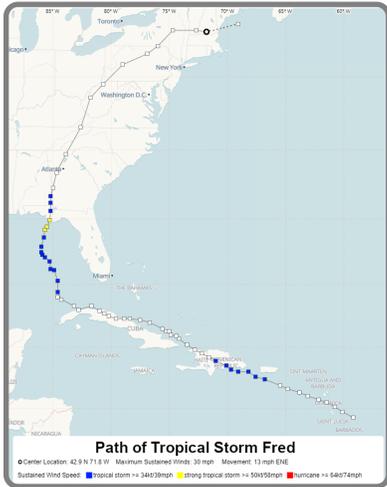


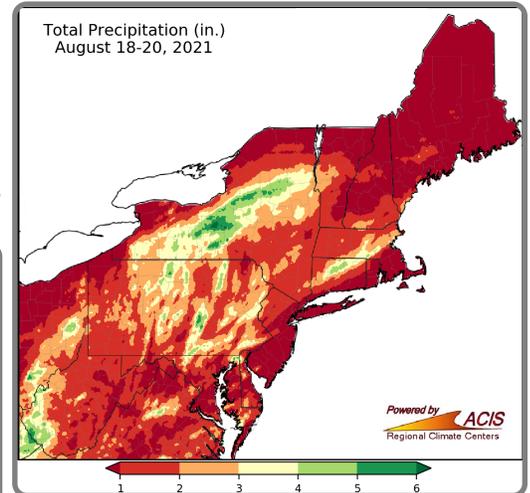
### Fred



Fred's track. Credit: NWS Binghamton

The remnants of Tropical Storm Fred moved through the Northeast from **August 18 to 20**.

- The storm spawned **10 weak (EF-0 or EF-1) tornadoes** in the region, seven of which [touched down in Pennsylvania](#). Tornado damage included snapped and uprooted trees, some of which fell on homes and cars, as well as [siding and roof damage](#) and flattened corn and wheat fields.
- Fred's remnants, as well as a frontal system, produced heavy rain in several locations, including parts of central/western New York, northern Connecticut, and central Pennsylvania which saw between **4 and 8 inches of rain**.
- **Flash flooding** led to impassable roads, flooded basements, stranded vehicles, and water rescues. In addition, a **rare Flash Flood Emergency** was declared for part of Steuben County, NY, where [as many as 100 people were evacuated](#).



Rainfall totals from Fred and a frontal system.

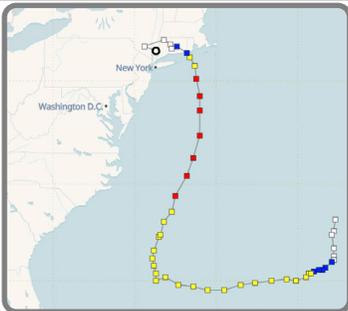


A field flattened by a tornado in Dauphin County, PA. Credit: NWS State College

### Henri

#### Track of Hurricane Henri

Center Location: 41.4 N 73.7 W Maximum Sustained Winds: 30 mph Movement: 6 mph E Sustained Wind Speed: Tropical storm == 34kt/39mph strong tropical storm == 50kt/58mph hurricane == 64kt/74mph

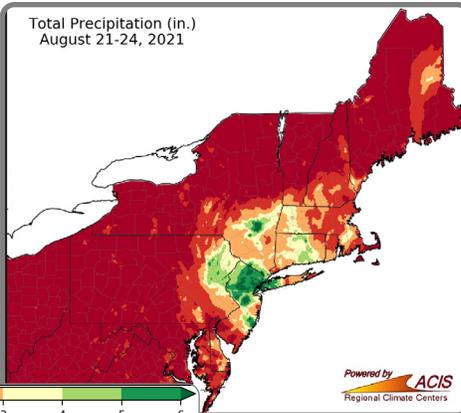
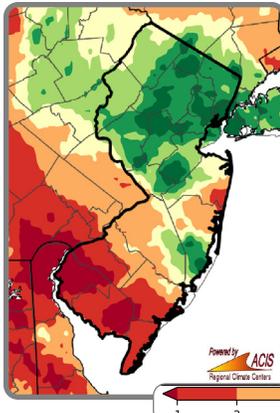


Above: Henri's track. Credit: NWS Binghamton;

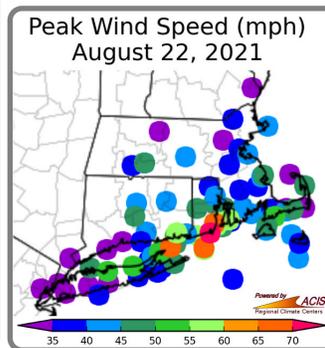
Below: Rainfall totals from Henri.

