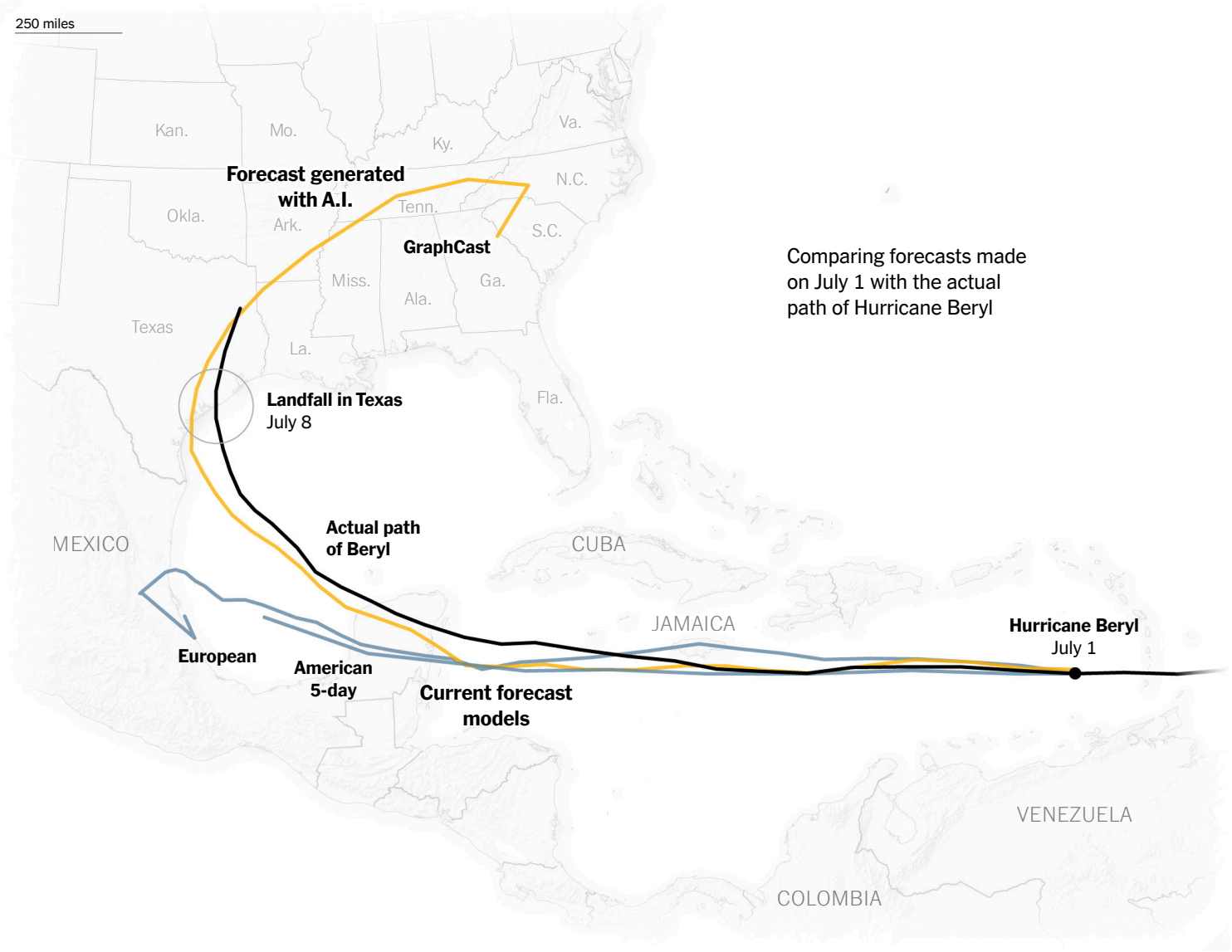
Artificial Intelligence Gives Weather Forecasters a New Edge

The brainy machines are predicting global weather patterns with new speed and precision, doing in minutes and seconds what once took hours.

