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SEISMIC HAZARD AND ANNUAL AVERAGE LOSS

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SUMMARY

A worldwide operating Reinsurance Company has to be aware of the possible loss levels that can be expected from natural catastrophe events and must determine the expected loss costs stemming from different natural perils. The estimation of such costs for building structures and the peril earthquake is dependent on many different parameters. These range from constructional features, specific to local construction technology to local soil conditions, regional geology and seismic activity. Although recent years have seen many improvements in the capture of insured risk data by primary insurance companies, this information does not always find its way through to the reinsurer.

In many countries, e.g. USA, Japan, New Zealand there are well known published methodologies for the creation of seismic hazard maps and these approaches have been used by commercial model vendors to create relatively sophisticated Catastrophe models, which when combined with good risk data have led to market confidence in modeling results. However, in wide areas of the world only aggregated information about insured values is available to the reinsurer and published seismic hazard information is comparably primitive or nonexistent. Consequently PartnerRe has developed pricing tools based on a uniform, catalogue based, approach to Seismic Hazard estimation. Within the pricing model framework the preliminary assumptions in any given region are an average soil type and geology. The construction quality can normally be defined on the same aggregated level as the insurance exposure values are delivered. Aggregation levels are normally per country or per political sub zone / CRESTA-zone of a country.

The results of the hazard analysis presented here show the annual average loss costs for a typical residential building with average construction type/quality built on average soil conditions not taking into account any insurance conditions.

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INTRODUCTION

In 1968 C.A. Cornell established the basic principles for probabilistic seismic hazard assessments (PSHA). He introduced a methodology, which was based on magnitude - frequency distributions and on the variability of attenuation relations. It is still the basis for many hazard models. The simplicity of the computational model was ideal for the available computing capacity when it was developed but has however some drawbacks regarding the seismicity definition. Usually the seismic activity within one source zone is not uniform unless the source zone is very small. Therefore the methodology was refined over the years and in some areas such models now incorporate multiple source zones, parameter smoothing, active fault lines etc (USGS Open file report 96-532). Since GSHAP source zone models are available almost for every country but the degree of details is sometimes not very high.

Alternatives have been proposed and implemented based on the Kernel methodology and comparisons of the two methodologies show good accordance in areas with medium to high seismicity (Probabilistic seismic hazard analysis: zoning free versus zoning methodology, S. Molina, C.D.Lindholm, H.Bungum, Boll. geof. Teor.Appl.,42). The great advantage of this method is the fact that it doesn't need the definition of source zones. This zoning free method was used for those areas where we didn't have access to a detailed zonal model.

PartnerRe has created a worldwide simulated earthquake catalogue and based on this catalogue, generated a world earthquake rate map. The earthquake rate indicates the ground up annual average loss at any given point on the globe in per mil (‰) of the insured value under very general assumptions regarding construction-/building types, average soil type and excluding any insurance conditions such as deductibles and limits. Bearing in mind these assumptions, although absolute numbers are displayed, this map is better as a relative rather than absolute indicator of risk. At the same time as the rate maps, a set of hazard maps, showing ground shaking intensities for various return periods were generated. The ground shaking maps are used to check the hazard part of the model against findings from other sources (GSHAP, SESAME, HAZUS etc).