Henri formed in the Atlantic on August 15 and strengthened into a hurricane off the Mid-Atlantic Coast on August 21. Henri weakened into a tropical storm prior to **making landfall** near Westerly, RI, on **August 22**. It was the first tropical storm or hurricane to make landfall in the state since [Hurricane Bob](#) in August 1991.

- Henri dropped excessive rainfall amounts of **5 to 9 inches** in portions of southeastern New York, New Jersey, and eastern Pennsylvania. In fact, Central Park saw 1.94 inches in an hour and recorded its **wettest two-day period on record for August**, picking up 7.12 inches of rain from August 21 to 22.
- [Multiple locations](#) from eastern Pennsylvania through New Jersey and southeastern New York and into southern New England experienced **flash flooding**, with [storm reports](#) noting flooded basements, closed roads, stranded vehicles, and water rescues. **Significant flash flooding** occurred in [Middlesex and Mercer counties](#) and Newark in New Jersey, with at least 150 residents [rescued or evacuated](#).

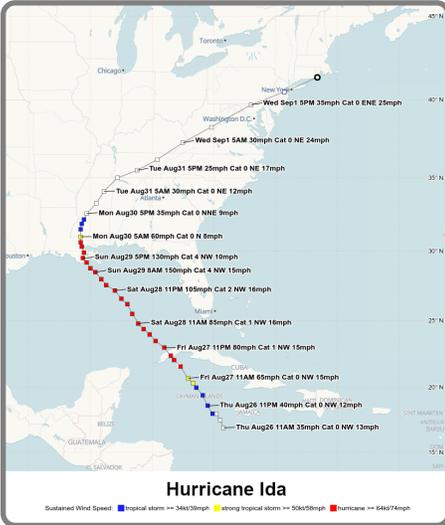


- Henri's **highest wind gusts** reached 70 mph, bringing down trees and power lines and resulting in numerous power outages, particularly in southern New England.



- Henri's remnants spawned **three short-lived EF-0 tornadoes** in Massachusetts, with damage consisting of a few downed trees and branches.

# Ida



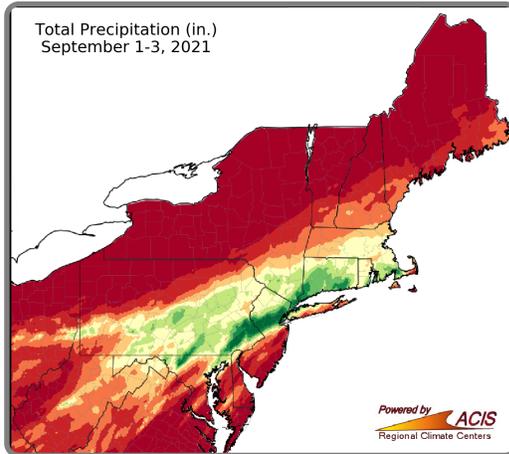
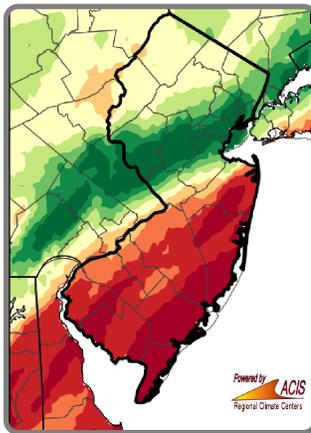
Ida's track. Credit: NWS Binghamton

## Rainfall

Ida formed on August 26 and rapidly intensified into a Category 4 hurricane as it passed over extremely warm waters in the Gulf of Mexico. The major hurricane made landfall in Louisiana on August 29. The storm weakened as it moved inland and was a tropical depression as it trekked across the Northeast on **September 1**. The storm interacted with a stationary front, dropping catastrophic amounts of rain on parts of the region.

