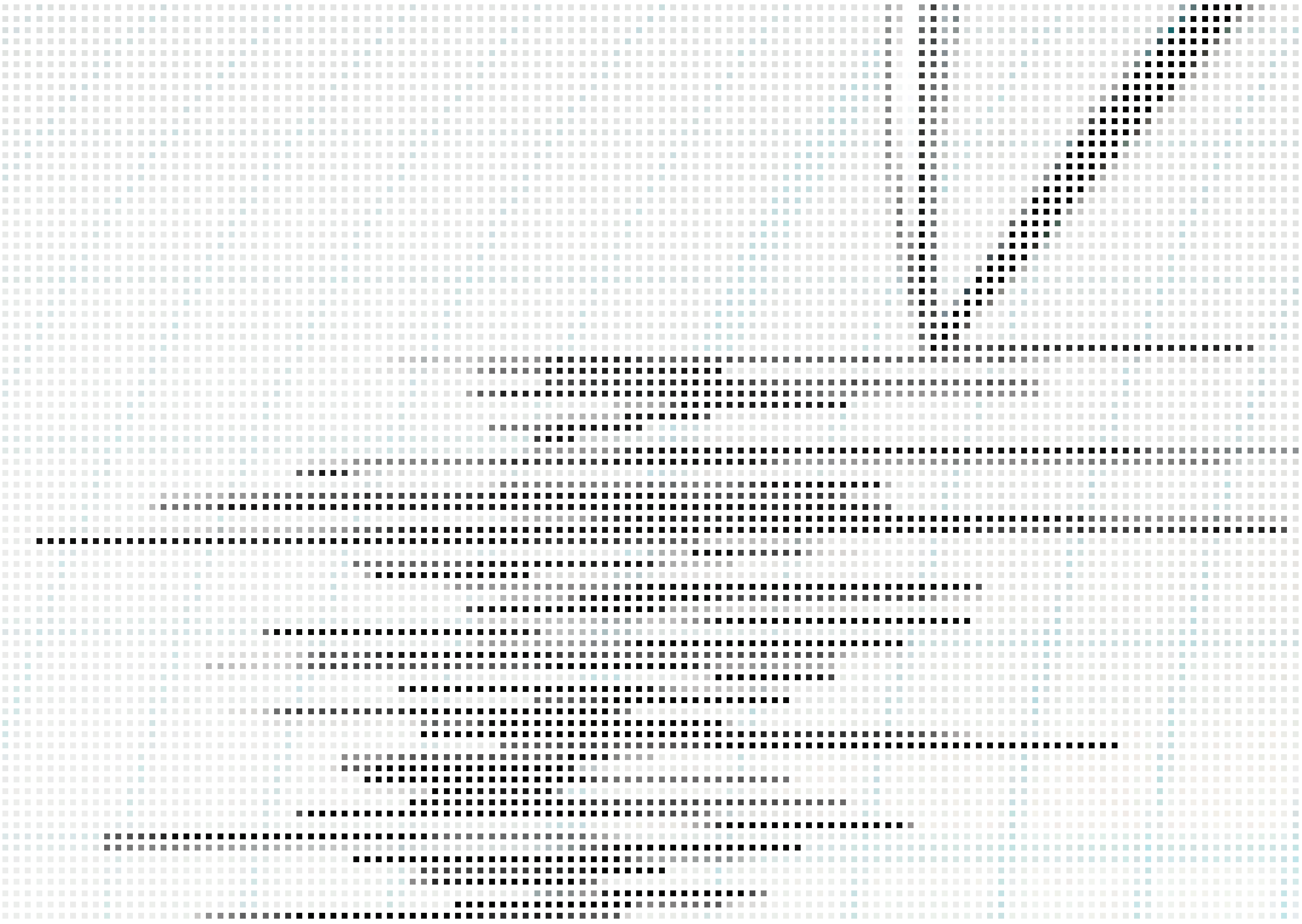


After the Mainshocks: Incorporating Aftershocks into Risk Assessment

Don't underestimate your earthquake risk.

TOKIO MARINE
T M R

Introduction

Following a large earthquake event, it is important for (re)insurers to understand the heightened seismic risks due to the possible aftershock sequences. Past experiences (e.g., the 2010–2011 New Zealand earthquake sequence and the 2011 Tōhoku earthquake sequence) have shown us that aftershocks can be as severe as, or sometimes more damaging than, the mainshock itself, depending on the magnitude, the time elapsed since the mainshock and the location of the aftershocks.

