CLOUDY with a chance of... savings

Weather affects every sector of the economy, so there's a lot to be gained from getting the forecasts right

BY JESSIE ROMERO

The local outpost of the National Weather Service (NWS) in Morehead City, N.C., is one of 122 such offices nationwide. But it was one of the first to get a new "dual-polarization" radar that can pick up an unprecedented amount of detail. "We can see the size and shape of water droplets and snowflakes. We can see the crops being ripped out of the ground by tornadoes," says Don Berchoff, director of the Office of Science and Technology at the NWS. Over the next year, the new radars will be installed at field offices nationwide, allowing meteorologists to see if the line between rain and snow falls over a major highway, or where exactly a tornado has touched the ground.

Humans have been trying to predict the weather since at least 650 B.C., when the ancient Babylonians made forecasts based on the shape of clouds. For most people, the major concern is whether or not to take an umbrella when they leave the house. But weather can affect GDP by as much as $485 billion per year, according to researchers at the National Center for Atmospheric Research and the University of Colorado, and advance warning of weather events can save both money and lives. Businesses ranging from construction firms to commodity brokerages rely on weather forecasts to plan future projects and make investment decisions. As forecasting technology has improved, so has these companies' ability to protect themselves against risk — but not to eliminate it entirely.

Disaster on the Lakes

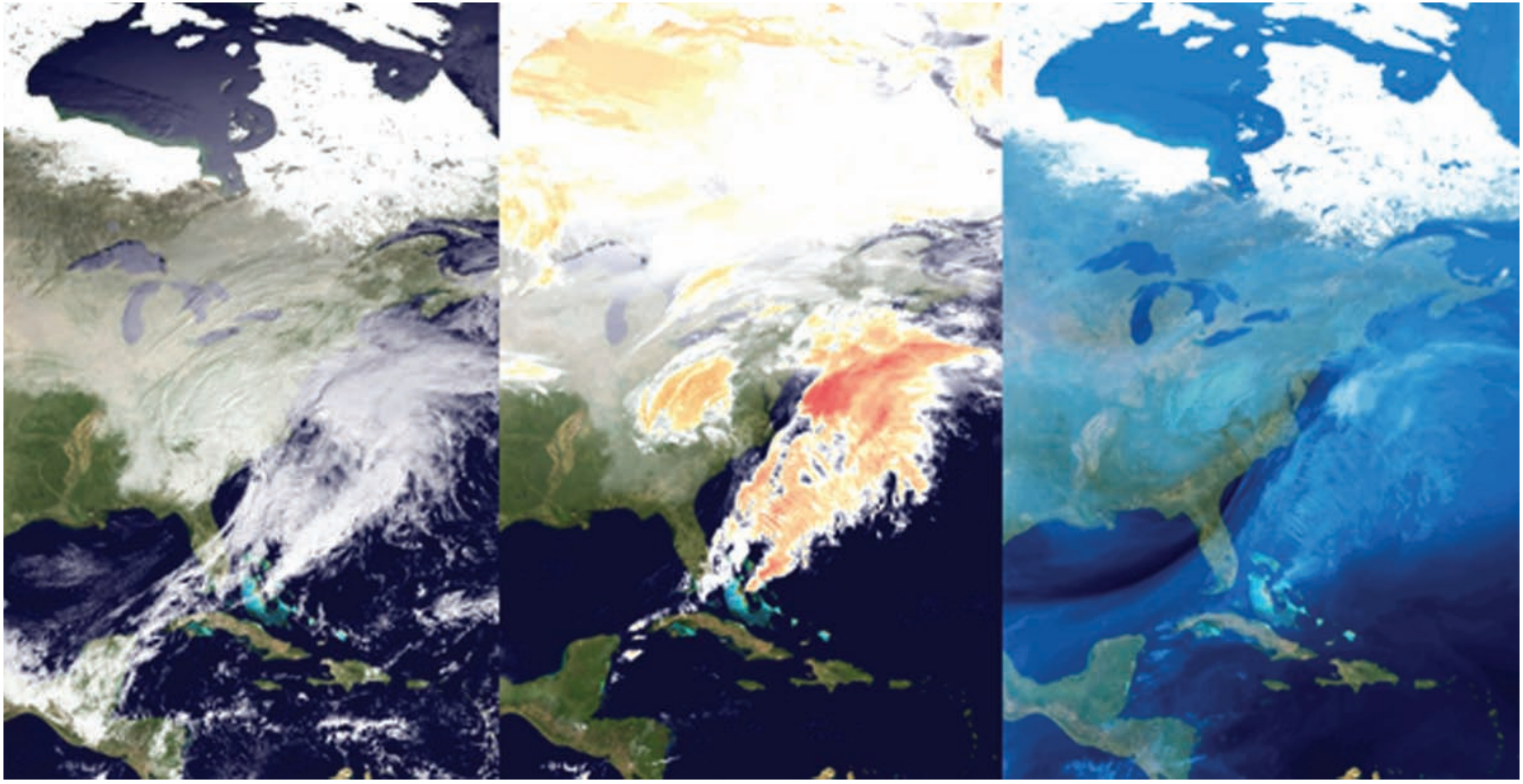
Between 1868 and 1869, storms on the Great Lakes destroyed 231 ships, killed 530 people, and caused more than $7 million in property damage and lost cargo (in 1869 dollars). After previous stalled private-sector attempts to create a national weather forecasting bureau, the publication of the pamphlet *Disaster on the Lakes* by Milwaukee scientist Increase Lapham finally gained the attention of politicians.