- A swath of the Northeast stretching from eastern Pennsylvania and northern/central New Jersey through the New York City metro area and into southern New England saw rainfall totals of more than 6 inches. In fact, a corridor of 8- to 11-inch rainfall totals was found in southeastern Pennsylvania, northern/central New Jersey, and the New York City area.
- Newark, NJ, saw 8.41 inches of rain, making it the site's all-time wettest day on record and on the first day of the month already making September 2021 the site's fourth wettest September on record. LaGuardia Airport, NY, also recorded its all-time wettest day with 6.80 inches of rain. Meanwhile, Bridgeport, CT, which saw 5.77 inches of rain, experienced its wettest September day. Rain fell at a rate of 3 to 5 inches per hour in some locations, with the bulk of the daily rainfall accumulating within a six-hour period in most areas.

### Rainfall totals from Ida.



Station	Sep. 1 Rainfall	Wettest Sep. Day Rank	All-time Wettest Day Rank	Wettest Sep. (month) Rank
Newark, NJ	8.41	1	1	4
Central Park, NY	7.13	2	5	18
LaGuardia Airport, NY	6.80	1	1	9
Harrisburg, PA	6.64	2	3	13
Bridgeport, CT	5.77	1	3	13
Scranton, PA	5.09	2	2	
Allentown, PA	4.15	6		
Baltimore, MD	4.13	8		
Hartford, CT	4.07	7		
Kennedy Airport, NY	2.56	7		

Daily rainfall and rankings for select sites in the Northeast.

## Rainfall from Fred, Henri, and Ida

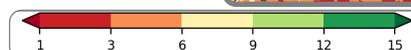
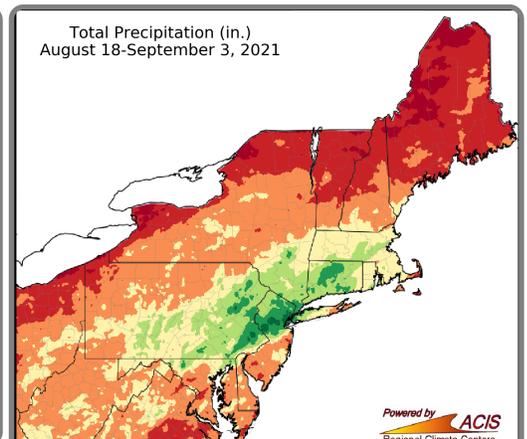
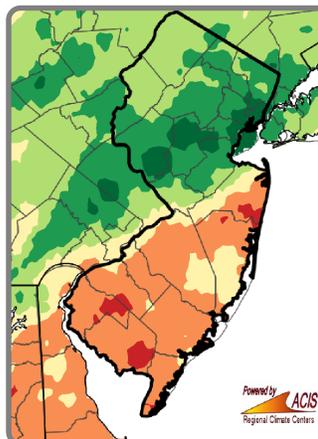
- Rainfall totals from all three storms, Fred, Henri, and Ida, approached 18 inches. For sites such as Central Park, NY, and Harrison, NJ, more than 3 months of rain fell during the 18-day period from August 18 to September 3. In fact, Central Park recorded its all-time wettest two-week period of 16.19 inches of rain from August 19 to September 1, with records back to 1869.

Maximum 14-Day Total Precipitation for New York-Central Park Area, NY (ThreadEx)			
Rank	Value	Ending Date	Missing Days
1	16.19	2021-09-01	0
2	16.09	2021-09-03	0
-	16.09	2021-09-02	0
4	15.46	1882-09-24	0
5	15.44	1882-09-23	0

Period of record: 1869-01-01 to 2021-09-09

The five wettest two-week periods on record at Central Park, NY.

Combined rainfall totals from Fred, Henri, and Ida.



