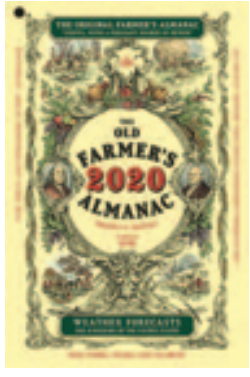
FERTILE FORECASTS

New technology is giving farmers better information to predict – and adapt to – the weather

By Matt Alderton

Human beings are obsessed with weather. They talk about it with restaurant servers and Uber drivers. They discuss it on the phone with loved ones, colleagues and customer service reps. They bring it up with neighbors on street corners and strangers at sporting events. They talk about it so much that the average person will spend 4 1/2 months of his or her life engaged in weather-related discourse, according to a 2018 study by England's Bristol Airport, which found that the typical person converses about the weather an average of three times per day.



What is small talk for most, however, is elemental for farmers, whose livelihoods hinge on accurate weather forecasts that help them decide the optimal times to plant, irrigate, fertilize and harvest. "Weather is important to everyone. But for farmers, reliable weather information is their lifeblood," said Janice Stillman, editor of *The Old Farmer's Almanac*, which has been providing long-range weather forecasts since 1792. "Whether you're a backyard gardener, a small grower or an industrial farmer, you benefit from having some idea of what the weather's going to be."

The Old Farmer's Almanac — North America's oldest continuously published periodical — uses a secret formula created by founding editor Robert B. Thomas, who based his methodology primarily on solar science.

"Historically, when the sun is very active, temperatures on Earth have been higher. And when the sun is quiet, temperatures on Earth have been lower," explained Stillman, who claims the *Almanac* has an 80 percent accuracy rate. "Right now, we're in ... one of the quietest solar cycles in history."

That means temperatures should be falling. Instead, they're rising, observed Stillman, who said the *Almanac* has had to recalibrate its calculations to account for climate change. "Human activities like heat island effect and greenhouse gas emissions have introduced a certain amount of chaos into the atmosphere," she remarked.

Although not everyone believes in the *Almanac*'s techniques, the chaos of which Stillman speaks is real. Faced with growing climate instability and increased weather variability, farmers need more and better daily forecasts on which to base vital decisions. A new generation of technology is poised to provide them.

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THE OLD FARMER'S ALMANAC; GETTY IMAGES


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INTELLIGENT AGRICULTURE

Third-generation farmer Roric Paulman of Sutherland, Neb., has seen firsthand the evolution of weather forecasting. When he began farming in 1985, the most accurate weather report he had — a three-day forecast published in the local newspaper — was based on data from a single weather station 40 miles away.

"It was a shot in the dark, but it was the best we had," said Paulman, owner of Paulman Farms, which grows corn, soybeans, sunflowers, chickpeas, lentils and other crops.

Today, Paulman receives field-level forecasts with 15-day outlooks that are continuously updated based on near-real-time data.

IBM subsidiary The Weather Company captures, consolidates and conveys that data for him using its Watson Decision Platform for Agriculture, a technology solution that integrates weather information with farm-based data — imagery from drones, for example, and readings from soil sensors — then uses artificial intelligence (AI) and machine learning to extract actionable insights.

"The average farmer in the United States is collecting 500,000 data points every day about their farm," said Cameron Clayton, CEO of The Weather Company and general manager of IBM Watson Media and Weather. "We can't make sense of all that data without help. That's where machine learning and artificial intelligence comes in. It's ingesting all that data, synthesizing it and making recommendations to farmers to help them make better decisions."

Consider Paulman, for instance, whose 10,000 acres generate 1 terabyte of data every month. Because he farms in a highly restricted water basin, irrigation and water stewardship are major concerns. To ensure his fields receive the moisture they need without depleting precious resources, he must simultaneously monitor precipitation in the sky and in the soil. By cross-referencing a hyperlocal weather forecast with real-time soil conditions, the Watson Decision Platform for Agriculture helps him determine whether he needs to irrigate, when and how much.

"Weather is front and center. Because if it rains, you don't have to irrigate," said Paulman, who added that unnecessary irrigation wastes not only water, but also money. "Priority No. 1 is stewardship of natural resources. But when we save resources, we also save energy, and that trickles down to the bottom line."