By William J. Broad July 29, 2024

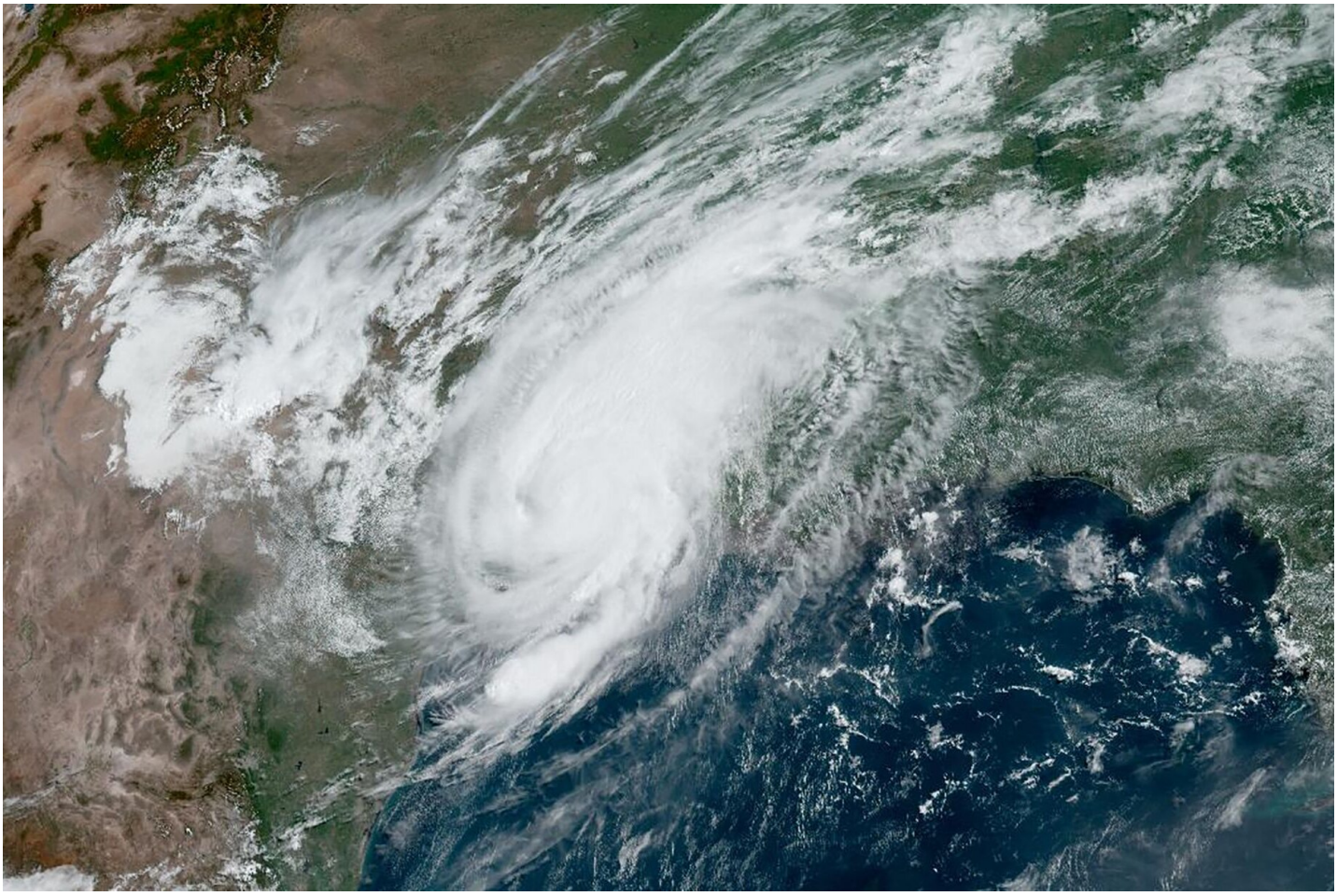


The National Hurricane Center (American) 5-day, ECMWF (European), and GraphCast models from July 1, 2024 at 8 p.m. Eastern. All times on the map are Eastern. • By William B. Davis

In early July, as Hurricane Beryl churned through the Caribbean, a top European weather agency predicted a range of final landfalls, warning that Mexico was most likely. The alert was based on global observations by planes, buoys and spacecraft, which room-size supercomputers then turned into forecasts.

That same day, experts running artificial intelligence software on a much smaller computer predicted landfall in Texas. The forecast drew on nothing more than what the machine had previously learned about the planet's atmosphere.