At the same time Lapham was advocating for a weather bureau, the U.S. Army was looking for a reason to maintain its signal corps, whose budget had been cut after the Civil War. The Army seized on the idea of a national weather system, and proposed creating a network of observation stations linked by telegraph. In 1870, Congress mandated the U.S. Army Signal Corps to begin recording meteorological observations in order to "give notice on the northern lakes and sea coast of the approach and force of storms" with the goal of reducing shipping losses. The new system had an immediate impact on the maritime industry, reducing losses by about $1 million annually by the mid-1870s, and by as much as $4.5 million annually by the early 1880s, according to economist Erik Craft of the University of Richmond.

From 1891 to 1940, the National Weather Bureau was housed in the Department of Agriculture, where it issued weekly forecasts to aid in crop planning. In 1940, President Roosevelt moved the bureau to the Department of Commerce to support the growing commercial interest in aviation, which relied heavily on weather forecasts. The bureau was renamed the National Weather Service in 1970 and today resides in Commerce as an agency of the National Oceanic and Atmospheric Administration. Hearkening back to its founding, the service's primary mission is the "protection of life and property and the enhancement of the national economy."

NWS headquarters are in Silver Spring, Md., but the agency depends on its field offices to gather regional data and report it back to the national level. The NWS also has a network of more than 11,000 volunteers who record weather observations such as temperature or rainfall on farms, mountaintops, and sometimes in their own backyards.

Local NWS offices also issue weather warnings and coordinate with local law enforcement and emergency management personnel to plan evacuations or to monitor conditions that could affect events such as a wildfire. "We provide support for anything that needs weather information, whether it's just a forecast, or a hazardous chemical release or a plane crash," explains Ron Morales, warning coordination meteorologist at the NWS office in Charleston, S.C. In the Fifth District, one of the major concerns is hurricanes. Although the National Hurricane Center, a division of the NWS, tracks storms while they are at sea, the local office is responsible for the storm once it makes landfall. During this past summer's Hurricane Irene, meteorologists worked in 12-hour shifts to issue warnings and keep track of the storm's effects on the tides and inland areas. As many as 200,000 tourists and residents were evacuated from Morehead City and other towns along North Carolina's coast, which suffered major flood damage.



Satellite images of a snowstorm taken in 2011.

As the population has grown in areas prone to wildfires, hurricanes, and floods, so has the potential scale of future "disasters on the lake." Between 1960 and 2008, the population in coastal counties increased 84 percent, compared to 64 percent in noncoastal counties, and growth in the number of housing units also outpaced growth in noncoastal counties. Using a technique called normalization, the NWS can estimate the damage that would occur if a storm from the past hit under current societal conditions. If the Great Miami Hurricane of 1926 had instead made landfall in 2005, it would have caused about $150 billion in direct damages (in 2005 dollars), nearly twice the damage caused by Hurricane Katrina.

Building a Better Mousetrap

In the early days of the signal service, forecasts were based primarily on the assumption that the weather in the West would continue moving east. Army personnel stationed at 24 points across the country meticulously recorded the temperature, barometric pressure, and wind speed three times per day and telegraphed the information to Washington, D.C., where maps were made of the conditions. If a storm was predicted, personnel on the Great Lakes and Atlantic Seaboard would hoist red flags to warn ships of dangerous weather.