PROMISING PREDICTIONS

Technology hasn't just made weather forecasts more accessible and more actionable. It's also made them better.

"We've improved our forecast skill greatly over the last three decades," said meteorologist Ray Wolf, science and operations officer at the National Weather Service (NWS) in Davenport, Iowa.

Wolf said modern-day meteorologists can

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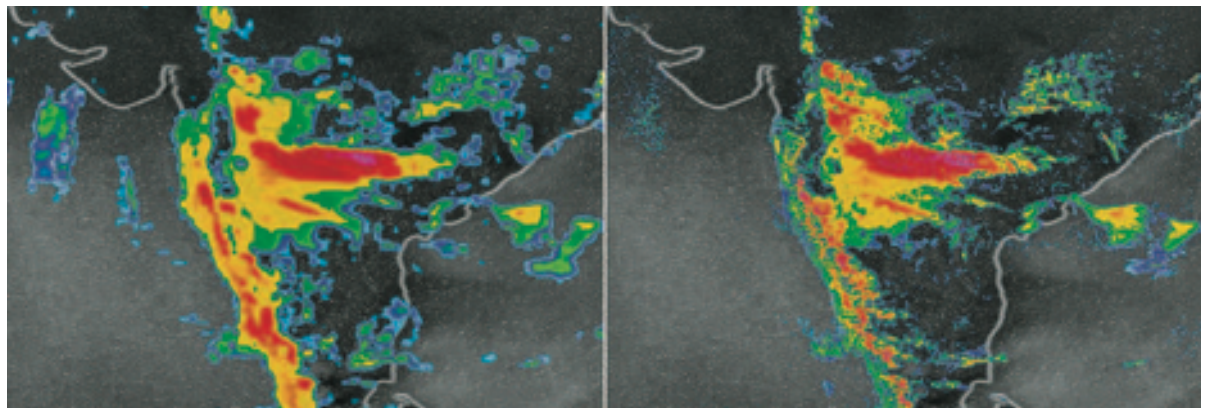
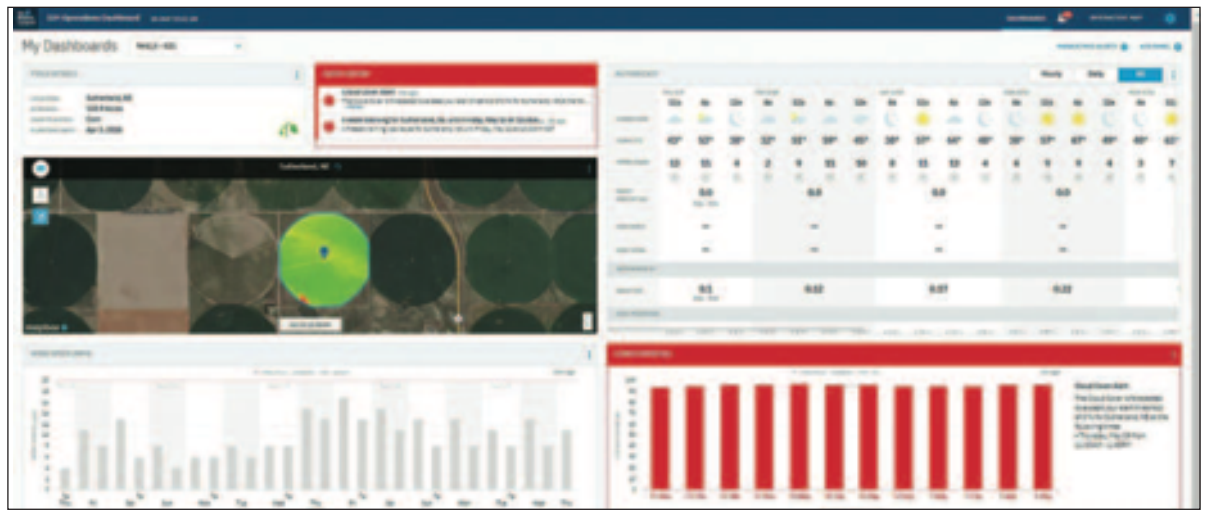