Four days later, on July 8, Hurricane Beryl slammed into Texas with deadly force, flooding roads, killing at least 36 people and knocking out power for millions of residents. In Houston, the violent winds sent trees slamming into homes, crushing at least two of the victims to death.



A composite satellite image of Hurricane Beryl approaching the Texas coast on July 8. NOAA, via European Press Agency, via Shutterstock

The Texas prediction offers a glimpse into the emerging world of A.I. weather forecasting, in which a growing number of smart machines are anticipating future global weather patterns with new speed and accuracy. In this case, the experimental program was GraphCast, created in London by DeepMind, a Google company. It does in minutes and seconds what once took hours.

"This is a really exciting step," said Matthew Chantry, an A.I. specialist at the European Center for Medium-Range Weather Forecasts, the agency that got upstaged on its Beryl forecast. On

average, he added, GraphCast and its smart cousins can outperform his agency in predicting hurricane paths.

In general, superfast A.I. can shine at spotting dangers to come, said Christopher S. Bretherton, an emeritus professor of atmospheric sciences at the University of Washington. For treacherous heats, winds and downpours, he said, the usual warnings will be "more up-to-date than right now," saving untold lives.

Rapid A.I. weather forecasts will also aid scientific discovery, said Amy McGovern, a professor of meteorology and computer science at the University of Oklahoma who directs an A.I. weather institute. She said weather sleuths now use A.I. to create thousands of subtle forecast variations that let them find unexpected factors that can drive such extreme events as tornadoes.

"It's letting us look for fundamental processes," Dr. McGovern said. "It's a valuable tool to discover new things."

Importantly, the A.I. models can run on desktop computers, making the technology much easier to adopt than the room-size supercomputers that now rule the world of global forecasting.

Abandoned vehicles under an overpass in Sugar Land, Texas, on July 8. Brandon Bell/Getty Images

“It’s a turning point,” said Maria Molina, a research meteorologist at the University of Maryland who studies A.I. programs for extreme-event prediction. “You don’t need a supercomputer to generate a forecast. You can do it on your laptop, which makes the science more accessible.”

People depend on accurate weather forecasts to make decisions about such things as how to dress, where to travel and whether to flee a violent storm.

Even so, reliable weather forecasts turn out to be extraordinarily hard to achieve. The trouble is complexity. Astronomers can predict the paths of the solar system’s planets for centuries to come because a single factor dominates their movements — the sun and its immense gravitational pull.

In contrast, the weather patterns on Earth arise from a riot of factors. The tilts, the spins, the wobbles and the day-night cycles of the planet turn the atmosphere into turbulent whorls of winds, rains, clouds, temperatures and air pressures. Worse, the atmosphere is inherently chaotic. On its own, with no external stimulus, a particular zone can go quickly from stable to capricious.

As a result, weather forecasts can fail after a few days, and sometimes after a few hours. The errors grow in step with the length of the prediction — which today can extend for 10 days, up from three days a few decades ago. The slow improvements stem from upgrades to the global observations as well as the supercomputers that make the predictions.

Not that supercomputing work has grown easy. The preparations take skill and toil. Modelers build a virtual planet crisscrossed by millions of data voids and fill the empty spaces with current weather observations.

Dr. Bretherton of the University of Washington called these inputs crucial and somewhat improvisational. "You have to blend data from many sources into a guess at what the atmosphere is doing right now," he said.

The knotty equations of fluid mechanics then turn the blended observations into predictions. Despite the enormous power of supercomputers, the number crunching can take an hour or more. And of course, as the weather changes, the forecasts must be updated.

The A.I. approach is radically different. Instead of relying on current readings and millions of calculations, an A.I. agent draws on what it has learned about the cause-and-effect relationships that govern the planet's weather.

In general, the advance derives from the ongoing revolution in machine learning — the branch of A.I. that mimics how humans learn. The method works with great success because A.I. excels at pattern recognition. It can rapidly sort through mountains of

information and spot intricacies that humans cannot discern. Doing so has led to breakthroughs in speech recognition, drug discovery, computer vision and cancer detection.