Today, the NWS processes more than 210 million weather observations each day, gathered by weather balloons, ocean buoys, automated surface observation stations (ASOS), and a sophisticated network of radar devices and satellites. In addition to the dual-polarization radars, NOAA is launching a new geostationary satellite, called GOES-R, in 2016. Geostationary satellites, which move at the same speed as the Earth's rotation and thus remain in the same relative position, orbit 25,000 miles above the ground, producing the images commonly seen on television during the evening news. Currently, it takes about 15 minutes to download a satellite image, but the new satellites will be able to create images every 30 seconds, allowing meteorologists to see storms develop almost in real time. "You can literally see the clouds moving up and down, and the boundaries of a storm moving around," says Morales. The GOES-R also can detect lightning while it's still in the clouds, making it possible to predict if and when lightning will strike the ground.

Those millions of observations are fed into large-scale numerical models, which require a massive amount of computing power. In 2009, the NWS finished installing a $180 million supercomputer system that's half the size of a tennis court and can perform 69.7 trillion calculations per second. But even that's not enough for some of the new technologies; in February of 2011, the NWS announced a 10-year, $502 million project to build an even faster computer. "Our science is actually getting ahead of our ability to run these models," Berchoff says.

The combination of better observations, more sophisticated models, and faster computers has greatly increased the accuracy of weather forecasts, especially during the past 10 years. A decade ago, forecasts were accurate for an area the size of a county; now, forecasters can predict weather specific to an area of 8 or 9 square miles. The next goal, according to Berchoff, is to improve the accuracy to the neighborhood level. Forecasters also are able to predict major storms with significantly more lead time than in the past. The NWS knew that "Snowmageddon," the snowstorm that shut down Washington, D.C., in 2010, was coming six days before it hit, which enabled airlines to cancel flights 24 hours in advance, preventing both people and airplanes from getting stranded. "Ten years ago, people would have gotten stuck in the airport — you would have seen them on CNN, in sleeping bags on the floor. And the airplanes could be sent to where they

PHOTOGRAPHY: NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION/DEPARTMENT OF COMMERCE could be productive the next day," Berchoff says. "Good forecasting avoided a lot of costs that would have occurred otherwise." Forecasters also are better able to predict the path that storms will take. The improved accuracy of hurricane forecasts prevented the evacuation of hundreds of miles of Florida coastline during Hurricane Irene. John Whitehead, an economist at Appalachian State University, estimates the cost of an evacuation is between $1 million and $50 million per county; some estimates are as high as $1 million per mile of coastline.

Good forecasting isn't always enough, however. The development of Doppler radar and a national warning system decreased tornado deaths by 70 percent between 1920 and 1990, to fewer than 60 per year. But in 2011, more than 500 people were killed in tornadoes, with most of the casualties in Tuscaloosa, Ala., and Joplin, Mo. "Unfortunately, we had good forecasts in Tuscaloosa and Joplin, but a lot of people still died," Berchoff says. "How do we reduce loss of life even when we put a good forecast out? Part of that is just communication. That's what we're working on now."

Communication was a major concern during Hurricane Katrina in 2005. About three days before the storm hit New Orleans, the NWS predicted Katrina's path within 15 miles, compared to a typical margin of error of about 100 miles, but it wasn't until the day before the storm that state and local officials ordered mandatory evacuations. Several hours before those evacuation orders, the NWS also issued a statement that "devastating damage [is] expected ... most of the area will be uninhabitable for weeks ... water shortages will make human suffering incredible by modern standards." Some private forecasters contend that the NWS waited too long to issue its warnings, but it's not clear how much destruction to person and property would have been prevented if they had issued them earlier. Coordination failures among local, state, and federal officials and private agencies prevented effective response to the storm.

A Public Good Goes Private

Weather information is generally viewed as a "public good," like the military or the U.S. highway system. A public good is characterized by nonexcludability, meaning that it is difficult to prevent an additional person from using it, and by nonrivalry, meaning that use by one individual does not diminish the availability of the good for another. These characteristics make it difficult to charge a price that would enable the private sector to recoup the costs of development; "free riders" can use the good without contributing to its creation or maintenance. In economic theory, these features are the basis for programs in which the government steps in to provide a socially desirable level of the good. Weather forecasts can be viewed as meeting both of these criteria, so although there were private organizations, such as Western Union and the Associated Press, that could have created a national forecasting network in 1870, it's doubtful that they had the incentives to do so, according to Craft of the University of Richmond. In addition, the feasibility and benefits of weather forecasts were far from proven at that time, so the private sector likely was happy to wait and see if the government's investment would pay off.

