Perfecting the Storm

The Evolution of Hurricane Models

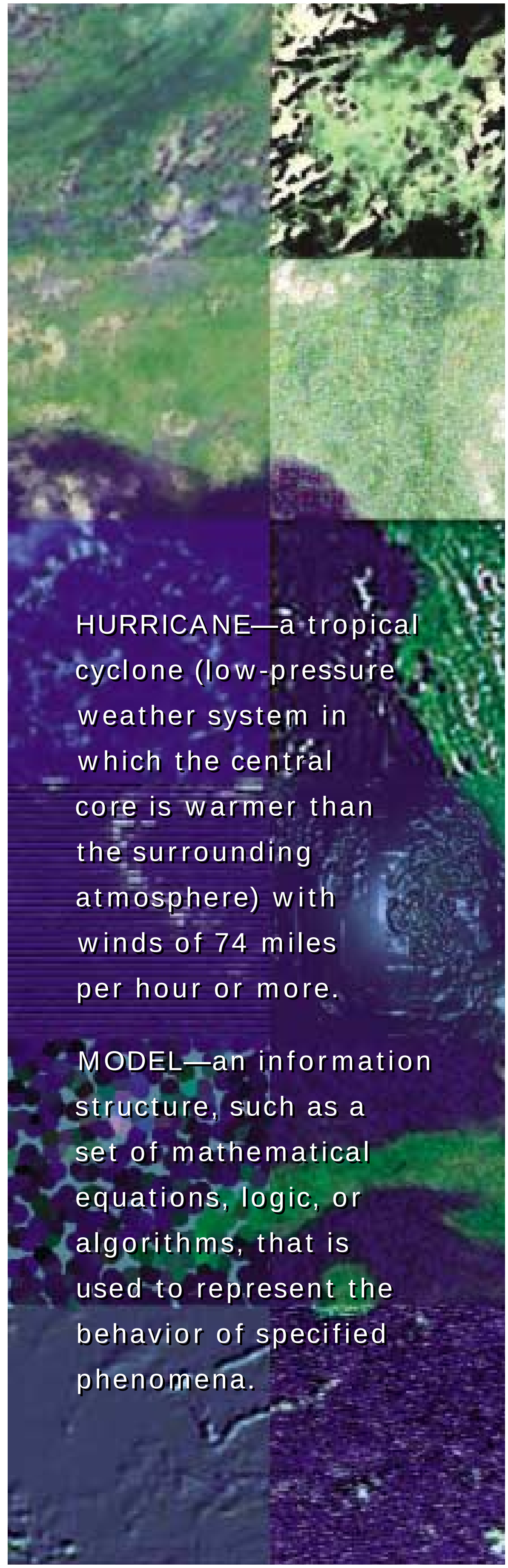
Hurricane models have become gradually more sophisticated over the last 15 years, but they're not without controversy. How do models work, how are they used, and what are some of the issues that hurricane modelers and the users of the models face?