## Rainfall and Climate Change

- An **increase in the frequency of extreme rainfall** is an expected **consequence of global climate change**. Warming temperatures enhance the evaporation of water from the oceans and also increase the capacity for the atmosphere to hold water vapor. When weather systems like hurricanes and fronts convert this vapor to liquid, [more water is available to produce rainfall](#). The Northeast, in particular, has seen [an increase in heavy rainfall](#). Rainfall extremes can be characterized by a specific amount of rainfall, for example 2 inches in a day, or in terms of the largest amount that can be expected to occur on average over some span of years, called a **return period**. An example of this is the 100-year-storm. Such an event is expected to occur on average once in 100 years or more specifically has a 1% chance of occurring in any given year. These rainfall amounts are also characterized by their duration, for instance the 100-year-storm based on the rainfall that occurs over an hour is different from that which occurs over a day. The **rainfall that occurred with Ida exceeded** the rainfall amounts that would be considered **the 100-yr storm** at many locations in Pennsylvania, New Jersey, New York, and Connecticut.
- Hourly rainfall totals were extreme. At Central Park, NY, the 3.15 inches of rain that fell between 9 and 10 pm on September 1 was the **greatest hourly amount recorded in the 132-year history** of the weather station. The 2-hour and 6-hour rainfall amounts of 4.65 inches and 6.63 inches, respectively, were also **record setting**. The site had also seen an impressive 1.94 inches in an hour just a week earlier from Henri.
- Newark also received record rainfall over 1-, 2-, and 6-hour durations. The site's **all-time wettest hour** on record occurred between 8 and 9 pm on September 1, with 3.24 inches of rain. The site's **record-setting** two-hour rainfall total was 5.06 inches, while the record-setting six-hour total was 7.88 inches.
- The amount of rain that fell during 1-, 2-, and 6-hour periods was indeed rare. Both Central Park and Newark saw amounts that **exceeded the 500-year storm**. There is only a 0.2% chance, about the chance of being dealt 4-of-a-kind in a 5-card poker hand, that Newark would see 5.06 inches of rainfall in a 2-hour period during a given year.

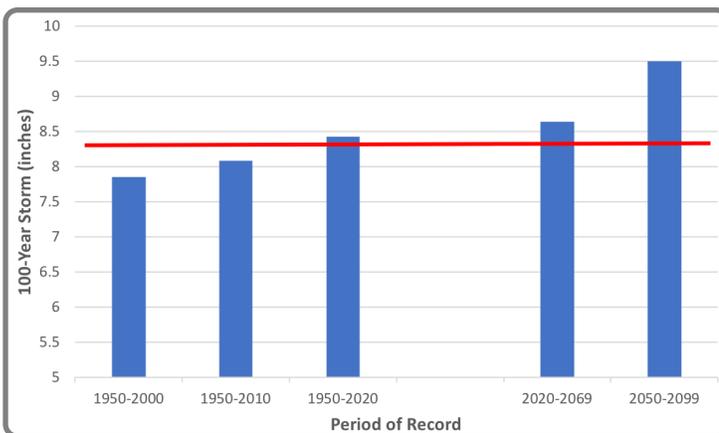
Station	Hourly Period of Record	1-hour Rainfall	2-hour Rainfall	6-hour Rainfall	Daily Period of Record	Daily Rainfall
Central Park, NY	1889-2020	3.15*	4.65*	6.63*	1882-2020	7.13
LaGuardia Airport, NY	1948-2020	2.25		5.87*	1916-2020	6.80*
Newark, NJ	1948-2020	3.24*	5.06*	7.88*	1897-2020	8.41*
Westchester Co. Airport, NY	1948-2020	2.16	3.73	5.59	1944-2020	6.06

\* denotes amount was the greatest for the period of record

Rainfall amounts in association with the remnants of Hurricane Ida. Asterisks denote that the amount was the greatest recorded in the indicated period of record.

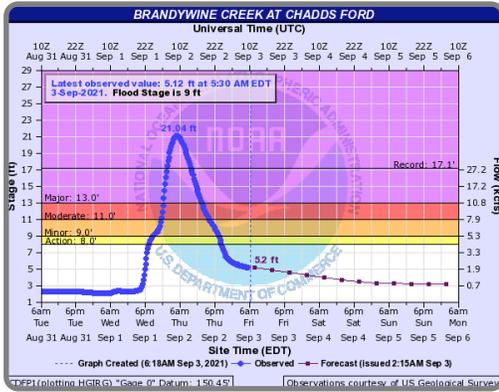
Station	1-hour Return Period	2-hour Return Period	6-hour Return Period	Daily Return Period
Central Park, NY	100+	500+	200+	25-50
LaGuardia Airport, NY	10+		100+	25-50
Newark, NJ	200+	500+	500+	100+
Westchester Co. Airport, NY	25-50	200+	100+	10-25

Estimated return period of the rainfall associated with the remnants of Hurricane Ida.



- The bar chart to the left shows the **rainfall associated with the 100-year storm** at Newark based on different data records. If only data through the year 2000 is considered, the 100-year daily rainfall event is estimated to be 7.85 inches. However, large rainfall events that occurred in 2005, 2006, and 2007 increased the 100-year storm to 8.08 inches when data through 2010 was considered. Two more daily rainfall extremes occurred from 2010–2020, 6.40 inches in 2011 and 5.24 inches in 2014. These increased the 100-year storm to 8.43 inches when the 1950–2020 data record is considered. Thus, the 8.41 inches that fell in Newark on September 1 was very close to that associated with the 100-year storm.

