Warming climate will affect streamflow in the northeast, says study

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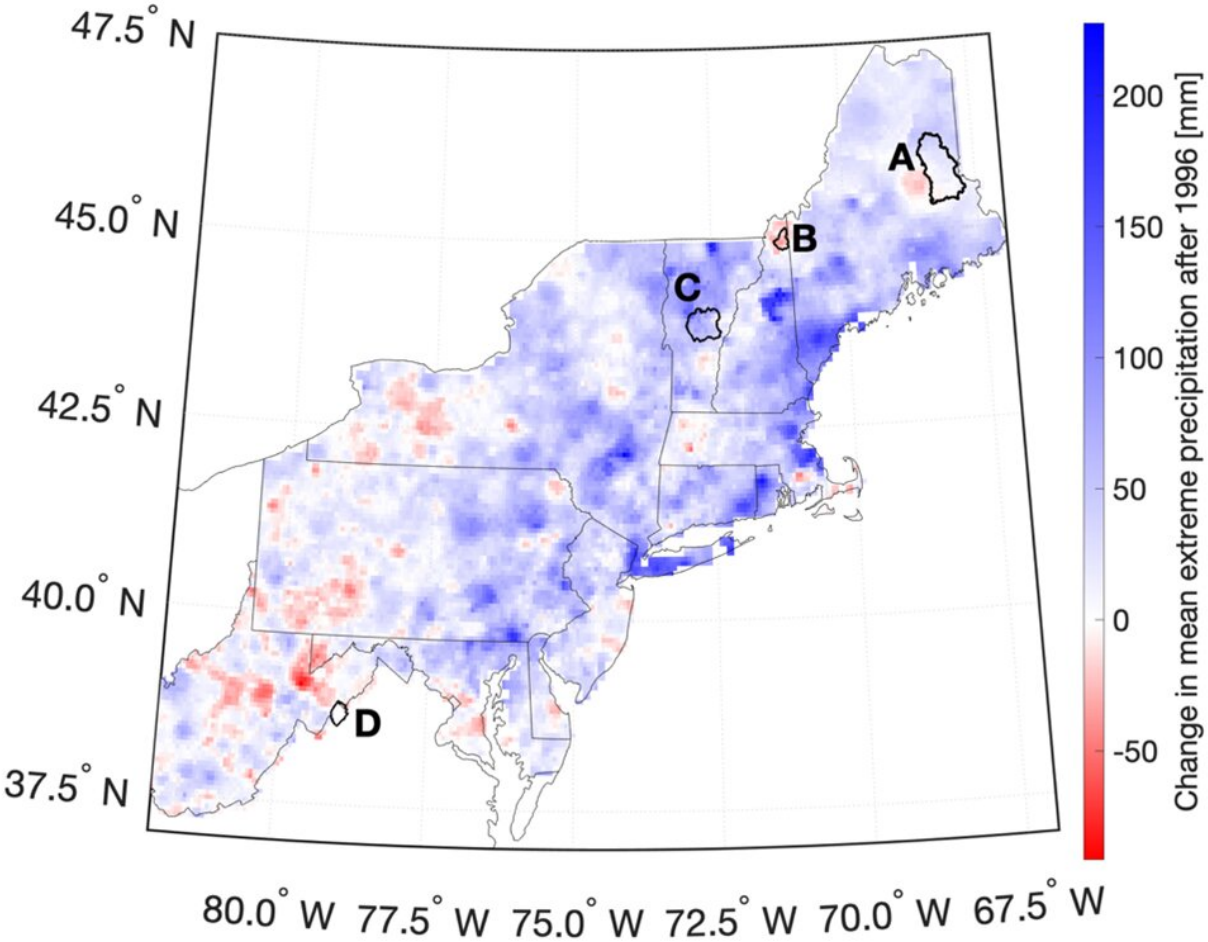

Map showing the average change in annual extreme precipitation 1996-2011 compared to the 1979-1996 average. Watersheds analyzed are outlined in black: (A) Mattawamkeag River in Maine, (B) Dead Diamond River in New Hampshire, (C) White River in Vermont, and (D) Shenandoah River in West

Virginia. Credit: C.Cockburn et al.

Over the past 25 years, the Northeast has experienced the largest increase in extreme precipitation nationally. Prior research has shown that the amount of extreme precipitation— rain or snow that results in one- to two inches of water in a day— over the past 25 years has been almost 50% greater than from 1901 to 1995.