By Charles S. White and Paul E. Budde

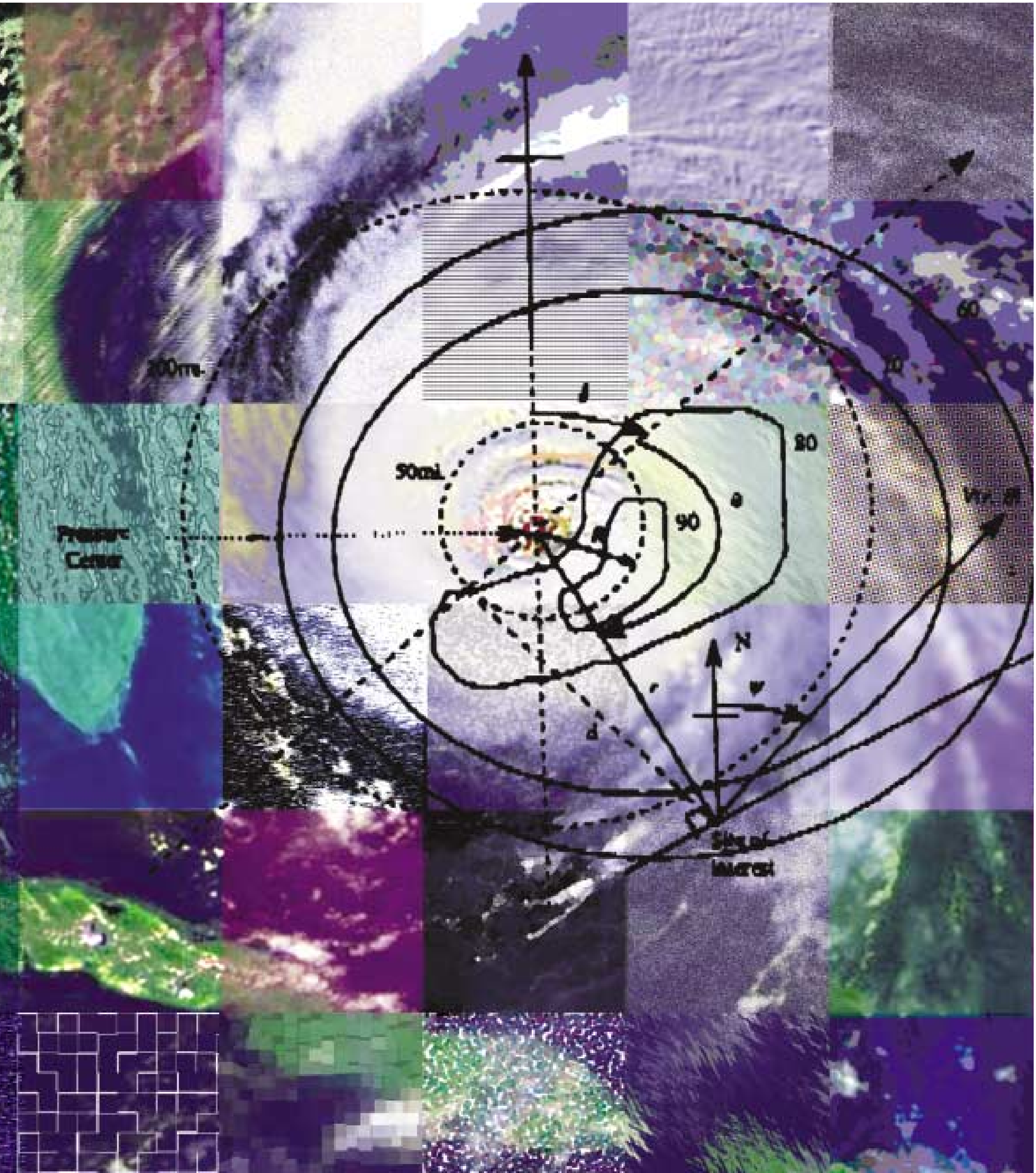
EVERYBODY TALKS ABOUT THE WEATHER but nobody ever does anything about it. Mark Twain was right, of course, but only up to a point. Though we're definitely getting better at it, we still can't predict the weather with pinpoint, infallible accuracy. But the more we know about the meteorological forces that affect us, the better we are at preparing for them. And now, after a long process of intensive study, trial and error, and intuitive leaps, we can also use computers to model them, helping to make it less likely that a single "perfect storm" will wreak financial as well as physical havoc.

Before the mid-1980s a number of methodologies were used to estimate insurance and reinsurance coverages for catastrophic events. These included a variety of rule-of-thumb approaches and tabular methods that were largely based on judgment. One of the more analytic methods related to the catastrophe loads used in primary insurance pricing.

