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Hurricane Forecasting: Reducing Future Losses

By Pam Frost Gorder

HURRICANES ARE BORN OF THE SEA, AND THEY DIE OVER LAND. IT'S AT THAT BRIEF MOMENT WHEN THEY CROSS BETWEEN THE TWO THAT THEY DO THE MOST DAMAGE.

The worst part of a hurricane's fury is over in hours, and its remnants subside in days. But a hurricane's other impacts—its human losses and economic costs—begin long before it ever reaches land, and linger long after it's gone.

Take Hurricane Dennis, for instance. The first hurricane of the 2005 season, Dennis officially struck the Gulf Coast on 10 July, but by then most Americans had already seen its specter at the gas pump. The US National Hurricane Center declared that Tropical Storm Dennis was likely to become a hurricane on 6 July, so the Gulf oil industry began curtailing production and evacuating its employees to safety. Mere anticipation of oil shortages drove already high gasoline prices to a record peak nationwide.

Two weeks later, insurers tallied just under US$1 billion dollars in property losses in four states. Floods destroyed half of Florida's cotton crop, and drought-stricken farmers in the Midwest were still wary that Dennis's high winds might have spread a deadly soybean fungus.

Then came Hurricane Katrina, and previous gas price hikes and crop damage paled in comparison to the nearly 1,000 lives lost in flood waters in Louisiana, Mississippi, and four other states. Hundreds of thousands of people lost their homes, their jobs—everything. To repair the devastation will cost insurers as much as US$60 billion. Another US$200 billion in projected federal aid, while vital to helping Katrina's victims rebuild their lives, will send aftershocks through the nation's economy for years to come. Everything from interest rates to lumber costs will be affected.

And as of this writing, yet another hurricane—Hurricane Rita—has just crossed the Florida Keys, and is headed for Texas.

How many more hurricanes are coming? The answer is tied up in ocean temperatures and wind patterns, which evolve through the most active part of a hurricane season. That's why experts mix meteorology with computer science and statistics to create their forecasts.

One forecast, created by Mark Saunders and his colleagues at University College London, goes beyond the question of how many hurricanes will form at sea to ask how severe and how damaging the hurricanes that strike the US coast will be. The idea is to help people anticipate hurricane damage and all the effects that follow. In Katrina's wake, knowing what to expect from a storm season—well in advance of a disaster—is more important than ever before.

Summer Winds

It was the rough storm season of 1995 that got Saunders thinking about hurricanes. The professor of climate prediction wondered what it was about global conditions during that year that could spawn a record 11 Atlantic hurricanes and cause a combined US$8 billion in damage across the US, Caribbean, and Mexico.

At that time, scientists were already using relatively simple statistical techniques to forecast how many hurricanes would occur in a year. Saunders began work on a computer model that could predict US landfall and storm intensity. When he published a paper on the subject in 1997 (*Geophysical Research Letters*, vol. 24, no. 10, p. 1255), the British insurance industry took notice. When American insurers have to pay large numbers of damage claims at once, they make up for their losses by filing claims of their own with so-called reinsurance companies, many of which are in the UK. A group of reinsurers asked Saunders for a tool that would help them predict how much disaster coverage their clients in the American insurance industry would need.

"Things have really developed from there," Saunders says. "Now I'm running this venture called Tropical Storm Risk [www.tropicalstormrisk.com], providing forecasts of tropical cyclone activity around the world."

The model that he and colleague Adam Lea recently published in *Nature* (vol. 434, 2005, p. 1005) is very simple statistically and not computationally intensive. It's a regression model, which means it calculates the average likelihood of hurricanes making US landfall based on factors that have correlated strongly with landfall in the past—in this case, July wind patterns in six key regions around North America dating back to 1950. To test their model, they created a "hindcast" of US-striking hurricane activity from 1950 to 2003. The model correctly anticipated whether hurricane-related financial losses were above or below average 75 percent of the time and performed equally as well in its "real-time" forecast for 2004.

Saunders says the wind model represents an advance meteorologically because such long-range forecasts normally rely on measurements of sea-surface temperatures. Winds and sea-surface temperatures are both key drivers of Earth's climate system, although scientists don't yet fully understand all the physical processes that link them.

"We find that for these six areas, the winds in July set up a pattern of winds that persist through the hurricane season, and tend to steer hurricanes toward or away from US landfall," Saunders says.

One important wind pattern is the eastern Pacific phenomenon known as El Niño (see the January/February 2005 issue of *CiSE* for a discussion of how sea-surface temperatures influence El Niño development). A strong El Niño can weaken a hurricane season by pushing high-altitude westerly winds across the Americas into the Atlantic. Storms need altitude to grow, so these strong "westerlies" effectively decapitate hurricanes before they even have a chance to develop.

ACE in the Hole

As it happens, a discovery concerning a different tropical climate pattern led US National Oceanic and Atmospheric Administration (NOAA; www.nhc.noaa.gov) meteorologist Gerry Bell to switch his career focus from El Niño to hurricanes. He is now NOAA's lead seasonal hurricane forecaster.

In the 1980s, hurricane forecasting pioneer William Gray, of Colorado State University, determined that hurricane incidence depends in part on El Niño. But scientists later discovered that a pattern called the *multidecadal signal*—which relates to the ocean temperatures and rainfall patterns that control atmospheric pressures in the tropics—was also important. This was the missing climate link Bell and his colleagues needed before they could construct their hurricane outlook, he says. Before that, "we had little bits and pieces of the puzzle, but we didn't have the big picture. Now we do." He feels that predicting hurricane landfalls is now the biggest outstanding problem in hurricane forecasting.

