9 MINS

AND NOW FOR THE WEATHER...

It may not always seem that way, but we're getting better at weather forecasting. Much better, in fact. And the information provided by forecasters is being put to ever more ingenious commercial uses. **Hannah Hudson** reports

NOAA/NASA

Eye in the sky
NOAA and Nasa's GOES-16 geostationary satellite promises more accurate forecasting

There were cool breezes across the UK on the afternoon of 15 October 1987 – certainly nothing to give cause for alarm. On the evening news, radio and TV forecasts noted slightly stronger winds, but suggested that heavy rain would be the main feature for the upcoming weekend. There was no mention of the gales gathering pace over the English Channel, nor the low atmospheric pressure over the Bay of Biscay. Weather forecaster Michael Fish chuckled as he told BBC viewers, on their way to bed, not to worry – there would be no hurricane tonight.

Technically he was right – there was no hurricane. Instead, southeast England experienced the worst storm to hit in three centuries. Gusting winds of up to 100mph felled around 15 million trees – some of which fell onto roads and railways, causing major transport delays. Others took down electricity and telephone lines, leaving thousands of homes without power for more than 24 hours. Buildings were damaged. Numerous small boats were wrecked or blown away. A Channel ferry was blown ashore near Folkestone. Eighteen people lost their lives.

The incident dramatically highlighted the gaps in our ability to accurately predict the weather, and demonstrated the need for better forecasting. Fast forward 30 years and recent global weather events have shown the demand is greater than ever. So how have things changed?

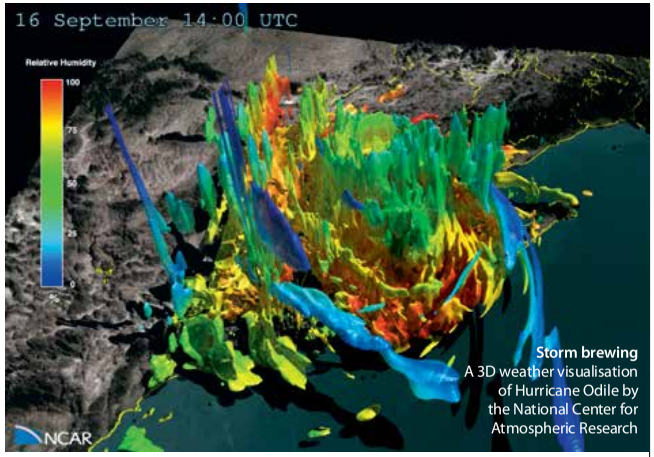
THE CURRENT ATMOSPHERE

"We're getting better all the time at predicting the weather," says Jonathan Dutton, head of aviation business at the UK's Met Office. "Since the Great Storm, the accuracy of three- to ten-day forecasts has increased by about one day per decade, with today's four-day forecast now as accurate as our one-day forecast 30 years ago."

One of the key reasons for the improvement is the increasing number – and better quality – of observation sources, which includes satellites, ground-based radiomagnetic detection equipment and networks of humidity sensors. Nasa's GOES-16 satellite, for example, which launched in November last year, can scan the Earth five times faster and with better image resolution than previous satellites, while weather radars can now distinguish between rain, snow, sleet and hail.

Computing has advanced, too. In October last year, the Met Office unveiled its new £97m supercomputer, capable of producing the most accurate short-term forecasts scientifically possible. "Supercomputers allow us to analyse more information, with more accuracy, to produce more relevant results," says Dutton. "We can also be more precise – coming up with models that operate at increasingly fine scales." While meteorologists used to divide the globe up into a grid of boxes about 25x25km in size, now they're down to 10km, and high-resolution models can focus on blocks of 1km.

Supercomputers also allow for better forecasting, says Hannah Christensen, from the National Center for Atmospheric Research in Boulder, Colorado. "It used to be the case that a forecaster would run a single simulation of the weather to come up with the forecast," she says. "Now, we run our simulator many times, up to 50, to get a range of possible outcomes – which is a much more truthful prediction. If you're only making a single prediction, you're being overconfident in what you're able to do.