Today, that investment totals a billion dollars per year, and a network of private weather forecasting companies has developed to take advantage of the federally created data. Because the NWS is taxpayer-funded, it shares its data with private firms. These companies run the data through their own proprietary models, customized for industries including construction, energy and utilities, agriculture, and commodity trading, among others. Currently, there are about 300 private weather organizations in the United States, including national brand names such as The Weather Channel, which operates a large weather consulting division in addition to its more famous television network. While the field is still relatively small, it's growing; the Bureau of Labor Statistics predicts that the number of meteorologists in the United States will increase 15 percent, to 10,800, by 2018, with nearly all of the growth in the private sector.

The demand for private weather information is boosted both by the perception that weather events have become both more frequent and more extreme, and by technological improvements that make highly specialized forecasts possible. In particular, advancements in geographic information system (GIS) technology have made it possible to combine weather information with detailed geographical data, allowing businesses to see how the weather will affect specific factories or jobsites. Construction companies, for example, can't pour concrete or install roofs when it's raining, and a sudden storm can damage thousands of dollars of materials at unprotected worksites — not to mention the danger of workers getting struck by lightning. Electric companies need to plan for usage days in advance, and under- or overestimating the temperature can cost millions of dollars when extra capacity has to be bought on the spot market or existing capacity goes unused. High winds, lightning strikes, and even minor storms can damage lines and cause power outages. The majority of investor-owned utilities, which provide about 75 percent of the United States' electricity, work with private weather firms to forecast peak demand and deploy repair crews.

Although state and local governments get general weather warnings and advisories from the NWS, they also hire private forecasters for more specialized uses such as planning for outdoor events or to see the effect of a storm on a block-by-block basis. In 2007, the departments of Public Works and Transportation in Montgomery County and Prince George's County, Md., for example, both began working with a private forecasting firm to predict hours in advance of winter storms which areas would be most in need of salt trucks and snowplows. Prince George's County estimates that it saved up to $100,000 during that first winter by sending trucks only to where they were needed rather than deploying them countywide when some areas saw only rain.

Agriculture is the industry most obviously affected by the weather; a long hot spell, too much rain, or an early frost all can affect when to plant or harvest, or even destroy most of a season's crop. Advance information about the weather helps farmers plan for such events. Highly detailed freeze/frost reports, for example, can inform a farmer's decision about the best method to protect crops, ranging from covering them up with blankets to hiring helicopters to fly over the fields circulating warm air. Although the U.S. Department of Agriculture (USDA) issues a weekly weather and crop bulletin, many farmers turn to other sources in order to get more frequent information about wind speed, precipitation, temperature, and evaporation rates. Large farming operations devoted to major crops such as corn, cotton, or soybeans generally hire private forecasters, while smaller farms tend to rely on their cooperative extension service and state climate office (SCO), according to Ryan Boyles, director of the North Carolina SCO at North Carolina State University.

Weather forecasts also inform pest and disease control decisions; certain diseases thrive only in certain weather conditions, which means that farmers can skip spraying on occasion, generating significant savings. The North Carolina SCO issues a daily disease update for peanut growers, eliminating several sprays per year, Boyles says.

Weather doesn't affect only the crops themselves — it also affects the value of billions of dollars worth of commodity futures and options contracts. The amount invested in commodities has more than doubled since 2006, to $431 billion, according to Barclays Capital, and agricultural products such as coffee, corn, soybeans, and wheat are among the most heavily traded products.