- Climate models** provide information on how extreme rainfall is expected to change in the future. Based on model-simulated rainfall, the **100-year storm** at Newark is **expected to continue to increase**, reaching 8.64 inches during the 2020–2069 future period and growing to 9.50 inches in the 2050–2099 period. By the end of this century, rainfall totals like those associated with Ida can be expected to **occur once about every 50 years as opposed to every 100 years** at Newark.



Record flooding along Brandywine Creek at Chadds Ford, PA. Credit: NOAA

### Water Levels

Many locations had just seen excessive rainfall from tropical systems Fred and Henri within the past two weeks.

- With saturated soils, waterways already running high, and the deluge from Ida, **dozens of streamgages reached major flood stage**, a water level high enough for the possibility of “extensive inundation of structures and roads” and “significant evacuations.”
- Water levels reached **historic levels** at several long-term sites. For example, Brandywine Creek at Chadds Ford, PA, which has records to the early 1900s, reached 21.04 feet, **approaching the operational limit** of the gage and beating the previous record of 17.15 feet from September 17, 1999. Similarly, the [Raritan River at Manville, NJ](#), which also has records back to the early 1900s, reached a **new record high water level** of 27.66 feet.
- Several other long-term sites reached **near-record water levels**. The [Schuylkill River at Philadelphia, PA](#), reached 16.35 feet, its **second highest crest** on record and just below the all-time highest water level of 17.0 feet set on October 4, 1869.

### Flash Flooding

Devastating flooding occurred in multiple locations.

- A **rare Flash Flood Emergency**, issued only when a significant threat to human life and property is happening or imminent, was declared in parts of southeastern Pennsylvania, northern/central New Jersey, and New York City. In fact, the New York National Weather Service office issued a Flash Flood Emergency for the **first time ever**, in [northern New Jersey](#), then declared another for New York City, **the first time** the city has been under such a warning.
- **Hundreds of roads were impassable**, including portions of major highways such as the [Vine Street Expressway](#) through downtown Philadelphia and FDR Drive, a major thoroughfare along the east side of New York City. **Countless vehicles were stranded** and several **people were swept away in rising waters** across the region, including at least three instances of [school buses getting stuck](#). Public transportation around the New York City metro area [ground to a halt](#), stranding thousands. **Floodwaters poured into New York City’s subway system**, with [more than 800 passengers](#) rescued, buses and above-ground trains were stranded, and lower levels of Newark International Airport took on water.
- Some residents were advised to [shelter in place](#). However, in a few areas, there were concerns that dams would be overtopped, resulting in [thousands of people](#) being evacuated. **Numerous structures**, including homes and apartments, were [inundated by floodwaters](#). Between flooded roads and buildings, **hundreds of water rescues were performed**, with the Philadelphia National Weather Service office noting that “crews are running out of resources to rescue people stuck in flood waters.”
- There were **at least 50 deaths** due to Ida in the Northeast, including at least 13 in New York City and at least 30 in New Jersey, making it **one of the state’s deadliest weather events**.
- Early estimates indicated the storm caused **\$117 million in damage in Pennsylvania** and **more than \$50 million in damage in New York**.



Neshaminy Creek at Langhorne, PA. Credit: Middle Atlantic River Forecast Center



Damage from an EF-3 tornado in Mullica Hill, NJ. Credit: NWS Philadelphia

### Tornadoes

Ida also produced **at least 11 tornadoes**, with the most in Pennsylvania.

- The strongest tornado, a **rare EF-3** with winds of up to 150 mph, carved a 12.6-mile [path of destruction](#) through southern New Jersey. The tornado tossed vehicles and caused [significant structural damage](#) to dozens of homes, **leaving some inhabitable**. It also destroyed barns and toppled silos at the state’s largest dairy farm.
- **Three EF-2 tornadoes**, two in southeastern Pennsylvania and one in Annapolis, MD, [damaged buildings and homes](#), tearing off roofs, blowing out exterior walls, and ripping off siding. They also caused considerable tree damage, with **one fatality** when a tree fell on a house. All three tornadoes were on the ground for more than 6 miles.
- In addition, **straight-line winds** of up to 80 mph [caused damage](#) in southeastern Massachusetts.