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DeepMind AI accurately forecasts weather — on a desktop computer

The machine-learning model takes less than a minute to predict future weather worldwide more precisely than other approaches.

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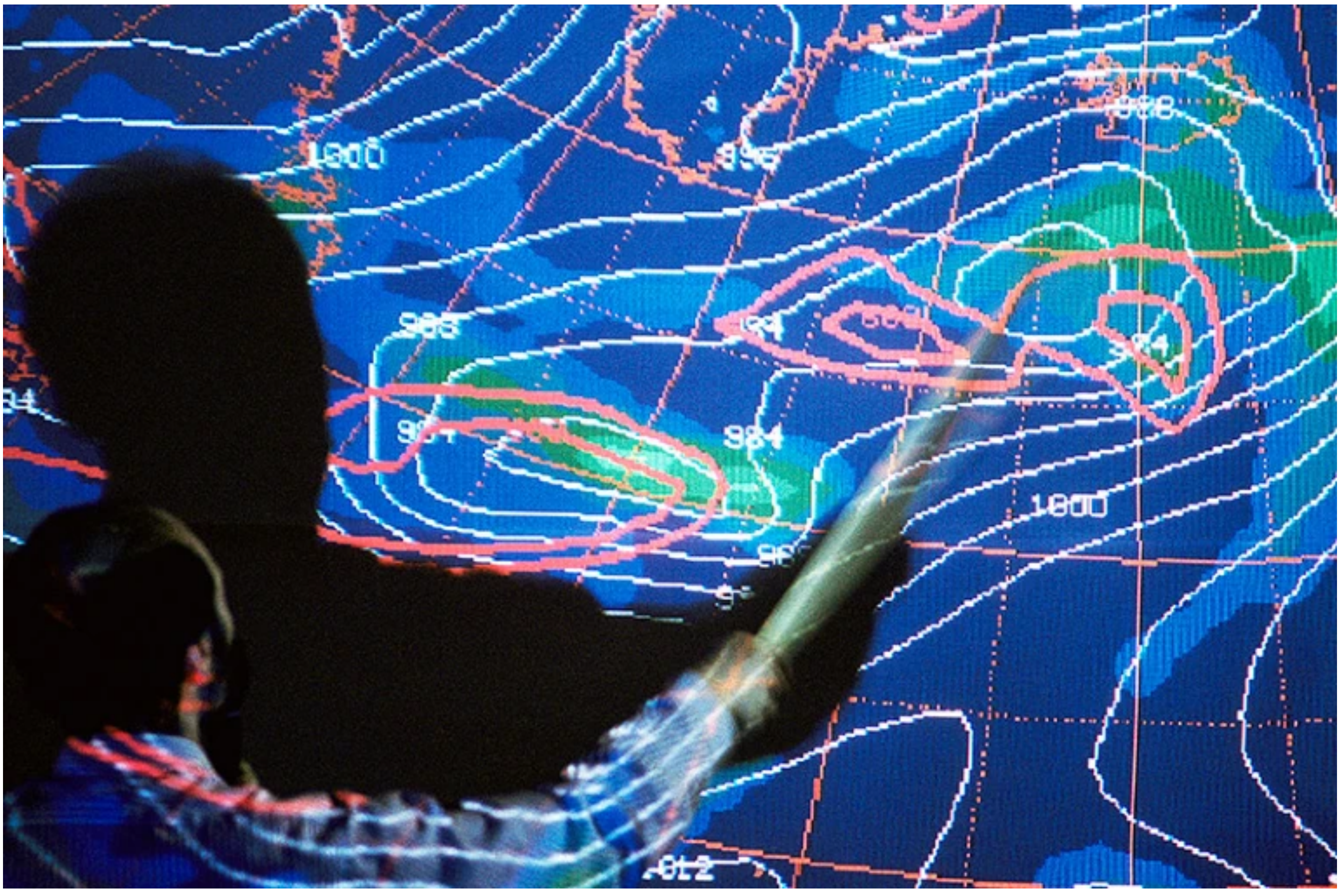

Conventional weather forecasts are the result of intensive processing of data from weather stations around the world. Credit: Carlos Munoz Yague/Look At Science/Science Photo

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Artificial intelligence (AI) firm Google DeepMind has turned its hand to the intensive science of weather forecasting — and developed a machine-learning model that outperforms the best conventional tools, as well as other AI approaches, at the task.