Futures and options are investments designed to hedge against risk. A futures contract specifies the amount of a good to be sold on a date in the future, at a price determined today. The buyer of the contract is making a bet that prices will rise, and thus that they'll be able to buy the good at the lower contract price and then profit by selling it at the market price. The seller of the contract is betting that prices will fall, and trying to lock in a higher price now. Options contracts operate on a similar principle, except that they give the buyer the right, not the obligation, to fulfill the contract in the future; many options traders choose to sell the contract itself at a profit rather than buying the underlying good. The prices of both futures and options contracts are affected by the same factors that affect supply and demand for the underlying commodity. In September, for example, a heat wave caused the USDA to cut its corn yield estimates for the second time in two months, causing corn futures prices to surge. Commodity traders pay close attention to weather forecasts in an effort to anticipate those price changes, often subscribing to multiple specialized forecasts for both the United States and around the world. "There are a lot of weatherheads out there. We get three or four different services sent to us daily," says George Kopp, a broker with the International Futures Group in Chicago, Ill. Those services might provide daily updates on the temperature in Argentinean soybean regions, or on the rainfall during the Midwest's corn harvest. Currently, Kopp and other traders are paying special attention to predictions of a La Niña episode over the Pacific Ocean; La Niña creates atypical patterns of drought and rainfall, which affects prices for crops throughout South America, Australia, and some parts of the United States.

Weather tracking has come a long way since this U.S. Army Signal Corps weather map drawn in 1872.

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The ubiquity of weather information and its easy availability on smartphones has changed the way people operate, says Scott Shellady, derivatives manager and an agricultural specialist at ICAP, an international interdealer broker. (Interdealer brokers facilitate high-volume trades between major dealers such as investment banks.) "Weather information gets around the world in two seconds. Where you used to have a lag on hot and dry weather in Argentina, now everybody knows that instantaneously. You have to pay attention or you're going to be left behind by everybody else," he says.

Predicting the Unpredictable

At the end of the day, weather is inherently unpredictable; no matter how fast the satellite or how large the computer, forecasts will never be 100 percent accurate. Hurricane intensity, for example, is notoriously difficult to predict; overestimations of the intensity of Hurricane Irene might have focused too much attention on coastal damage, when inland flooding was the real threat. But the goal isn't perfection, says Berchoff of the NWS; instead, it's improving the accuracy of the probabilities. "If we can consistently provide information that says there's a 70 percent chance that something is going to occur, and it really occurs 70 percent of the time, that's a tremendous amount of intelligence."

Weather forecasters might not be able to provide absolute certainty, but the market has found a way to further mitigate the risks of unpredictable weather. In the late 1990s, energy companies began trading weather derivatives as a hedge against lost revenue due to adverse weather conditions. The typical weather derivative is based on the average temperature over a period of weeks or months; one party to the trade profits if the number of hot (or cold, depending on the contract) days is above the strike price, and the other party profits if the number is below. A heating oil company, for example, stands to lose revenue if a winter is warmer than expected, so it might place a bet that the number of hot days will be higher than the strike price. If the winter is warm, the decrease in revenue is offset by profits on the derivative contract. If the winter is cold, then the increase in revenue covers the losses on the derivative.

The Chicago Mercantile Exchange launched its first weather derivative product in 1999, and last year more than 1.4 million derivative contracts were written, for a total value of more than $11 billion. In 2006, after Hurricane Katrina, the value of contracts was more than $45 billion, according to the Weather Risk Management Association. The primary users of weather derivatives are energy companies, but a growing number of construction, agricultural, and outdoor entertainment companies are entering the market. Unlike insurance, which protects only against catastrophic events, weather derivatives offer these companies a bulwark against more mundane occurrences.

Catastrophic or mundane, weather is beyond the control of the people it affects. As the models and technology improve, however, it becomes increasingly possible for individuals and businesses to use that information to arm themselves against whatever the weather might bring. Models aren't perfect; the residents of Vermont knew Hurricane Irene was coming, but they didn't expect that much of their landlocked state would end up under water. Still, as scientists keep trying to get better at predicting the unpredictable, businesses will continue to seek out every extra drop of certainty. **RF**

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RETIREMENT • *continued from page 28*

increasingly opting to move into a less stressful line of work, take a part-time position, work a few months of the year, or pursue lifelong passions for which their careers never allowed time. Their reasons might be economic — but then again, maybe not. A recent survey by insurance company Allstate and the *National Journal* found that 68 percent of near-retirees planned to work in retirement, but only half out of financial necessity. Only 11 percent of current retirees reported some form of work. For boomers, the concept of retirement is growing more ambiguous.

It would seem fitting for baby boomers to be the ones to set this trend in motion. "I think we're going to have to just watch them to see what happens," Weatherford says. "These are boomers. They have always been the hard-charging, hard-working generation. I really do think they're going to redefine it for us all." **RF**

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