A new Dartmouth study provides insight into how changes in precipitation and temperature due to global warming affect streamflow and flooding in the Northeast. The findings are published in the *Journal of the American Water Resources Association*.

The researchers examined how precipitation, including snowfall, winter rain on snow events, springtime snowmelt, and soil conditions, impact streamflow. They focused on four watersheds in the Northeast: the Mattawamkeag River in northeastern Maine; the Dead Diamond River in northern New Hampshire; the White River in eastern Vermont; and the Shenandoah River in West Virginia.

Streamflow in the three northern watersheds is strongly affected by snowmelt, while the Shenandoah River watershed is affected more by rainfall. All four watersheds were selected because they are unregulated rivers, meaning the streamflow is not controlled by a dam, and span a range of latitudes.

For the first part of the study, the team created a machine learning model from the historical relationships between streamflow and factors that included: temperature; precipitation (rainfall versus snow); the "antecedent precipitation index" or how much moisture is stored in the soil before a storm; the "standardized precipitation index," which is used to characterize wet and dry spells; and streamflow.

They drew on more than 95 years of historical climate data spanning from 1915 to 2011, as well as on streamflow data from the U.S. Geological Survey and snow depth observations from the Northeast Regional Climate Center.

"Both the antecedent precipitation index and the standardized precipitation index are basically measures of how wet the land surface is already, which affects runoff and streamflow," says first author Charlotte Cockburn, Guarini '21, who was a master's student in earth sciences at Dartmouth at the time of the research.

"If you have a really big rainstorm on a relatively dry surface, a lot of that water can be absorbed by the soil, but if you have multiple rainstorms leading up to the really big rainstorm, there's no room in the soil for the water, which creates higher streamflow."

That was what happened in August 2011, when Hurricane Irene, known as Tropical Storm Irene in much of New England, caused devastating flooding, multiple deaths, and billions of dollars in damage, Cockburn notes.

To predict streamflow in the cold season months of November to May, the team used average temperature, three-day and 30-day rainfall, and three-day and 30-day snowfall as variables in their model. They created a sub-model to simulate snowmelt. The model would look at a particular date, for example April 1, 2009, and would then predict streamflow based on the model variables.

"For context, the highest streamflow in Northeast watersheds tends to occur in the spring, actually right around now, when there is snowmelt, larger rainfall events than in the winter, no vegetation to pull water out of the soil, and when the soil is either saturated or frozen," says senior author Jonathan Winter, an associate professor of geography at Dartmouth.

As the researchers explain in the study, one of the conundrums with the model is that it is based on historical data and is trained to rely on snowpack as an important driver for projecting streamflow in the cold season.

So when the model runs into future dates when there will be reduced snowpack due to global warming, it predicts decreases in streamflow. But as Cockburn explains, "The models don't exactly capture the dynamics of winter changes in streamflow because they are trained on the past and in a world that is warmer due to climate change, we expect rain to be a much more important driver of winter streamflow."

For the second part of the study, the team forced the machine learning model with a projection of climate from 2070 to 2099, to see what happens to streamflow in a future climate.

The key findings are:

- Across watersheds and seasons, three-day precipitation and initial soil moisture are the most important variables that determine streamflow in the Northeast.
- Thirty-day snowmelt and 30-day rainfall are important to Mattawamkeag River streamflow because the watershed is both the largest and most northern, making it less sensitive to short extreme precipitation events and more sensitive to snow.
- Future cold season streamflow depends on how New England watersheds respond to the change from more snowfall dominated winters to more rainfall dominated winters.
- Future warm season streamflow depends almost exclusively on

changes in rainfall.

"If the Northeast gets wetter soils and more heavy rainfall events, as climate models predict it will, the Northeast will have increased streamflow and higher flood risk," says Winter.

This past winter the Northeast had below normal snowpack due to temperatures that were more than 4 degrees Fahrenheit warmer than average.

"The winter we just had is what we are going to experience more often in the future. It's a glimpse of what's to come," says Winter. "Our analysis however, surprisingly reveals that in the Northeast, snow matters relatively little in comparison to how sensitive streamflow is to precipitation."

Winter says, "With climate change, understanding how streamflow may change in a warmer and wetter climate is important as these dynamics have implications for flooding, ecosystems, water resources, and hydropower."

More information: Charlotte Cockburn et al, Drivers of future streamflow changes in watersheds across the Northeastern United States, *JAWRA Journal of the American Water Resources Association* (2023). DOI: 10.1111/1752-1688.13120

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