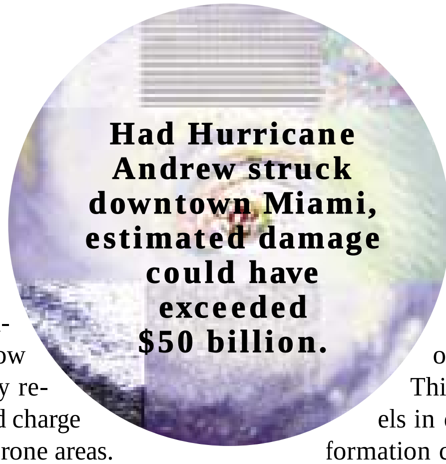
Estimating the catastrophe load for a property insurance rate filing in a given state and line of business (homeowners, commercial fire, etc.) required analyzing a 30-year history of large wind losses. An average amount was selected to anticipate the expected statewide cost of catastrophes, without considering that some areas of a state were more prone to losses than other areas. This general approach is still used to make estimates for catastrophe perils that aren't generally modeled, such as hail, tornado, and winter freeze.



BonoTom Studio Inc.



200mi.
50mi.
Pressure
Center
90
80
60
70
N



By the mid-1980s, some people were uncomfortably aware that the insurance industry didn't adequately understand its exposure to catastrophic loss due to events such as hurricanes and earthquakes. It could not accurately judge how much reinsurance a company should purchase, how much exposure a company was actually retaining, and how much a company should charge its insureds for coverage in catastrophe-prone areas.

Why? Primarily because the historical record of catastrophic losses was, and is, relatively short. Using the available losses, especially for low-frequency events such as hurricanes and major earthquakes, was problematic. The increase in population density (from 1960 to 1990 the population density more than doubled in the Atlantic coastal areas of North Carolina, South Carolina, Georgia, and Florida) and the corresponding growth of building density, along with increasing values for buildings and their contents, made past insurance losses less and less predictive.

From 1988 to 1995, for example, the value of insured property in Florida's coastal areas rose from $566 billion to $1 trillion. In addition, homeowners insurance coverages expanded. New items were covered, along with higher relative values of items replaced through replacement-cost coverage. What could be done to better estimate the potential for catastrophic losses?

While there are a number of different types of catastrophic events, hurricane was the first to be looked at in a new way. The first efforts to integrate different disciplines into one model centered on a joint venture between Karen Clark, who later formed Applied Insurance Research (AIR), and E. W. Blanch (EWB). From this came Karen's groundbreaking paper in the 1986 *Proceedings* of the Casualty Actuarial Society.

In 1987, AIR and EWB introduced the first hurricane model. Risk Management Solutions (RMS) introduced its first hurricane model in 1993. EQE introduced a model in 1995. EWB introduced its Catalyst 3.0 model in 1998. Applied Research Associates (ARA) introduced its model in 1999. TOPCAT from Tillinghast was introduced in the early 1990s. It has been discontinued. [Impact Forecasting; REI]

Even with the introduction of a model in 1987, the insurance industry didn't embrace catastrophe modeling. The industry's attitude changed on August 24, 1992, when Hurricane Andrew came ashore near Homestead, Florida, causing $15.5 billion of insured loss. Before Andrew, the largest loss considered possible was less than half the cost of Andrew and almost double the size of the largest loss the industry had ever faced (Hurricane Hugo, 1989).

Andrew caused 12 companies to become insolvent. A million homeowners policies were dumped into the newly created Florida Residential Property and Casualty Joint Underwriting Association. Clearly, the old methods weren't working. From this point forward, modeling became the normal means of estimating catastrophic exposure to hurricane losses.

In 1995, the Florida legislature created the Florida Commission on Hurricane Loss Projection Methodology to review hurricane models for ratemaking in Florida. The commission developed standards for models and an enforcement system that includes on-site examinations by a professional team. This allows the commission to review the models in detail while modelers keep proprietary information confidential. The commission currently accepts five models for use in Florida.

In 2000, the Actuarial Standards Board adopted two related actuarial standards of practice. The first is No. 38, *Using Models Outside the Actuary's Area of Expertise (Property and Casualty)*. This standard addresses the use of models, such as hurricane models, that "incorporate specialized knowledge outside of the actuary's own area of expertise."

The second standard is No. 39, *Treatment of Catastrophe Losses in Property/Casualty Insurance Ratemaking*. This standard provides "guidance to actuaries in evaluating catastrophe exposure and in determining a provision for catastrophe losses and loss adjustment expenses in property/casualty ratemaking."

