Build capacity for data storytelling

Although quantitative weather and education data tell part of the story about the impacts of extreme weather on schools, the ability to link these data to personal stories may increase the effectiveness of data communication. This brief spotlights just one example of each type of extreme weather event that occurred during the study period. Moving forward, the field may benefit from mixed-methods approaches that combine quantitative and qualitative data sources to communicate both the breadth and depth of impact. For example, interactive dashboards may combine dynamic, quantitative spatial visualizations with qualitative data from interviews, focus groups, or photo documentation to describe how extreme weather events impact schools.

Identify impacts on student outcomes

This brief presents descriptive findings on the prevalence of extreme weather events in districts across the U.S. However, decision-makers are also interested in understanding how current weather events may affect key school and student outcomes such as teacher retention, student attendance, and test scores. Prior research has documented associations between extreme weather and outcomes such as graduation rates, academic performance, and attendance;[18] standardized test scores and executive functioning (such as concentration and emotion regulation following disasters);[19] and incidence of mental health issues such as post-traumatic stress disorder, depression, and anxiety.[20] Yet many questions remain unanswered, especially those about the causal impacts of specific weather events on key education outcomes and how long those impacts persist.

To address these questions, researchers can use quasi-experimental methodologies that integrate education and disaster data geospatially and leverage complete and granular data about individuals and weather events across all relevant localities and years. Such research can drive actionable information for school system decision-makers before, during, and after extreme weather disasters. To maximize the utility of these findings, researchers can partner with state and local education agencies to explore impacts on specific school and student outcomes that are most critical to recovery following an extreme weather event.

Contact us to learn more and collaborate

SRI researchers and technical assistance providers are available for further discussion about the impacts of extreme weather on school systems. Please contact **education@sri.com** for more information and to discuss potential partnerships, technical assistance opportunities, and other ways to expand this model for supporting K–12 systems.

Footnotes

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