The New U.S. Earthquake Models: A Wake-up Call to Actuaries?

By Karen Clark

INTRODUCTION

Earlier this year, the two major catastrophe modeling companies, AIR and RMS, within a day of one another announced releases of new earthquake models for North America. The new model versions, based partly on the 2008 U.S. Geological Survey National Seismic Hazard Maps, produce significantly reduced loss estimates for most regions of the United States. While the amount of reduction varies by model, by region, and by type of business, most companies with significant earthquake exposure will see reductions in loss estimates of at least 20 to 30 percent.

Implemented as is, these changes will have enormous implications for company risk management decisions, including earthquake underwriting, capital allocation, and reinsurance purchasing. Company capital requirements will also change if the rating agencies, such as A.M. Best, continue to rely on point estimates of the modeled 250 year earthquake losses in their assessments of financial strength and capital adequacy.

The new earthquake models are just the latest indicators of the fallacy of basing business decisions on point estimates from models with such significant uncertainty and instability. Due to the paucity of earthquake data, particularly in regions outside of California, the catastrophe models cannot provide reliable point estimates of the probabilities of large earthquake losses. The models can provide plausible scenario losses, but there is not enough scientific data to estimate with any degree of accuracy the probabilities of these large losses.

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The new research on which the updated models are based is part of ongoing scientific investigations that will lead to future significant changes, quite probably back up, in the earthquake model loss estimates. This paper explains why and calls for a more advanced and robust approach to catastrophe risk management.

WHY THE MODELS CHANGED

The earthquake models have three primary components—hazard, engineering, and loss. For the U.S. earthquake models, the hazard component is based largely on the U.S. Geological Survey (USGS) National Seismic Hazard Maps. The USGS seismic hazard maps have been revised every six years since 1990 to reflect research that has been published in the intervening years. The first probabilistic seismic hazard map of the United States was published in 1976 by Algermissen and Perkins.

While the maps themselves have not changed radically since 1976, the process for updating the maps has become more sophisticated. Major enhancements have been the inclusion of more published research, additional peer review, and a better, more explicit recognition of uncertainty. For the 2008 report, there were "hundreds of participants, review by several science organizations and State surveys, and advice from two expert panels." The first formal workshops for the latest report were held in 2005.

The conclusions of the 2008 report end with the following statements: "The 2008 National Seismic Hazard Maps represent the 'best available science' based on input from scientists and engineers that participated in the update process. This does not mean that significant changes will not be made in future maps. We plan on holding several workshops over the next several years to define uncertainties in the input parameters and to refine the methodologies used to produce and distribute the hazard information." The report then lists 11 specific recommendations for ongoing research.

NEW MADRID ILLUSTRATION

The potentially most destructive U.S. seismic zone outside of California is the New Madrid Seismic Zone (NMSZ). A series of large earthquakes occurred along the Mississippi River valley between Northeast Arkansas and New Madrid, Missouri in the winter of 1811-12. The largest quake, occurring on Feb. 7, 1812 destroyed the town of New Madrid, and hence the name of this important seismic source zone. While the exact magnitudes of these events are not known, they are believed to be of the largest magnitude events ever to impact the continental United States. While the area was only sparsely populated at the beginning of the 19th century, if these events were to occur today millions of people and trillions of dollars of property value would be impacted. Insured losses could easily exceed $100 billion.

What little information scientists know about these historical events has been derived from newspaper and personal accounts of the damage the earthquakes inflicted. These accounts were used by Otto Nuttli to create the first isoseismal map of the events in 1973, and later work by Arch Johnston formed the basis of the 1996 Seismic Hazard Maps for this region. In this early work, the estimated magnitude used to represent these series of events was 8.0. Since there are no known accounts of other major earthquakes in this region, the only way for scientists to estimate the return period of the 1811-12 events is to find evidence of prehistoric earthquakes. They have done this using paleoliquefaction studies.

When large earthquakes occur, layers of soil can lose shear strength and behave like a fluid. The water pressure in the liquefied layer can cause an eruption of liquefied soil at the ground surface, often resembling a volcano. This can carry large amounts of sand to the surface, covering areas tens of feet or more in diameter, and creating what are known as sand boils. Sand boils on the surface are evidence of recent earthquakes and sand boils buried by sediment over time are evidence of prehistoric earthquakes. Paleoliquifaction studies find the buried layers of sand and attempt to date when an earthquake may have occurred in the past and caused those features. Early paleoliquefaction studies indicated a return period of 1,000 years for events of the magnitude of the 1811-12 series.

By the time of the 2002 report, however, there was a range of expert opinion on both the return period and the maximum magnitude of these events. For the 2002 National Seismic Maps, a logic tree was introduced to weight four possible magnitudes. Along with scientific debate on the maximum magnitude, new paleoliquefaction evidence suggested that the return period might be considerably shorter than previously assumed and on the order of 500 years rather than 1,000 years. The other important component of seismic hazard, ground motion, was also updated in the 2002 report. Specifically, following the logic tree approach, five ground motion attenuation functions were weighted as opposed to two in the 1996 report.

The NMSZ logic tree again expanded in the 2008 report with additional ground motion models, five hypothetical fault scenarios instead of three, more uncertainty around the magnitude, and the introduction of temporal clustering. Evidence suggests that large earthquakes in the NMSZ have occurred in sequences of three events similar to the 1811-12 series. There are four different clustered scenarios in the report, and the clustered and unclustered models are each given fifty percent weight in the logic tree.

Figure 1 shows how the NMSZ assumptions have evolved over time. It's clear that the updates to the seismic hazard maps, rather than being based on definitive new information, are based on new research that reflects the wide uncertainty in this region. Different scientists, using the same limited data, can and do come to very different conclusions. This is illustrated by the multiplying branches of the logic tree and the more explicit treatment of uncertainty. This is the uncertainty underlying the catastrophe models.