Models Today

Developing hurricane models involves three general disciplines:

- *Meteorology.* Understanding, analyzing, and modeling hurricane frequencies, paths, and the winds they produce
- *Engineering.* Understanding, analyzing, and modeling the effects of winds and windborne debris on building structures and contents; estimating the time necessary to rebuild structures.
- *Insurance*. Understanding the coverages provided by insurance policies and reinsurance treaties that protect primary insurance companies.

Storms are simulated based on historical data from meteorological observations of tropical cyclones beginning in the late 1800s. Most models are developed by dividing the Atlantic and Gulf of Mexico coastlines into 50- to 100-mile segments. Though only several hundred hurricanes have made landfall in the continental United States during the past 100-125 years, storm sets simulating as many as 50,000 years of activity are developed. A large number of storms are necessary for the models to smooth out historical results.

Had Hurricane Andrew struck downtown Miami, for example, just 25 miles north of Homestead, estimated damage could have exceeded $50 billion. One can make a strong case that it was pure luck (for the insurance industry, not the people of Homestead) that Andrew made landfall where it did. Hence, the historical storm set isn't representative of the potential losses from hurricanes. A much larger simulated storm set is needed.

The important parameters that define each simulated storm are:

- Measures of location and duration, such as landfall location, heading, and forward speed
- Measures of storm intensity, such as the central pressure dif-

ference (difference in atmospheric pressure at the center of the cyclone and in the ambient atmosphere)

■ Measures of size, such as the radius to maximum winds.

Segment by segment, modelers sample parameters of historical storms that have made landfall to derive probability distributions for these parameters. They calculate a likelihood of occurrence for each simulated storm.

Once a modeled storm makes landfall, a filling rate model is used to estimate its weakening. A wind-field model describes the wind speed at points away from the storm track. Finally, a wind-profile model adjusts the wind speed at ground level to account for the effects on winds of topography, vegetation, and human-built features. The end product is the speed of the wind striking the insured properties.

The second component of a model is a set of damage functions that translates maximum sustained wind speeds into property damage. These functions vary by such features as construction materials, height and age of building, type of occupancy, and the presence (or absence) of damage-mitigation features such as storm shutters. Occupancy is used to estimate what sort of contents are in a structure.

The age of a building can indicate the standards to which it was constructed. Last year, for example, Florida adopted the Uniform Statewide Building Code to strengthen codes for buildings constructed in areas threatened by 120 miles-per-hour or greater hurricane winds. Future buildings constructed to these standards should have damage functions that reflect their reduced vulnerability to wind.

The third component converts damage estimates for property losses into insurance losses. It applies deductibles and policy limits, and can include retentions and limits of any reinsurance. Models are usually flexible and can handle fairly elaborate insurance and reinsurance structures, such as aggregate deductibles over multiple locations. Most models can distinguish between single- and double-landfall hurricanes. The double-landfall hurricane presents problems in pricing reinsurance when a single retention might be applied to a storm making landfall more than once.

To assess the risk of hurricane damage for a particular set of properties, an insurer supplies a modeler with an exposure database. This file contains information describing the properties and must be compiled into a format compatible with a particular model. As a basic starting point, the insurer must supply information concerning the location, construction of the property (frame, masonry, etc.), insured value of property by type of coverage (building, contents, appurtenant structures, loss of use), and policy deductible.

Missing or invalid data elements are inferred based on their characteristics in an industry database, or using the company's own database. Modelers associate a latitude and longitude with each property, using either the street address of the property or the geographical or population-weighted centroid of the ZIP code in which the property is located.

Output from an analysis can be as detailed as the amount of total loss and insured loss for each simulated event. When combined with the likelihood of each event, a modeler can calculate the expected annual loss for a particular set of insured properties.

Another statistic insurers are interested in is the size of the 100- or 250-year probable maximum loss (PML). This is the dollar value of the largest loss an insurer might expect to incur annually with probability 1% or 0.4%.

