Combining AI and Analog Forecasting to Predict Extreme Weather

New deep learning technique brings an obsolete forecasting method "back to life" to predict extreme weather events.

Credit: Unsplash/Aaron Burden

By Richard J. Sima 4 March 2020

The future of extreme weather prediction may lie in modernizing a piece of technology from the past. Researchers recently developed a new technique to augment an old-fashioned weather forecasting method with the power of deep learning, a subset of artificial intelligence (AI). Once the deep learning system is fully trained, it is able to predict extreme weather events like heat waves and cold spells with ~80% accuracy up to 5 days beforehand.

"This is a very inexpensive way of predicting extreme events at least a few days ahead of time," said Ashesh Chattopadhyay (https://github.com/ashesh6810), a mechanical engineering graduate student at Rice University in Houston and lead author on the project.

The project began when Pedram Hassanzadeh (https://mech.rice.edu/users/pedram), an assistant professor of mechanical engineering at Rice, realized that extreme weather events like heat waves and cold spells usually arise from very unusual atmospheric circulation patterns that could potentially be taught to a pattern recognition computer program.

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"And then we realized that this was how weather prediction used to be done," said Hassanzadeh, who was the senior author on the study recently published in the *Journal of Advances in Modeling Earth Systems* (https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019MS001958).

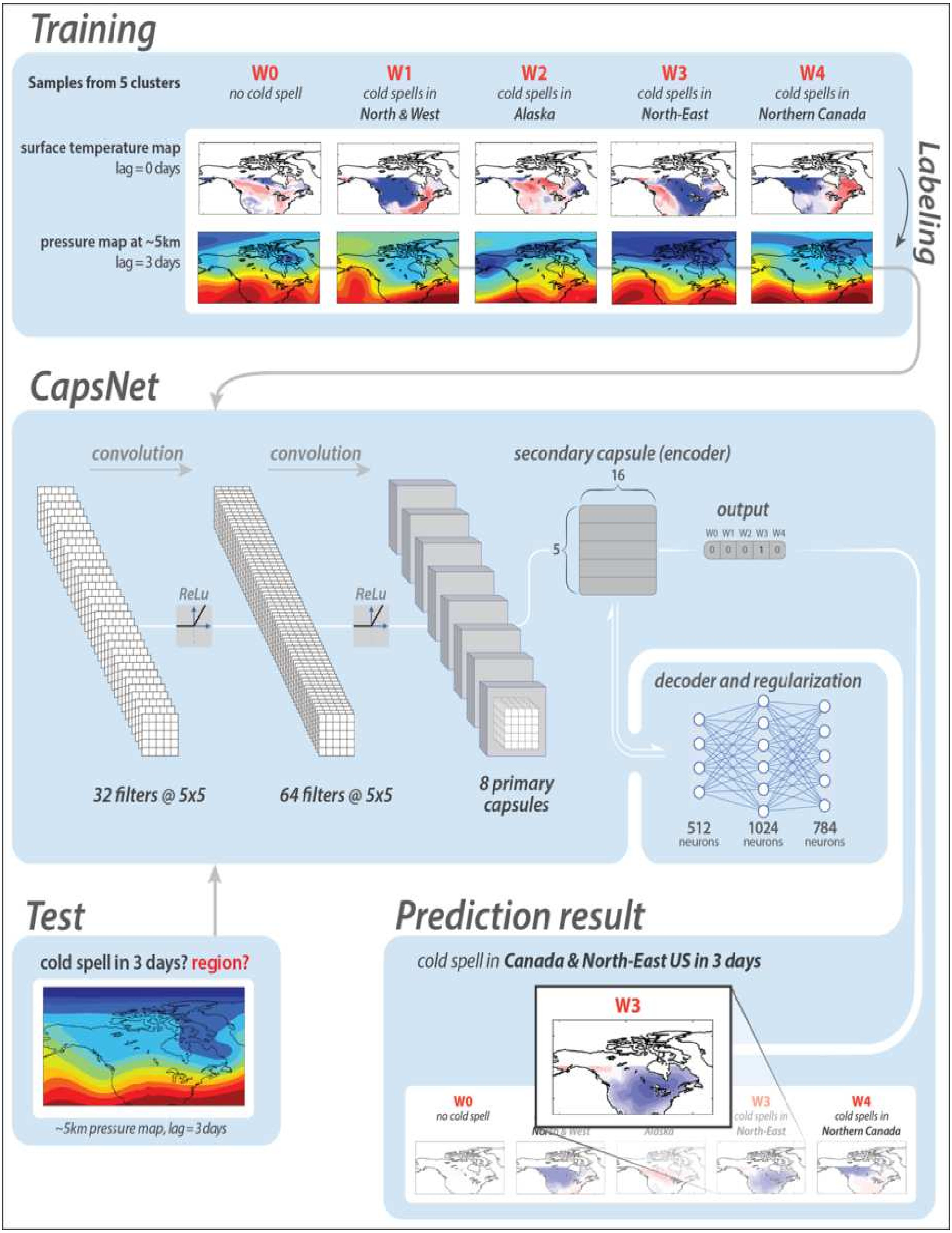
Analog forecasting, as the technique is called, operates on the straightforward principle of making predictions by comparing current weather patterns to similar patterns (or analogs) from the past. Historically, it had a key role in weather prediction (in fact, it was crucial for planning the D-Day Normandy invasion of 1944 (https://books.google.com/books?id=yPdABAAAQBAJ&printsec=frontcover#v=onepage&q&f=false)) but is hindered by challenges in finding enough useful analogs from past weather catalogs. With the rise of computer-based numerical weather prediction (NWP) in the 1950s, analog forecasting was rendered nigh obsolete.