Storm brewing
A 3D weather visualisation of Hurricane Odile by the National Center for Atmospheric Research

Finally, we have become better at understanding how the atmosphere works, and how thunderstorms or other disturbances evolve. "In order to make a prediction of a thunderstorm, you need accurate estimates of the starting conditions, and a forecast simulator that captures all the important processes," says Christensen. "Through our research and thanks to better technology, our forecasts are really improving. Plus, we're now able to produce 3D weather visualisations, which really helps us to wrap our heads around the structure of a storm."

GENERAL OUTLOOK

"Weather is the largest source of pervasive disruption on the planet," says Alex Rutter, managing director EMEA of The Weather Company, an IBM subsidiary. "Solving the problem of how to extract true meaning and genuinely useful insight from weather, not just figures and stats, is an exciting prospect."

He points to the 50 million people worldwide who suffer from allergies – 88 per cent of whom are able to correlate changes in their symptoms with changes in the weather. "Using weather analytics, we can help pharmaceutical companies and healthcare providers alert patients to developing weather conditions that could initiate or intensify allergic episodes," he says. "This gives people a chance to use their medication pre-emptively to avoid symptoms before they occur."

The Weather Company also works in developing countries to track patterns between infectious disease outbreaks and severe weather events. "Monsoons see an increase in water-borne and vector-borne diseases, such as malaria and cholera, while rainfall, temperature and humidity can aid in the development of the primary mosquito that carries diseases such as dengue and Zika," says Rutter. "We share this data with the life sciences industry, vaccine companies and associations that specialise in infectious disease control."

Insurance companies, too, are using weather data in clever ways. US-based Weather Analytics creates risk-assessment products from predictive weather models based on atmospheric data. "The weather impacts everything – from underwriting property and insuring against rainfall, to forecasting crop yields and planning exercises for national security," says Cyrena-Marie Arnold, the company's senior director of product sciences. "Our expertise comes in combining multiple sources of data to create genuinely useful information for our customers."

In the US, insurers pay about $2bn each year in compensation for vehicles damaged by hail. "We can provide hyper-local forecast information to customers to help them avoid this," says Arnold. "People can request notifications when it looks like there's a chance of hail in their area. We then send them an email to say, 'You may want to put your car in the garage tomorrow'. You don't have to go out and look for the forecast – it comes to you."

Weather forecasts have long been helpful to retailers, and now that's even more the case. "Combining weather information with human emotion can give retailers the tools they need to personalise their services to an incredible degree," says Rutter. "On a cloudy, rainy day, data shows customers will spend about 30 per cent more in a store, for example, while the temperature can also have an impact.

> "On a cloudy, rainy day, data shows customers will spend about 30 per cent more in a store"

"We have clients who set up alerts if there will be a shift of three or more degrees after a steady period as they know this will trigger certain buying behaviours, and they want to be ready to adjust stock or staffing levels. This means businesses are running in a predictive, in-control manner, not constantly reacting to events outside their control."

Planalytics, a weather analytics company with offices in Pennsylvania and London, converts weather information into useful business insights. One client, Subway, was able to work out why one region in the US had not performed well during a recent campaign that had increased sales everywhere else in the country. "It turned out that this region experienced unusually rainy weather, which kept customers from visiting their restaurants," says Planalytics' VP marketing, David Frieberg,

"Companies that don't consider weather data are ignoring the biases that are embedded in their past performance," he adds. "Since the prior year's sales are commonly used as a basis for next year's plan, businesses essentially end up planning for the same weather conditions to occur again and they rarely do."

Startups have also spotted the opportunities swirling around weather analysis. Forecasting company Climendo tracks the historical accuracy of various forecasters for specific locations, compares them, and combines the best ones in a single app. It recently launched a new standalone app, Climendo 71%, for swimmers, surfers, anglers, kayakers and anyone who spends time on open water. Surfers can set personalised alerts for when their favourite surf spots are optimal, while sailors receive lightning warnings and data on currents. Anglers, meanwhile, can gather information on when fish are most likely to be active.