Before and After

Models in use today have changed from the first generation. Some of these adjustments have grown out of modelers' continued efforts to improve the accuracy of their product. End-users have been affected by two other advances.

First, models are becoming more user-friendly. Early models were all run in-house by professionals. Today's models are often released to insurers or other users so they can analyze their exposures more flexibly. Insurers can also go online and run models on their data.

Second, current models are faster. While analyses on early models often took all night to run, today's faster computers can produce more timely results. Along with their improved accuracy, however, today's models perform many more calculations to analyze a book of business.

Design changes to the software have also had a significant effect on speed. For example, some models can be run distributively, employing several desktop computers to accomplish an analysis. This has significantly reduced the time required for the largest analyses. Preprocessing of data has also enabled modelers to provide insurers with loss estimates almost immediately after a hurricane strikes.

Uses of Models

Insurers, reinsurers, insurance rating agencies, and government agencies use catastrophe models in a number of different areas of risk and financial management.

■ *Assessing and managing risk.* Insurers need to be able to estimate potential catastrophic losses. For insurance to work well, a company must adequately diversify its risks. Catastrophe models enable underwriters to guard against concentration of risk and optimize the spread of risks. Even today, model results are being incorporated into underwriting workstations, providing underwriters with an immediate analysis of a policy's cat risk.

■ *Designing risk transfer programs.* A. M. Best, a rating agency that assesses insurer financial strength, applies a stress test as part of its review of an insurer's financial strength. Best reduces a company's surplus by the net after-tax catastrophe loss from a 1-in-100-year hurricane to see its effect. Models are used to identify the risks and risk levels that a prudent company needs to transfer through the use of reinsurance, catastrophe bonds, or other risk transfer mechanisms, to reduce the impact of such an event on its surplus.

■ *Pricing risk and risk transfer.* When actuaries calculate the premium for an insurance policy, one of the components in a hurricane-prone state is a load that's intended to cover this exposure. Models are the best means available to quantify those potential losses, both at a primary level and when an insurer itself wants to transfer some or all of its risk to other financial entities. This risk transfer is usually achieved through the purchase of reinsurance. A new market is developing, however, for what are called "cat bonds," which move some of the risk into the larger financial market. In either case, catastrophe model results are central to the calculation of a fair price for such products.

■ *Allocating capital and expenses.* To evaluate the performance of different segments of an insurance company's book of business, a company must allocate surplus and assign costs to various programs or divisions. Modeling has allowed companies to improve their allocations.

■ *Dynamic Financial Analysis (DFA).* Any reliable DFA analysis for insurance companies with a significant catastrophe exposure must include potential cat losses in order to properly measure the impact of reinsurance agreements and the volatility of company earnings.

■ *Post-hurricane planning.* After a hurricane has occurred, models provide an early estimate of the losses that might soon be reported to them. Such information is very useful for planning where and for how long to deploy claims personnel, knowing which assets to liquidate, and estimating loss reserves.

■ *Loss mitigation.* Governmental agencies and insurers want to reduce the potential for hurricane losses. By modeling specific measures such as storm shutters and comparing these results with the costs of their implementation, insurers can estimate the most cost-effective means for loss mitigation.

Model Challenges

■ *Government accreditation of models.* Though the Florida Commission on Hurricane Loss Projection Methodology provides outside review and certification without loss of proprietary information, modelers are in the position of trying to meet the demands of someone other than their direct customers, something that almost always creates friction.

■ *Accuracy.* Prospective analyses of future hurricane risk are, for all practical purposes, impossible to verify because the time scale for events is so long and because hurricanes making U.S. landfall are so infrequent (averaging 1.6 per year over the last 100 years). Even single events give only an indication of accuracy, not a specific assessment of accuracy. A model may not measure some effects of a storm well, but this may not reflect how accurate the model is overall.

Many model estimates of Hurricane Andrew, for example, are below what was actually reported to insurers for at least two reasons. First, many damaged properties weren't built to code. Second, due to the sudden jump in demand for services and materials, the prices insurers paid for these services and materials rose significantly (often referred to as demand surge).