Bell and his NOAA team designed the Accumulated Cyclone Energy (ACE) index, a single number that rates overall hurricane activity for a season. It's the sum of the top wind speeds attained by all hurricanes all season long, but it only includes data from when the storms sat over the open ocean.

In their *Nature* article, Saunders and Lea created an ACE index for landfall activity by adding up the top wind speeds for tropical storms as they hit the US mainland. They showed that the severity and damage of hurricane activity striking the US during the main hurricane season was indeed correlated with the six wind patterns they'd identified. By then tying their modified ACE index to recorded hurricane damages for the past 50 years, they showed that July wind patterns could help forecast damages.

"I think that was the really innovative thing they did—to link climate variations to actual economic losses," says James Elsner, professor of geography at Florida State University. He too heads a team that produces an annual hurricane forecast, although with a slightly different method. He's also the president of Climatek (http://garnet.acns.fsu.edu/~jelsner/climatek/), which develops hurricane models for the insurance industry.

Three Forecasts, Many Hurricanes

All three forecasts—Saunders' at University College London, Bell's at NOAA, and Elsner's at Florida State—are statistical and rely on meteorologists' understanding of the physical processes that cause hurricanes. Because such processes are always evolving, all three teams can get some idea of an outlook before hurricane season starts in June, but they can develop much more confident forecasts by the end of July, just in time for the season's August to October peak. All three teams generated similar predictions for 2005.

Saunders' team forecasted an exceptionally active hurricane season, with 22 tropical storms in the Atlantic basin as a whole. Half of those tropical storms would become hurricanes, and seven of the hurricanes would be intense. Four of the tropical storms and three of the hurricanes would strike the US coast. This prediction has borne out so far, as Rita is the 17th tropical storm and ninth hurricane of the season. It's also the third hurricane to make landfall.

Elsner uses a different kind of regression model than Saunders, but says he's only interested in the raw number of hurricanes that are expected for the season. He's found a way to make his forecasts more precise by incorporating historical data from much further back in time—as far back as 1850 (http://garnet.acns.fsu.edu/~jelsner/www/forecasts.html). Much of that data comes from ship's logs and newspaper reports, which he acknowledges are less reliable than today's information. Given this, he uses another statistical method called Bayesian analysis to weight the old data against the modern, in a process that requires several hours' computation time on a desktop PC. In this Bayesian scheme, the older data count less, but they still count. And Elsner says his forecasts have become anywhere from 10 to 30 percent more precise, depending on whether an average or above-average season is expected. His forecast for this year was an above-average season, with six or seven hurricanes.

NOAA's forecast is the gold standard. NOAA is in the middle of developing an entirely physical hurricane model—one that generates forecasts based on constantly updated atmospheric conditions recorded worldwide and requires a supercomputer to do the job. Right now, however, Bell's team creates its forecasts from a statistical analysis of El Niño and the multidecadal signal, based on physical conditions in May and then again in July. The NOAA forecast also predicted an extremely active season, with 18 to 21 tropical storms, and 9 to 11 of those becoming hurricanes. Five to seven could become major. Again, these numbers are proving true. Even after Hurricane Rita fades, another two months of hurricane season will remain.

Uncertain World

Bell would like to be able to forecast how many hurricanes will make landfall, but that, he says, depends a lot on local weather patterns along the coast at the time the hurricane is approaching. NOAA's ultra-detailed physical model could one day help answer that question. The challenge isn't one of computing or statistics, but of meteorology. He says he'd like to see scientists continue to improve their understanding of climate phenomena such as the multidecadal signal and El Niño. He's recently determined, for example, that the two account for 70 to 80 percent of climate anomalies along the middle latitudes (*Journal of Climate*, vol. 17, no. 9, 2004, p. 1777).

"Right now, all we can say is whether conditions are favorable for an increased threat of hurricanes," Bell says. "That's an important thing to say, but we eventually want to be more precise. Whether that's possible, I don't know—that work is just beginning. But now that we [better understand] these climate signals, we're making headway."

At Florida State, Elsner suspects that future hurricane models will use a combination of physics (to get a handle on current and future climate conditions) and statistics (to get a handle on forecast variability). To him, one key to making more precise long-range forecasts could be to look even further into the past, possibly using hurricane data that's been preserved in tree rings and rock deposits.

At University College London, Saunders is building his hurricane model into a financial analysis model, so that his insurance clients can test its effectiveness at forecasting their financial risk. He believes progress must be made on the meteorological side of hurricane forecasting, and also in methods for linking forecasts to business and industry.

The insurance industry is acutely aware of how such forecasts affect business, and following Katrina, they may pay even more attention. Financial experts suspect that by the time the total losses are tallied, the hurricane might have driven some insurers out of business.

"If the insurance and reinsurance companies responsible for paying the estimated record-breaking US$40 to 60 billion claims from Katrina had bought extra reinsurance cover in early August based on the [Tropical Storm Risk] forecast, many would now be facing much smaller losses," Saunders said in an email following the hurricane. "The same is also true in 2004. The 2004 and 2005 hurricane seasons have demonstrated the skill and value of seasonal hurricane forecasts."

Katrina, the costliest hurricane on record, will also change the way the US prepares for natural disasters. The insurance industry, to sustain itself, might change, too.

In the end, that's the point of insurance—it must be reliable so that when disaster strikes, we can start over again.

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