WINDS OF CHANGE

So what comes next? "We're in the middle of this big revolution in how we use weather," says Bill Gail, chief technology officer at Global Weather Corporation (GWC) in Colorado. "In a decade, we won't have to check a weather app – we'll have devices and apps already using weather to help us."

He points to a few examples: "Thermostats will consider weather information to turn your home heater up and down, anticipating changes in the weather to avoid wasting energy. Calendar apps will advise against scheduling outdoor activities when rain is expected. And your lawn irrigation system will skip a watering cycle if rain is anticipated the following day."

GWC is currently working on a joined-up solution to alert drivers in real time to where roads may be treacherous due to poor weather in the US, Europe and China. In the US, more people are killed in weather-related vehicle accidents than large-scale weather disasters (around 5,900 people die every year in these accidents, while the ten-year average combined number of deaths each year from flooding, lightning, tornadoes, hurricanes and heat is 375).

Weather data will be fed to connected cars, so drivers will receive alerts if dangerous conditions are on the horizon. "Your satnav will automatically include forecasts when it advises you to take a particular route," explains Gail.

Meanwhile, Boston startup, ClimaCell is concentrating on hyper-local, real-time weather reporting. It claims to be able to forecast the weather with pinpoint accuracy – even down to tracking the intensity of rainfall on one street versus another in the same neighbourhood.

Developed by Israeli air force veteran Shimon Elkabetz, ClimaCell works by combining meteorological signals from wireless and communications networks with traditional sources such as radar and satellites. "If you know what the signal should look like without weather interference and you know how each weather phenomenon affects the signal, then you can retrieve the weather phenomenon from the interference,"

Climate controls
'Under the hood' of Climendo's weather app

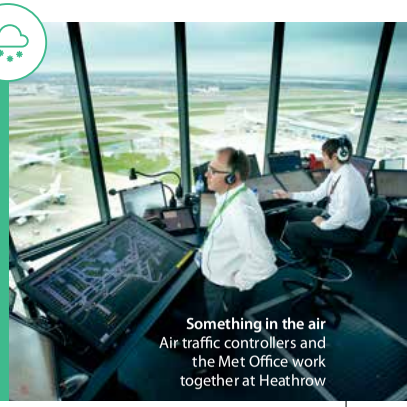
HOW ARE FORECASTS MADE?

Jonathan Dutton, The Met Office

"To make a forecast, forecasters have to understand what the weather is doing now. To do this, they receive millions of observations from all over the planet. This includes information from over the oceans, from the surface (ships and buoys), from high in the atmosphere (satellites) and below the oceans (a network of special floats called Argo). All this information is beamed back to the Met Office HQ and fed into its supercomputer. This high performance machine, capable of doing more than a hundred trillion calculations a second, takes this information as a starting point to run complex equations. Comprising more than a million lines of code, the equations form a mathematical model designed to mirror the dynamics of the atmosphere. By putting current weather observations into the model, the computer generates simulations of what might happen next. Output from the computer is then studied by experienced forecasters who look at a range of information to determine how accurate the simulations from the computer are. They add finer points to the forecasts before they are broadcast."

HOW DOES BRITISH AIRWAYS USE WEATHER DATA?

Since 2013, a team of meteorologists has been embedded in the Heathrow Airport Operations Centre (APOC) alongside air traffic experts from National Air Traffic Services and airport operational management teams. Ironically, the collaboration itself is the result of bad weather. The winter of 2009/10 was one of the coldest for 30 years. Snowfall all but shut Heathrow for four days and more than 4,000 flights were cancelled. The government therefore commissioned the Heathrow Winter Resilience Enquiry to improve the airport's readiness for incidents. Overlooking the airfield in a high-tech command centre, the Met Office's role is to give detailed, Heathrow-specific reports to their NATS colleagues. If the team sees a potential storm forming in the early morning, they can recommend bringing in aircraft that have arrived in the airspace ahead of schedule to land before the airport opens. At the other end of the day, they can advise if aircraft will be able to leave or if a cancellation is likely. Ultimately, however, it's up to individual airlines to make the final decision. "The aim is to give the most up-to-date recommendations to keep traffic flowing," says James Shapland, Heathrow Met Office operations manager. In most cases, we won't recommend serious actions such as cancellations more than 24 hours in advance.