In weather forecasting, A.I. learns about atmospheric forces by scanning repositories of real-world observations. It then identifies the subtle patterns and uses that knowledge to predict the weather, doing so with remarkable speed and accuracy.

Recently, the DeepMind team that built GraphCast won Britain's top engineering prize, presented by the Royal Academy of Engineering. Sir Richard Friend, a physicist at Cambridge University who led the judging panel, praised the team for what he called "a revolutionary advance."

In an interview, Rémi Lam, GraphCast's lead scientist, said his team had trained the A.I. program on four decades of global weather observations compiled by the European forecasting center. "It learns directly from historical data," he said. In seconds, he added, GraphCast can produce a 10-day forecast that would take a supercomputer more than an hour.

Dr. Lam said GraphCast ran best and fastest on computers designed for A.I., but could also work on desktops and even laptops, though more slowly.

In a series of tests, Dr. Lam reported, GraphCast outperformed the best forecasting model of the European Center for Medium-Range Weather Forecasts more than 90 percent of the time. "If you know where a cyclone is going, that's quite important," he added. "It's important for saving lives."

A damaged home in Freeport, Texas, in the hurricane's aftermath. Brandon Bell/Getty Images

Replying to a question, Dr. Lam said he and his team were computer scientists, not cyclone experts, and had not evaluated how GraphCast's predictions for Hurricane Beryl compared to other forecasts in precision.

But DeepMind, he added, did conduct a study of Hurricane Lee, an Atlantic storm that in September was seen as possibly threatening New England or, farther east, Canada. Dr. Lam said the study found that GraphCast locked in on landfall in Nova Scotia three days before the supercomputers reached the same conclusion.

Impressed by such accomplishments, the European center recently embraced GraphCast as well as A.I. forecasting programs made by Nvidia, Huawei and Fudan University in China. On its website, it now displays global maps of its A.I. testing, including the range of path forecasts that the smart machines made for Hurricane Beryl on July 4.

The track predicted by DeepMind's GraphCast, labeled DMGC on the July 4 map, shows Beryl making landfall in the region of Corpus Christi, Texas, not far from where the hurricane actually hit.

Dr. Chantry of the European center said the institution saw the experimental technology as becoming a regular part of global weather forecasting, including for cyclones. A new team, he added, is now building on “the great work” of the experimentalists to create an operational A.I. system for the agency.

Its adoption, Dr. Chantry said, could happen soon. He added, however, that the A.I. technology as a regular tool might coexist with the center’s legacy forecasting system.

Dr. Bretherton, now a team leader at the Allen Institute for A.I. (established by Paul G. Allen, one of the founders of Microsoft), said the European center was considered the world’s top weather agency because comparative tests have regularly shown its forecasts to exceed all others in accuracy. As a result, he added, its interest in A.I. has the world of meteorologists “looking at this and saying, ‘Hey, we’ve got to match this.’”

Weather experts say the A.I. systems are likely to complement the supercomputer approach because each method has its own particular strengths.

“All models are wrong to some extent,” Dr. Molina of the University of Maryland said. The A.I. machines, she added, “might get the hurricane track right but what about rain, maximum winds and storm surge? There’re so many diverse impacts” that need to be forecast reliably and assessed carefully.

Even so, Dr. Molina noted that A.I. scientists were rushing to post papers that demonstrate new forecasting skills. “The revolution is continuing,” she said. “It’s wild.”

Jamie Rhome, deputy director of the National Hurricane Center in Miami, agreed on the need for multiple tools. He called A.I. “evolutionary rather than revolutionary” and predicted that humans and supercomputers would continue to play major roles.

“Having a human at the table to apply situational awareness is one of the reasons we have such good accuracy,” he said.

Mr. Rhome added that the hurricane center had used aspects of artificial intelligence in its forecasts for more than a decade, and that the agency would evaluate and possibly draw on the brainy new programs.

“With A.I. coming on so quickly, many people see the human role as diminishing,” Mr. Rhome added. “But our forecasters are making big contributions. There’s still very much a strong human role.”

Sources and notes

The National Hurricane Center (NHC) and European Centre for Medium-Range Weather Forecasts (ECMWF) | Notes: The “actual path” of Beryl uses the NHC’s preliminary best track data.