Currently, these aftershock events tend to be neglected in traditional (re)insurance pricing, largely because catastrophe modeling firms have typically explicitly excluded aftershocks in their traditional earthquake models. This is primarily because vendor earthquake models were originally developed using the traditional Probabilistic Seismic Hazard Analysis, closely following the parameters and methodology adopted by the U.S. Geological Survey (USGS) national seismic hazard mapping project.

The drawback is that the USGS seismic hazard analysis aims to predict the long-term seismic hazard. Although it considers the long-term time-dependent earthquake risks (e.g., the recurrence period of a characteristic event), it neglects the short-term time-dependent seismic risk caused by aftershocks.

This paper aims to highlight the importance of considering aftershock risk, and to show how to incorporate aftershocks into risk assessment and calculate the resulting financial impact on insured and economic losses.

Methodology

At TMR we simulate the spatiotemporal seismicity patterns of earthquake sequences, including aftershocks, by using the Epidemic Type Aftershock Sequence (ETAS) model, one of the most widely used statistical models for description and forecasting of seismicity.

The ETAS model assumes that every event, regardless of whether it is a Poissonian background event or an aftershock-triggered event, generates its own offspring independently. The expected number of direct offspring is an increasing function of the magnitude of the “mother” event. The elapsed times of the triggered events after the mother event follow Omori’s law (smaller earthquakes tend to follow larger events and the aftershock rate will decay as a reciprocal of time after the mainshock). This is what defines the productivity of aftershocks following a mainshock, and the magnitude distribution of triggered events follows the Gutenberg-Richter law (the relationship between the earthquake magnitude and annual frequency of exceedance). The spatial distribution of triggered events is typically assumed to follow an inverse power law decay away from the mother event.

The ETAS model, in essence, reflects the fundamental observation that aftershocks tend to cluster near and after a mainshock.

Hypothetical Aftershock Scenarios in Northern California

The U.S. Geological Survey examined a hypothetical scenario (termed the HayWired Scenario) in which a magnitude 7.0 mainshock occurred on the Hayward Fault with its epicenter in Oakland, California. Aftershocks are also simulated following the large mainshock. By adopting the same approach, we can simulate similar hypothetical but scientifically plausible scenarios, with an emphasis on the effects of aftershocks.

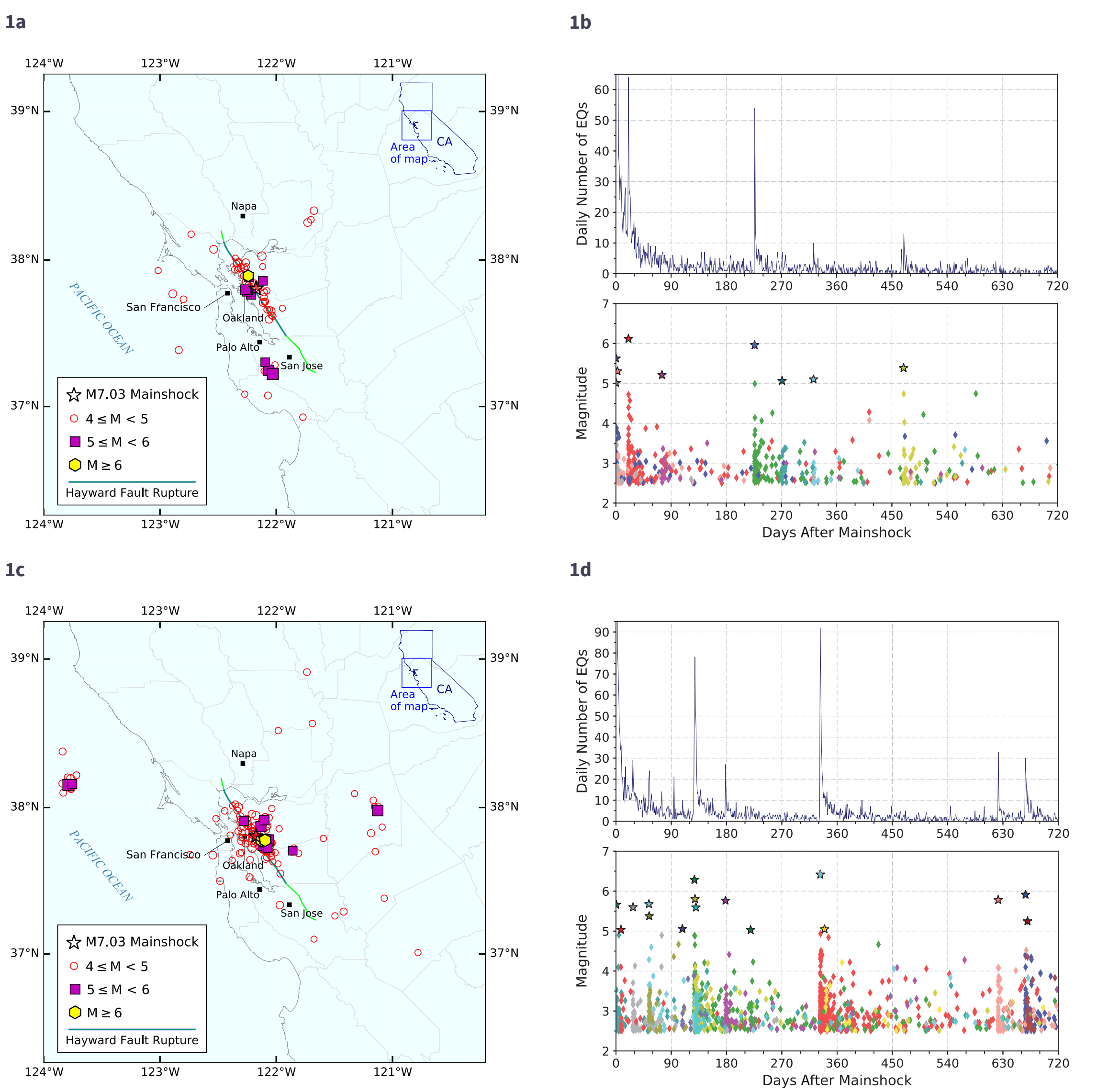
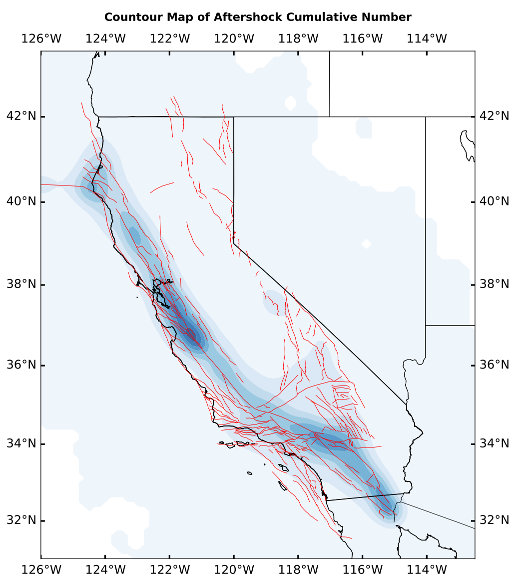