■ *Differences among models.* Florida regulators especially are concerned about the variations among models. The Florida Commission on Hurricane Loss Projection Methodology provides all of the modelers with two common sets of exposure data. The following table shows modeled losses for the models the commission has accepted for use in 2000 using one of these sets, in this case an artificial data set.

These results should not be considered indicative of how the models' results would compare if a different set of exposures were analyzed. They do, however, illustrate that there are differences in the results. While differences are expected, regulators and companies face the challenge of determining rates that will directly impact consumers' pocketbooks. Essentially, should the use of one model versus another influence how much consumers pay for coverage?

■ *Differences between different versions of the same model.* As modelers adapt their models for new information, new approaches, and new assumptions, the modeled results change. This is expected. But what if the modeled results of the newer version vary significantly from the prior version? These revised results will impact measures such as probable maximum loss and changes in expected loss costs, both overall and in specific locales such as individual ZIP codes or counties. This may be important for actuaries since one of the considerations in ratemaking is stability in rates, but stability isn't a specific consideration in modeling.

■ *Frequency of parameter updates.* How often should modelers update the parameters used in their models? Many modelers feel their models are robust enough to accommodate updates to the parameters based on another year or two of historical storm data. The Florida Commission on Hurricane Loss Projection Methodology recently decided to require adjusting parameter distributions and re-simulating annually to incorporate one more year of historical storm data.

■ *Using Multiple Models*. If a company uses two or more models, how should the data from multiple models be combined to arrive at a single estimate of average annual loss or probable maximum loss? One possibility is that each of the models is viewed as equally correct so the average should provide the best answer. Another is that one or more models might be more biased than the others. In this case a method that focuses on the median results or drops the highest and lowest estimates might be more appropriate. This use of multiple models is a way to address some of the practical issues caused by differences between models.

■ *Modeling newer constructions*. With the push toward more wind-resistant buildings, one of the future challenges for modelers is to incorporate a variety of mitigation devices into their damage functions. Storm shutters were the first wind mitigation device that modelers adjusted for. Other important construction enhancements to be incorporated into models include

- *Hurricane straps.* Used to tie down roof trusses and rafters
- *Secondary water resistance.* Rubber or asphalt sheets applied to roofing deck seams to reduce water penetration once the primary protection (shingles) are blown away
- *Garage construction.* Particularly on homes with attached garages, the garage door is the largest opening into the home. Does the garage door have shutters? Is it impact resistant?
- *Number of sliding glass doors.* Are these glazed to make them impact resistant? Are there shutters on the doors?

■ *Large-scale climactic changes.* How seasonal are hurricanes? While we can't predict where a particular tropical cyclone is headed, large-scale climactic phenomena can be used to predict their general patterns of frequency in a coming year. Dr. William Gray of Colorado State University has pioneered work in this area.

Just within the last few years, we've experienced both El Niño years, which have generally produced few major hurricanes, and La Niña years, which have been more active than normal. Can we fine-tune models to adjust their storm sets for the coming year based on climactic data?

The period from 1960 to1990 was particularly low in the frequency and severity of hurricanes. Currently it appears that we're leaving this calm era for a more standard period. Will we be able to predict such multi-year eras in the future? If so, should modelers fine-tune their models to make them year-specific?

Even if models can be so fine-tuned, actuaries and risk managers will have to decide when it's appropriate to use such fine-tuned information. Ought the price of a homeowners policy in Miami vary from year to year, depending on whether we're in an El Niño or a La Niña cycle?

Hurricane models have come a long way in a short time. Their use has been widely accepted for pricing, reinsurance analysis, and other related uses. While there may be issues that modelers and users have to deal with, it's clear that hurricane models provide the best tool for analyzing exposure to loss from hurricanes and answering related questions. The continued growth in the number of modelers will provide competing variations in methodology and competition in developing the latest information to improve the models' results and their ease of use. ●

Charles S. White is senior vice president and actuary for E.W. Blanch in Minneapolis; **Paul E. Budde** is vice president and associate actuary for E.W. Blanch.