

Facial recognition technique could improve hail forecasts

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The shape of a severe storm, such as this one, is an important factor in whether the storm produces hail and how large the hailstones are, but current hail-prediction techniques are typically not able to take the storm's entire structure into account. NCAR scientists are experimenting with a new machine-learning technique that can process images to weigh the impact of storm shape and potentially improve hail forecasts. Credit: ©UCAR. Carlye Calvin

The same artificial intelligence technique typically used in facial recognition systems could help improve prediction of hailstorms and their severity, according to a new study from the National Center for Atmospheric Research (NCAR).

Instead of zeroing in on the features of an individual face, scientists trained a [deep learning model](#) called a convolutional neural network to recognize features of individual storms that affect the formation of hail and how large the hailstones will be, both of which are notoriously difficult to predict.

The promising results, published in the American Meteorological Society's *Monthly Weather Review*, highlight the importance of taking into account a [storm](#)'s entire structure, something that's been challenging to do with existing hail-forecasting techniques.

"We know that the structure of a storm affects whether the storm can produce hail," said NCAR scientist David John Gagne, who led the research team. "A supercell is more likely to produce hail than a squall line, for example. But most hail forecasting methods just look at a small slice of the storm and can't distinguish the broader form and structure."

The research was supported by the National Science Foundation, which is NCAR's sponsor.

"Hail—particularly large hail—can have significant economic impacts on agriculture and property," said Nick Anderson, an NSF program officer. "Using these deep learning tools in unique ways will provide additional insight into the conditions that favor large hail, improving [model predictions](#). This is a creative, and very useful, merger of scientific disciplines."

The shape of storms

Whether or not a storm produces hail hinges on myriad meteorological factors. The air needs to be humid close to the land surface, but dry higher up. The freezing level within the cloud needs to be relatively low to the ground. Strong updrafts that keep the hail aloft long enough to grow larger are essential. Changes in [wind direction](#) and speed at different heights within the storm also seem to play a role

But even when all these criteria are met, the size of the hailstones produced can vary remarkably, depending on the path the hailstones travel through the storm and the conditions along that path. That's where storm structure comes into play.

"The shape of the storm is really important," Gagne said. "In the past we have tended to focus on single points in a storm or vertical profiles, but the horizontal structure is also really important."

Current computer models are limited in what they can look at because of the mathematical complexity it takes to represent the physical properties of an entire storm. Machine learning offers a possible solution because it bypasses the need for a [model](#) that actually solves all the complicated storm physics. Instead, the machine learning neural network is able to ingest large amounts of data, search for patterns, and teach itself which storm features are crucial to key off of to accurately predict hail.

For the new study, Gagne turned to a type of machine learning model designed to analyze visual images. He trained the model using images of simulated storms, along with information about temperature, pressure, wind speed, and direction as inputs and simulations of hail resulting from those conditions as outputs. The weather simulations were created using the NCAR-based Weather Research and Forecasting model (WRF).

The machine learning model then figured out which features of the

storm are correlated with whether or not it hails and how big the hailstones are. After the model was trained and then demonstrated that it could make successful predictions, Gagne took a look to see which aspects of the storm the model's neural network thought were the most important. He used a technique that essentially ran the model backwards to pinpoint the combination of storm characteristics that would need to come together to give the highest probability of severe hail.

In general, the model confirmed those storm features that have previously been linked to hail, Gagne said. For example, storms that have lower-than-average pressure near the surface and higher-than-average pressure near the storm top (a combination that creates strong updrafts) are more likely to produce severe hail. So too are storms with winds blowing from the southeast near the surface and from the west at the top. Storms with a more circular shape are also most likely to produce hail.

Building on random forests, testing with actual storms

This research builds on Gagne's previous work using a different kind of machine learning model—known as a random forest—to improve hail prediction. Instead of analyzing images, random forest models ask a series of questions, much like a flowchart, which are designed to determine the probability of hail. These questions might include whether the dew point, temperatures, or winds are above or below a certain threshold. Each "tree" in the model asks slight variants on the questions to come to an independent answer. Those answers are then averaged over the entire "forest," giving a prediction that's more reliable than any individual tree.

For that research, published in 2017, Gagne used actual storm

observations for the inputs and radar-estimated hail sizes for the outputs to train the model. He found that the model could improve hail prediction by as much as 10%. The machine learning model has now been run operationally during the last several springs to give on-the-ground forecasters access to more information when making hail predictions. Gagne is in the process of verifying how the model did over those few seasons.

The next step for the newer [machine learning](#) model is to also begin testing it using storm observations and radar-estimated hail, with the goal of transitioning this model into operational use as well. Gagne is collaborating with researchers at the University of Oklahoma on this project.

"I think this new method has a lot of promise to help forecasters better predict a weather phenomenon capable of causing severe damage," Gagne said. "We are excited to continue testing and refining the model with observations of real storms."

More information: David John Gagne II et al, Interpretable Deep Learning for Spatial Analysis of Severe Hailstorms, *Monthly Weather Review* (2019). [DOI: 10.1175/MWR-D-18-0316.1](https://doi.org/10.1175/MWR-D-18-0316.1)

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