Today, NWP is the gold standard used for day-to-day weather prediction. However, it is computationally expensive and has not been completely reliable in predicting extreme weather events. By contrast, the new method of combining AI deep learning with analog forecasting is relatively inexpensive. "While weather models need to be run on supercomputers, you can run this pretty much on a computer, like even my laptop," said Chattopadhyay.

Analog Forecasting in the Age of AI

The researchers trained a novel deep learning pattern recognition program called capsule neural networks (or CapsNets) to identify patterns of atmospheric circulation in the days leading up to an extreme weather event in North America, either a heat wave or a cold spell. To do this, the researchers first used a different "unsupervised" computer algorithm to identify four different regions, or clusters, within North America where extreme weather events could occur, plus a cluster for no extreme weather. CapsNet was then trained with a data set of hundreds of maps depicting atmospheric circulation patterns paired with the subsequent extreme weather event clusters occurring days later. CapsNet was able to teach itself to predict whether a particular circulation pattern would lead to an extreme weather event and which of the four geographic regions it would occur in.

When CapsNet was trained using temperature information in addition to atmospheric circulation patterns, its accuracy for predicting extreme weather in winter was from 82% 1 day in advance to 76.7% 5 days in advance. In summer, its accuracy was 79.3% 1 day in advance and 75.8% with 5 days' lead-up.



(https://eos.org/wp-content/uploads/2020/02/weather-ML-training.png)

This schematic depicts the data-driven framework for prediction of cold spells based on large-scale circulation patterns of 3 days earlier. Only the patterns and their labels are inputted into the capsule neural network (CapsNet) during training. For the shown test example, a cold spell in cluster W3 in 3 days is predicted. Credit: Chattopadhyay et al., 2020, https://doi.org/10.1029/2019MS001958 (https://doi.org/10.1029/2019MS001958), CC BY 4.0 (https://creativecommons.org/licenses/by/4.0/legalcode)

CapsNet was more accurate in its predictions compared to the more commonly known convolutional neural network (CNN), a class of deep learning that many scientists in the environment and weather research community are trying to use, Hassanzadeh said. CNNs run into what's called a "Picasso problem": They can robustly detect features within an image (e.g., the eyes and nose) but not their relative positions or orientations (e.g., the networks do not "care" where those eyes and nose are located on a face). CapsNet, on the other hand, tracks those relative positions and orientation information, which may be key for more accurate predictions.

"It brings analog forecasting back to life, but using deep learning."
"One point of our paper is that capsule neural networks (CapsNets) are much better tools for our problems," said Hassanzadeh.

In addition, the researchers found that CapsNets did not require as much data for training; feeding it fewer samples did not decrease its prediction accuracy like it did for the convolutional neural network. CapsNets could thus potentially address difficulties in obtaining enough high-quality data to effectively use deep learning.

"This paper brings analog forecasting back to life, but using deep learning," said Redouane Lguensat (https://redouanelg.github.io/), a postdoctoral researcher at the University of Grenoble's Institute of Environmental Geosciences in France. Lguensat, who was not involved in the study, worked on analog forecasting for his graduate research but "in the classical way" without deep learning algorithms. To his knowledge, this study is the first time that CapsNets have been applied to weather-related problems like forecasting.

Augmenting Current Weather Prediction

Though this study was a proof of concept, the overarching goal is to augment (but not replace) current numerical weather prediction systems by giving early warnings about which regions may have extreme weather events in the future, said Chattopadhyay. "Next, we want to go beyond 5 days to 10 days, 15 days, maybe a month, possibly subseasonal scales."

Hassanzadeh is optimistic about the potential for deep learning programs to help scientists understand what features and mechanisms in atmospheric dynamics lead to extreme weather events in the first place. He also hopes this work encourages people from the computer science community, from the atmosphere dynamics community, and from the weather forecasting community to work more closely together.

"I think this is an interesting area for the application of deep learning," he said.

—Richard J. Sima (@richardsima (https://twitter.com/richardsima)), Science Writer

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