Figure 1. Two scenario simulations of aftershock sequences following a magnitude 7.0 mainshock on the Hayward Fault in Oakland, California, using the ETAS model. Plots on the left (1a and 1c) show the spatial distribution of the aftershocks. Plots on the right (1b and 1d) show the time series of aftershocks with quick rate decay after the mainshock and how they are clustered over time following Omori's law. The star symbols indicate the occurrence of large aftershocks (magnitude ≥ 5.0) that trigger a prominent sequence of aftershocks of their own. The magnitude values of aftershocks can also be seen from figures 1b and 1d.

Aftershock Loss Impact from Application to California

At TMR we use the latest Epidemic Type Aftershock Sequence parameter values from the U.S. Geological Survey UCERF3-ETAS (Uniform California Earthquake Rupture Forecast v3) study for our aftershock simulations. These aftershock simulations are based on a catastrophe risk model's California Year Event Table and Industry Exposure Database. The simulations show that the Aggregate Exceedance Probability loss inflation caused by earthquake aftershocks goes from zero to approximately 30% in the low return period (ranging from zero to 100 years) and is capped around 50% for return periods up to 1,000 years.

2a



2b

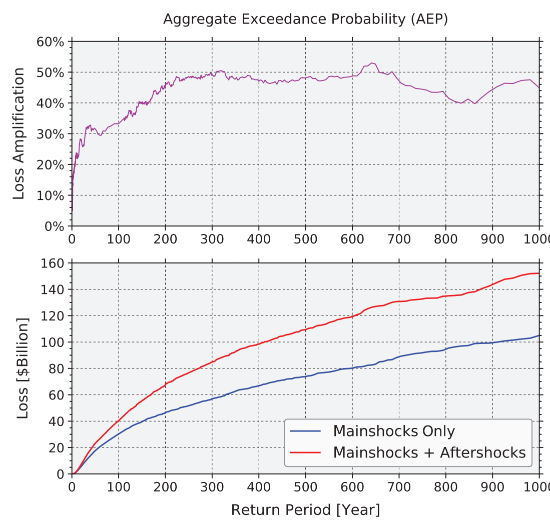


Figure 2. The plot on the left (2a) shows the smoothed annual frequency of aftershocks for California when using a catastrophe model's stochastic catalog for the mainshocks. The plot on the right (2b) shows the potential industry loss impact, when considering the mainshock alone and when aftershocks have been incorporated into risk assessment.