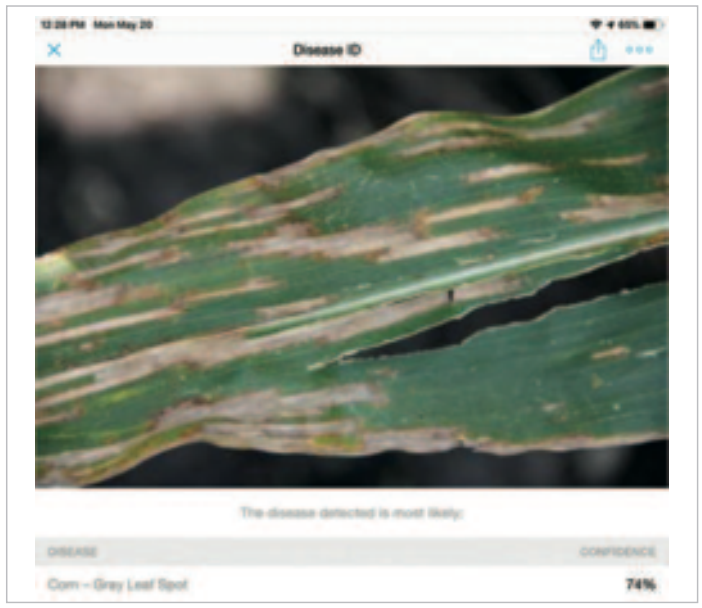
▲ **ADVANCED MODELING** **A 2018 monsoon in India is shown at left by current weather modeling with 13-kilometer resolution. On the right, the new IBM GRAF modeling operates at a more precise 3-kilometer resolution and updates six to 12 times more frequently than current global models.**



▲ **WEATHER DATA** **The Operations Dashboard within IBM Decision Platform for Agriculture shows crop health analysis, detailed weather data and weather-based threshold alerts for specific areas.**

▶ **DISEASE IDENTIFICATION**

The Operations Dashboard also aids farmers with crop disease identification. Farmers can upload a photo of the affected plants and the software analyzes the image and delivers a diagnosis.



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predict weather earlier and more accurately, thanks to a massive increase in weather observations, including surface observations from automated weather stations and volunteer weather observers, as well as aerial observations from NWS' Next Generation Weather Radar (NEXRAD), a national network of advanced Doppler radars that can detect wind, tornadoes, rainfall and hail.

"All of our forecasts start with observed weather data, and our observing systems are much better than they used to be," continued Wolf, who said forecasts are created using sophisticated computer models; when the models ingest better data, they generate better forecasts.

Next to radar, the most transformative data source for weather models has been satellites.

"The No. 1 thing that satellites allow us to do is track clouds," said Dan Lindsey, a senior scientific adviser at the National Oceanic and Atmospheric Administration's (NOAA) National Environmental Satellite, Data and Information Service (NESDIS). "Radar is good because it allows us to see precipitation falling, but it doesn't see clouds. And not all clouds produce precipitation."

NOAA operates two types of satellites: Polar-orbiting Operational Environmental Satellites (POES), which scan the entire globe several times daily, and Geostationary Operational Environmental Satellites (GOES), which provide near-continuous observation of a targeted region. NOAA is upgrading both.

The first of five satellites in the next iteration of POES, called the Joint Polar Satellite System (JPSS), was launched in 2017. Carrying five weather-monitoring instruments, it gathers global measurements of atmospheric, terrestrial and oceanic conditions that help meteorologists predict the intensity and location of severe weather events days in advance.

The next iteration of GOES, the GOES-R Series, launched its first two of four satellites in 2016 and 2018. Each carries six instruments designed to improve the detail and accuracy of weather forecasts, the most significant being the advanced baseline imager (ABI), which views Earth across 16 spectral bands and scans the entire Western Hemisphere every 10 minutes. The previous generation of GOES featured only five spectral bands and could image the Western Hemisphere once every 30 minutes.

"We get really low-latency data and very frequent data, which allows us to watch clouds as they form," explained Lindsey, who oversees the GOES-R program. "We also can learn more about the clouds themselves, like whether they're composed of ice or liquid water. That brings a lot of extra capability to the table."

ATMOSPHERIC IMPROVEMENTS

Although GOES-R satellites generate 60 times more data than their predecessors,

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Artist's rendering of the GOES-16 and GOES-17 satellites.

that's still not enough to satiate weather models' voracious appetite. Scientists are therefore investing bullishly in yet another data source: radio occultation, which makes weather observations — including temperature, pressure and humidity — by measuring how GPS and Global Navigation Satellite System (GNSS) signals are refracted, or bent, by the atmosphere.