Something in the air
Air traffic controllers and the Met Office work together at Heathrow

ADDITIONAL WORDS: GRAEME PARK

COULD THE UK GET CAUGHT OUT BY ANOTHER GREAT STORM?

Predicting the Great Storm of 1987 could have been very different if forecasters had used probabilistic forecasting – a method that was first suggested in the early 1990s and has been developed dramatically since. "In the 1980s, all people had to go on was a single, best-guess prediction, which showed the storm sweeping to the south," says Hannah Christensen. "Probabilistic forecasting means we'd run the model many times over and see the different variations in outcome." That said, even if you use a modern model and repeat the forecast for that night, there's still a huge spread in what could happen. "Even a day in advance, it's still not clear," says Christensen. "It's very unusual to have so much uncertainty so close to the event. "It's about 50/50 whether it would pass to the south."

Shore thing
The *Hengist*, a Sealink passenger ferry, ran aground at Folkestone during the Great Storm of 1987

explains Elkabetz. The result is minute-by-minute, street level weather data, for historical, real-time, and short-term prediction (within six hours of the event).

Elkabetz wants ClimaCell to be used by everyone from developing countries to private companies, such as airlines. "Because we're very good at measuring intensity and classifying type of precipitation, we're also well equipped to support the 'new economy', companies such as Uber and Lyft, and new transportation types such as drones and autonomous cars," he adds.

The future of forecasting will also see a much increased role for social media. "Citizen science is continuing to grow – especially when it comes to weather," explains Christensen. "Everyone with a smartphone has this incredibly powerful computer in their pocket, capable of recording all sorts of useful information. We already share our location with Google, – why not incorporate barometer readings? There's huge potential."

"We have 20 million active mobile users checking the forecast multiple times a day," says Rutter. (TWC is the default weather forecast for Yahoo, iPhone and Snapchat.) "This means we can map over one billion locations every week – gaining unique insight into customer journeys that map back to real-world locations. We can also ask users to verify the accuracy of our forecasts, by simply asking, 'Is it raining in your area?' and get immediate feedback and adjust our forecasts, if necessary."

Machine learning is another tool shaping the landscape. "We're only just beginning to think about these kinds of computational techniques in atmospheric research," says Christensen. "It takes a huge amount of time to analyse all the data we collect – machine learning helps us do it faster and better. We feed in the data and the algorithm looks for the patterns we might not notice otherwise."

So does this mean the end for weathermen and women? "There will always be a role for people," says Christensen. "You still need someone to look at what the machine is telling you and to work out if it's sensible."

THE FORECAST FOR FORECASTS

So will we ever be able to perfectly predict the weather? "In a word… no," says Dutton. "While, statistically, our forecasting models have improved, there's a fundamental predictability limit in the atmosphere. Accurate forecasts rely on having a good understanding of what the atmosphere is doing at the present time, but the atmosphere is inherently chaotic. No matter how good our technology, we'll never be able to measure the precise position of every air particle or the temperature at every location in the world."

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"If we overemphasise how accurate we can be – and then get it wrong – that's doubly annoying for people," says Christensen. "Thunderstorms are notoriously hard to pinpoint. If we say there'll be a big storm over Oxford at X-time, and then it actually passes to the south – the people in Oxford will be upset because the forecast is wrong, and so will the people in the south!"

"The way we communicate is an important part of the value of forecasting," adds Dutton. "As forecast skill develops, so does the need to use language that's relevant and meaningful to the user. This may be increasingly in the language of risk and focused on the impact."

It seems that, instead of expecting a definitive forecast on the ten o'clock news, we should just simply stay tuned. ■

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