The model, called GraphCast, can run on a desktop computer, and its predictions are more accurate than those of conventional models — and it makes them in minutes, rather than hours.

“GraphCast currently is leading the race amongst the AI models,” says computer scientist Aditya Grover at the University of California, Los Angeles. The model was described[1] in *Science* on 14 November.

Predicting the weather is a complex and energy-intensive task. The standard approach is numerical weather prediction (NWP), which uses mathematical models based on physical principles. These tools, known as physical models, are run on supercomputers and crunch weather data from buoys, satellites and weather stations worldwide. The calculations accurately map how heat, air and water vapour move through the atmosphere, but they are expensive to run.

Forecast revolution

To reduce the financial and energy costs of forecasting, several technology companies have developed machine-learning models that rapidly predict the future state of global weather from past and current weather data. Among them are DeepMind, computer-chip-maker Nvidia and Chinese tech firm Huawei, alongside a slew of start-up companies such as Atmo, based in Berkeley, California. Of these, Huawei’s Pangu-weather model is the strongest rival to the gold-standard NWP system at the European Centre for Medium-Range Weather Forecasts (ECMWF) in Reading, UK, which provides world-leading weather predictions up to 15 days in advance.

Machine learning is spurring a revolution in weather forecasting, says Matthew Chantry, a machine-learning coordinator at the ECMWF. AI models run 1,000–10,000 times faster than conventional NWP models, giving scientists more time to interpret and communicate the predictions, says data-visualization researcher Jacob Radford at the Cooperative Institute for Research in the Atmosphere in Fort Collins, Colorado.

GraphCast outperforms conventional and AI-based approaches at most global-weather-forecasting tasks. Researchers first trained the model using estimates of past global weather made from 1979 to 2017 by physical models. This allowed GraphCast to learn links between weather variables such as air pressure, wind, temperature and humidity.

The trained model uses the 'current' state of global weather and weather estimates from 6 hours earlier to predict the weather 6 hours ahead. Earlier predictions are fed back into the model, enabling it to make estimates further into the future. DeepMind researchers found that GraphCast could use global weather estimates from 2018 to make forecasts up to ten days ahead in less than a minute, and the predictions were more accurate than were those of the ECMWF's high-resolution forecasting system (HRES) — one version of its NWP — which takes hours to forecast.

Severe weather

"In the troposphere, which is the part of the atmosphere closest to the surface that affects us all the most, GraphCast outperforms HRES on more than 99% of the 12,000 measurements that we've done," says computer scientist Rémi Lam at DeepMind in London. Across all levels of the atmosphere, the model outperformed HRES on 90% of weather predictions.

GraphCast predicted the state of five weather variables close to Earth's surface, such as the air temperature 2 metres above the ground, and six atmospheric variables, such as wind speed, further from Earth's surface.

It also proved useful in predicting severe weather events, such as the paths taken by tropical cyclones, and extreme heat and cold episodes, says Chantry.

When they compared the forecasting ability of GraphCast with that of Pangu-weather, the DeepMind researchers found that their model beat 99% of weather predictions that had been described in a previous Huawei study.

Chantry notes that although GraphCast's performance was superior to that of other models in this study, based on its evaluation by certain metrics, future assessments using other metrics could lead to slightly different results.

Training data

Rather than replacing conventional approaches entirely, machine-learning models, which are still experimental, could boost particular types of weather prediction that standard approaches aren't good at, says Chantry — such as forecasting rainfall that will hit the ground within a few hours.

"And standard physical models are still needed to provide the estimates of global weather that are initially used to train machine-learning models," says Chantry. "I anticipate it will be another two to five years before people can use forecasting from machine-learning approaches to make decisions in the real world," he adds.

In the meantime, problems with machine-learning approaches must be ironed out. Unlike with NWP models, researchers cannot fully understand how AI tools such as GraphCast work because the decision-making processes happen in the AI's 'black box', says Grover. "This calls into question their reliability," he says.

AI models also run the risk of amplifying biases in their training data and require a lot of energy for training, although they consume less than NWP models, says Grover.

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References

1. Lam, R. *et al. Science* https://doi.org/10.1126/science.adi2336 (2023).

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