Conclusion

The potential impact from aftershocks could have an adverse effect for the (re)insurance sector and ultimately for societies, amplifying potential losses across a much larger exposed area. The aftershock sequence could have its own clustering of events farther away from the mainshock, causing higher potential losses – as seen in the 2010–2011 New Zealand earthquake sequence, when damaging aftershocks clustered far away from the mainshock but closer to the main population region.

Neglecting the risks from spawning earthquakes could have undesired consequences: underestimating risks, pricing and risk selection – and ultimately resulting in insufficient capital reserved to withstand the financial impact from the full earthquake sequence. TMR has long been focused on its own view of risks, aiming to understand, differentiate and more accurately quantify the risks than is possible with the generic model view.

With TMR's Epidemic Type Aftershock Sequence approach, the simulated aftershock sequences can be incorporated more explicitly into a stochastic catalogue. TMR can then directly embed this stochastic catalogue into its internal pricing platform to assess seismic risks with greater precision. Similarly, when a large earthquake occurs, a conditional stochastic catalogue can be constructed to properly reflect and quantify the heightened short-term seismic risk. This would help an underwriter or risk manager to distinguish risks within the vicinity and properly assess and manage those risks.

TMR believes in improving science and understanding and in differentiating risks. Our company has invested heavily in analytics and research both internally and externally, working with respected academic institutions. With our advanced internal view of risks, TMR can ultimately deploy its capital so that it meets risk appetite more effectively.

Published by
Tokio Millennium Re AG
Beethovenstrasse 33
8002 Zurich,
Switzerland

Tokio Millennium Re (TMR, as we've come to be known in the reinsurance industry) was originally established by Tokio Marine Group in Bermuda in 2000 to diversify the Group's risk portfolio and address a worldwide need for reinsurance capacity by providing, primarily, property catastrophe reinsurance. We have continued to expand and diversify our business through broader product offerings and wider geographical locations. We now maintain our headquarters in Switzerland with branch offices in Australia, Bermuda, the U.K. and the U.S.

Since its founding, TMR has been recognised for its long-term vision, deep technical skill and proactive customer relationships. Tokio Marine Group's "Good Company" philosophy enables us to continually look beyond profit to do what is right for our customers. This view is supported by our analytical orientation, and backed by our financial strength, which facilitates our ability to remain agile and hit above our weight. Further, we are empowered to be proactive in our partnerships to come up with the best solution for your unique reinsurance case.

Experts
Dr. Polsak Tothong, Vice President, Catastrophe Pricing, +1 441 278 4461
Dr. Zheqiang (Sam) Shi, Lead Risk Modeler, Tokio Marine Technologies, +1 678 942 2713

References

Detweiler, S.T., and A.M. Wein, editors. "The HayWired Earthquake Scenario." U.S. Geological Survey Scientific Investigations Report 2017–5013, 2017. https://doi.org/10.3133/sir20175013.

Field, E.H., et al. "A Spatiotemporal Clustering Model for the Third Uniform California Earthquake Rupture Forecast (UCERF3-ETAS): Toward an Operational Earthquake Forecast." Bulletin of the Seismological Society of America 107, pp. 1049–1081, 2017.

Hardebeck, J.L. "Appendix S: Constraining epidemic type aftershock sequence (ETAS) parameters from the Uniform California Earthquake Rupture Forecast, Version 3 catalog and validating the ETAS model for magnitude 6.5 or greater earthquakes," U.S. Geological Survey Open-File Report 2013-1165-S, and California Geological Survey Special Report 228-S, 2013.

Helmstetter, A., and D. Sornette. "Importance of direct and indirect triggered seismicity in the ETAS model of seismicity." Geophysical Research Letters 30, no. 11, pp. 1576, doi: 10.1029/2003gl017670, 2003.

Ogata, Y. "Statistical models of point occurrences and residual analysis for point processes." Journal of the American Statistical Association 83, pp. 9–27, 1988.

Ogata, Y. "Space-time point-process models for earthquake occurrences." Annals of the Institute of Statistical Mathematics 50, no. 2, pp. 379–402, 1998.

Reasenberg, P.A., and L.M. Jones. "Earthquake hazard after a mainshock in California." Science 243, pp. 1173–1176, 1989.

Reasenberg, P.A., and L.M. Jones. "Earthquake aftershocks: Update." Science 265, pp. 1251–1252, 1994.

Graphic design
Agenda