NOAA endorsed radio occultation in June 2019 when it launched the Constellation Observing System for Meteorology, Ionosphere and Climate-2 (COSMIC-2), a network of six microsatellites that detects changes in radio signals as they pass through the atmosphere, also known as radio occultation.

As part of its Commercial Weather Data Pilot program, the agency also is procuring data from commercial satellite companies that specialize in radio occultation. Among them are Spire Global, which currently operates a fleet of 86 satellites, and PlanetiQ, which plans to launch its first in a fleet of 20 satellites early this year. Because their platforms are small — the size of a shoebox and a piece of carry-on luggage, respectively — they can iterate technology more quickly and more affordably than the federal government.

"Radio occultation provides us an incredibly precise understanding of global atmospheric conditions at any given point in time," said John Lusk, Spire Global's vice president and general manager. "It gives us better global weather visibility, allowing us to better predict disruptive and/or extreme weather events."

What makes radio occultation so special is that it measures the atmosphere at virtually all altitudes, from the surface of the Earth to the top of the ionosphere. That means more and better inputs for weather models.

"What that really comes down to is the ability to make accurate weather predictions further into the future," said PlanetiQ CEO Steve Joanis. "The one-day forecast right now is very good. Having global, high-density readings that go from the surface of the Earth to the top of the atmosphere allows us to extend the accuracy of the one-day forecast to two or three days initially, then four or five days, and eventually to seven days. That can have a dramatic impact on agriculture."

THE 'GOLDEN AGE' OF WEATHER

Although climate change will continue wreaking havoc on global weather patterns, the convergence of new sensors and software with increased computing power promises to equip farmers with the forecasts they need to weather the storm — literally and figuratively.

"If you study the history of science, you'll see that each of the sciences has a sort of golden age during which it makes some really stellar, fundamental improvements. We're in the middle of that golden age for weather," Wolf said. "As our knowledge and computer capabilities improve, so will the complexity of our models. Things will just keep getting better."

WEATHER FOR THE WORLD

Like clean water, affordable energy and comfortable housing, it's easy to take accurate weather forecasts for granted. Sure, the forecast isn't always perfect, but when a major storm's brewing, Americans typically have ample warning to protect themselves and their property. People in developing countries don't have the same luxury.

"We have what we call a 'meteorological divide,'" said Cameron Clayton, CEO of IBM subsidiary The Weather Company. "North America, Japan and the United Kingdom have all done a good job of investing in the science, satellites and infrastructure that make up the weather forecasting ecosystem. Unfortunately, the rest of the world has not kept pace."

Farmers in the developing world are therefore more vulnerable to extreme weather events, the severity and frequency of which are increasing due to climate change.

"Poor people are disproportionately impacted by climate change and by severe weather," Clayton continued. "If you're a farmer in Kenya who lives off of $100 a year, a monsoon falling on your field right as you plant your seed is fatal, whereas if you're a farmer in Kansas who lives off of $150,000 year, it's painful but not life-threatening."

The Weather Company recently launched IBM GRAF — the Global High-Resolution Atmosphere Forecasting System. A high-resolution weather model that can predict hyperlocal weather conditions up to 12 hours in advance, it delivers improved forecasts to users in 2.5 billion locations around the world who can access them for free via IBM websites and apps, including weather.com and Weather Underground. In remote areas of Africa, Asia and South America, forecasts typically cover 6 to 10 square miles and are updated only two to four times per day; with GRAF, forecasts zoom in to less than 2 square miles and are updated hourly.

"It's the first time in the world that there's been a global weather model at such a high resolution," according to Clayton, who said GRAF's secret sauce is a powerful new supercomputer that ingests 10 terabytes worth of weather observations each day, and on which it performs roughly 2 trillion computations per second. "We've always wanted to solve this problem, but we didn't have the capacity to do it until our colleagues at IBM Power Systems built us a supercomputer just for GRAF ... we know it's going to help us make materially better forecasts that will help people around the world make better decisions — particularly as it applies to agriculture."

— Matt Alderton

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GLOBAL FORECASTS **IBM GRAF offers advanced weather modeling data for farmers in remote areas of Asia, Africa and South America.**