THE FALLACY OF RELYING ON CATASTROPHE MODEL POINT ESTIMATES

Clearly, the fallacy and danger of basing risk management decisions, such as capital requirements and reinsurance purchases, on point estimates from models with such inherent uncertainty is indisputable. Yet the current practice is for the catastrophe modeling companies to take the science in the USGS reports, perform their own analyses (different for each modeling company), and update their models to produce new Exceedence Probability (EP) curves. Current modeling practice is for insurance companies to then use point estimates from the new EP curves to make important risk management decisions. One could make the case that this is modeling "malpractice" on the part of the insurers.

To be more explicit using the New Madrid example, there have been only a handful of loss-producing earthquakes in

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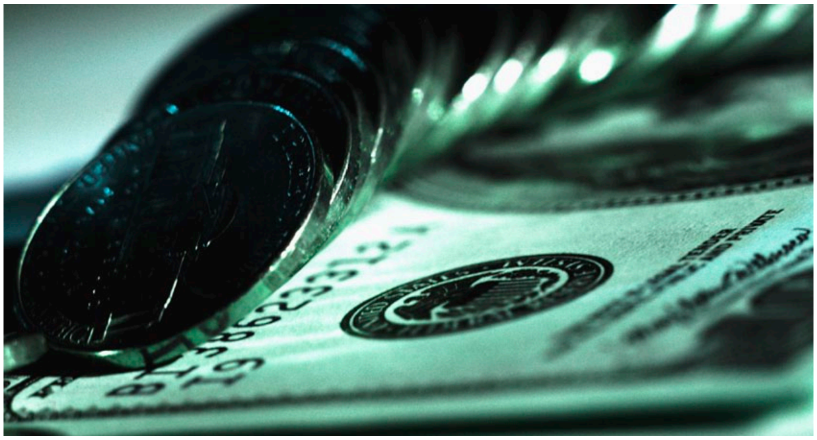

the central United States over the past 200 hundred years. Scientists do not know the magnitudes, exact locations or return periods of these events. Any first year statistics student can tell you that you cannot develop a reliable probability distribution from so few data points with unknown parameters, yet that is exactly what the catastrophe models are attempting to do. Based on this scant data, the catastrophe models are giving companies 1 in 100, 1 in 250 year and other "tail" loss estimates and probabilities frequently with two or more decimal point precision!

To most insurance company executives, the catastrophe models are "black boxes" that spit out answers. There is no transparency around the limited data and wide uncertainty around the model assumptions. Of course, the catastrophe models are far better than the simplistic rules of thumb used before there were models. But certainly we can do better than blindly following the ever-changing numbers produced by the black boxes. The industry is overdue for a more advanced and robust approach to catastrophe risk management.

A MORE ADVANCED AND ROBUST APPROACH

The credibility of the model results can be no greater than the credibility of the least accurately known model component. In the earthquake models, the most uncertain assumptions are the return periods of the large magnitude events and the ground motion those events would cause. While this paper has discussed the NMSZ, this is true for the Pacific Northwest, California and other seismic zones in the United States.

Instead of trying to pinpoint a loss at a particular probability level, which is an exercise in false precision, insurance companies should evaluate a set of representative scenarios for each seismic zone in which they have significant exposure. Insurance companies should have transparency on how their losses change along different branches of the logic trees. They should also have transparency on the estimated loss "footprints" and apply reasonability tests using other information.

A more robust approach to catastrophe risk management utilizes fixed event sets of representative loss scenarios rather than ever-changing "PML" estimates. If, in fact it is possible at all, it will be many decades before the models have significantly less uncertainty with respect to the earthquake peril. In the meantime, fixed event sets allow management to develop and implement effective catastrophe risk management strategies over time.

The U.S. earthquake model updates clearly indicate that it's time for a paradigm shift. It's time to start thinking outside the black box. By now, model users should be sophisticated enough to use information from the catastrophe models intelligently and in conjunction with other information to make more credible and robust risk management decisions. A more balanced, holistic approach that combines the skills of catastrophe modeling, actuarial science, and financial risk management is what insurance companies need to develop and maintain profitable books of catastrophe-exposed property business. ✦

Figure 1: USGS Seismic Hazard Map Assumptions for the New Madrid Seismic Zone (Numbers in parenthesis are weights)

	1996	2002	2008
Fault Sources	3	3	5
Recurrence Interval (Years)	1,000	500	*Clustered (0.5) ** 750,1500 (0.45) 500 (0.45) 1,000 (0.10) *Unclustered (0.5)* 500 (0.90) 1,000 (0.10)
Magnitude	8	7.3 (0.15) 7.5 (0.20) 7.7 (0.50) 8.0 (0.15)	*Clustered (0.5) ** 7.1, 7.3 (0.15) 7.3, 7.5 (0.20) 7.5, 7.7 (0.50) 7.8, 8.0 (0.15) *Unclustered (0.5)* 7.3 (0.15) 7.5 (0.20) 7.7 (0.50) 8.0 (0.15)
Ground Motion Models	Toro, et al (0.5) Frankel, et al (0.5)	Toro, et al (0.25) Frankel, et al (0.25) Atkinson and Boore (0.25) Campbell (0.125) Somerville, et al (0.125)	Toro, et al (0.2) Frankel, et al (0.1) Atkinson and Boore (0.2) Campbell (0.1) Somerville, et al (0.2) Tavakoli and Pezeshk (0.1) Silva, et al (0.1)

** Two magnitudes reflect assumptions for different fault scenarios*

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