The short-term rain forecast system is broken. Can AI do a better job of predicting deadly floods?

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The floods that killed 20 people in Waverly, Tennessee, and the surrounding area came with little warning.

Meteorologists predicted 2 to 3 inches of rain. But 21 inches fell within the course of that August day in 2021, sweeping away cars, houses, businesses, pets and people, including 7-month-old twins.

"They were not prepared at all. As a result, they could not inform people. Entire neighborhoods washed away," says Puja Das, a fourth-year Ph.D. candidate in interdisciplinary engineering at Northeastern's Sustainability and Data Sciences Lab.

Now Das is working with river managers and forecasters to explore a better way to predict devastating rainstorms with the help of physics-guided generative AI.

Her research, which is funded by a grant from NASA, recently took her and two Northeastern colleagues to flood-prone Tennessee, where they toured dams and met with officials from the Tennessee Valley Authority.

The country's largest public power company, the TVA is also responsible for managing the nation's fifth-largest river system.

"We also had meetings with the River Forecast Center in Knoxville about the models they use and how they decide which forecasts they will use for a particular extreme event," Das says.

"We asked what they needed from us. They said they need better quality forecasts, because their existing High Resolution Rapid Refresh (HRRR) model is not working very well. They're looking for better forecasts for their dam operations and river and flood management," she says.

A broken forecasting model

A physics-based model updated hourly, HRRR was introduced by

NOAA less than 10 years ago, in 2014.

But forecasters and civil officials question whether it can keep up with extreme weather events, which climate scientists and NASA say are growing in intensity and frequency.

Even though HRRR "embeds the best possible physics that we know so far," it often gave "misleading guidance" and failed to predict large precipitation events that cause flash and other dangerous floods," says Auroop Ganguly, Northeastern Distinguished Professor of Civil and Environmental Engineering, principal investigator at the SDS Lab.

"It gave a false sense of complacency," says Ganguly, who is also director of AI4CaS (AI for Climate and Sustainability) focus area within Northeastern's Institute for Experiential AI.

The Waverly flood that occurred nearly on Aug. 21, 2021, is an example, Das says.

"By 7:30 a.m. rain was coming down at a rate of 3 inches per hour. But their model was giving them .25 inches per hour. So they were not concerned at all," she says. "But it kept accumulating."

Video of the flood aired by news stations such as WSMV 4 Nashville show the astonishing rate at which flood waters rose.

The topography of the Tennessee River Valley, which encompasses seven states, puts it at risk of flash flooding and in danger of dams being overtopped, Ganguly says.

Can AI help?

Scientists say climate change in recent years has contributed to

devastating and deadly floods around the world, including deluges in Germany and Pakistan.

The frequency and severity of extreme rain events is lending a sense of urgency to come up with new prediction models. Ganguly says the TVA has dropped HRRR as an operational tool and considers it only as a reference point.

Das' research project, called "Remote-sensing data driven Artificial Intelligence for precipitation-Nowcasting (RAIN)," which she presented at a NASA PI meeting in Huntsville, Alabama earlier this year, is exploring the use of hybrid models incorporating traditional physics and hydrometeorology with information provided by radar and synthetic data generated by AI.

She also plans to evaluate the role of AI and machine learning in developing weather prediction models using data from satellites in collaboration with Kate Duffy and Thomas Vandal, who got their doctoral degrees from Northeastern and worked for NASA before creating a new NASA SBIR funded weather forecasting startup, Zeus AI.

Existing deep learning models such as DGMR from Google's DeepMind and NowcastNet from Tsinghua and Berkeley "claim to outperform traditional physics-based models for some tasks," says August Posch, a data scientist at Northeastern's Seattle campus who is also working with Das on satellite data.

"Now I want to understand (what happens) if we try to use those state-of-the-art models specifically for the Tennessee Valley problem with very short-term precipitation forecasting," Posch says.

"What are their strengths and weaknesses?" he asks.

The RAIN research will evaluate several machine learning models "in this specific context of a dam in the Tennessee Valley that needs to get opened and closed when extreme precipitation happens and then developing metrics that are relevant to the TVA—metrics that might not exist yet," Posch says.

Das visited Tennessee in late September with Posch and fellow doctoral student Ashis Kumar Pal, who is working on a research project on how flooding affects urban metro systems.

Ganguly, who envisions this project informing a marquee research direction at AI4CaS, joined in several of the discussions.

Touring the Norris and Douglas dams and seeing their control centers and sluice gates first hand provided valuable information on how long it takes to open the spillways and perform other flood prevention procedures, she says.

The goal of the RAIN research is to provide valuable tools to dam operators and forecasters, Das says. "We are hopeful it will help us generate better forecasts."

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