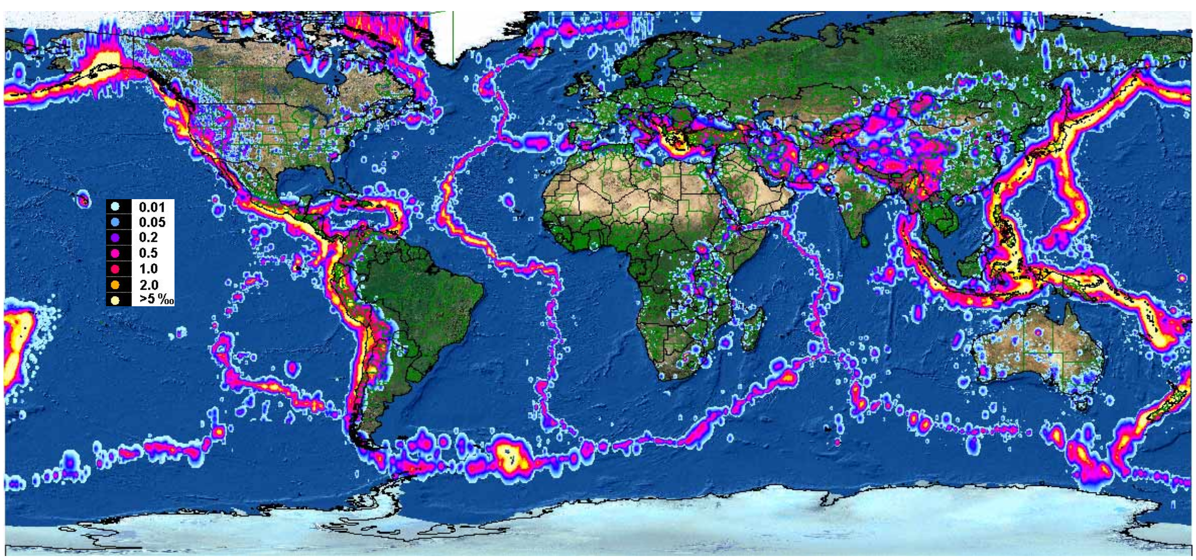


Figure 1: Annual average loss expressed in per mil (‰) of the insured value.

When it comes to contract pricing hazard maps are of little use to the reinsurer. This is because the deductibles and limits built into typical reinsurance contracts ensure that only a small subset of events trigger payments. This means pricing has to be done using event-based simulation, which has the advantage of making it easy to perform summation across a portfolio of reinsurance. Individual events are simulated using standard attenuation functions to calculate the intensity of the ground motion at various distances from the sources. Any such model must implement, as far as possible, the best practice for each location worldwide. Earthquake events are created using Monte Carlo simulation based on the parameters defined in the seismic zonation. For each potentially damaging earthquake a ground motion map must be produced using standard attenuation functions and local soil conditions. Vulnerability is modeled based on ATC13, or modified ATC13 or based on more recent published damage studies and actual claims experience. These data can then be combined with client portfolio information within the standard model interface, and used to produce prices.

EQ CATALOGUES AND EVENT-SET GENERATION

1 Source data

The world map (Fig 1.) was calculated using a worldwide-simulated earthquake catalogue. It consists of catalogue subsets that were simulated according to local standards using refined source zone modeling.

Alternatively we used a smoothed historical seismicity model in areas with poor seismic hazard information. This zoning free method was also applied in the European area where a detailed zonal model exists but we haven't been able to implement it yet.

USA:

The US catalogue was modeled according to the methodology described in the USGS open file report 96-532.

Canada:

The Canadian EQ catalogue simulation methodology is fully consistent with the Geological Survey of Canada (GSC) hazard methodology outlined in Adams et al. 1999 (GSC OF-3724) and is representing simulated activity for the whole of continental Canada.

New Zealand:

The New Zealand catalogue represents an event set which is consistent with the hazard methodology developed by the Institute of Geological and Nuclear Sciences Ltd. in their NZ seismic hazard model.

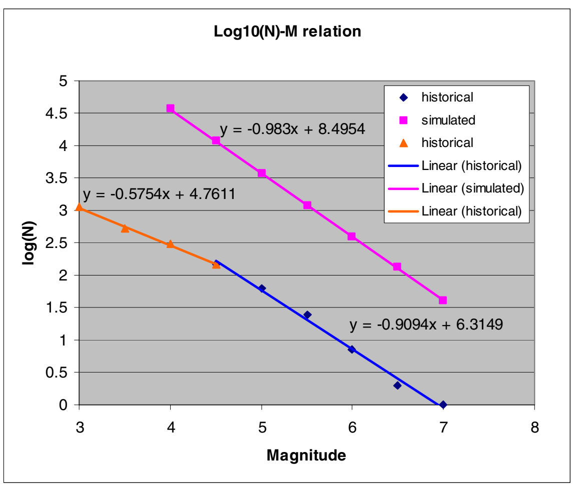
Europe:

The European event set is based on a combination of local historical earthquake catalogues (the earthquake catalogue of Switzerland ECOS and the Italian historical earthquake catalogue) combined with the ISC catalogue and the CNSS catalogue. The different sources and different time periods they are covering had to be considered individually for the regions where the catalogues are valid.

Rest of the world:
The stochastic event set for the rest of the world was created based on the ISC catalogue data for the time period from 1904 to 1997. Data for the time period from 1997 to 2001 was added from the CNSS catalogue.

We found problem zones in areas where two simulated catalogues overlap, when different seismic source parameters were used to generate the simulated events. This is a problem for example in the area of Seattle and Vancouver where the USGS and the GSC methodology produce significantly different results. We found that the final price for a reinsurance cover for a portfolio in this area can differ by a factor of five depending on the event set that was used.

2 Event Set Generation "Rest of the World and Europe" (Example: Australia)
The Australian simulated catalogue represents 10'000 years. The simulation was carried out based on the assumption that the ISC catalogue is more or less homogenous for Australia in terms of the detection level for different time periods and also magnitude levels. The historical catalogue was used to calculate the theoretical number of earthquakes that would be occurring in 10'000 years in the region of interest.



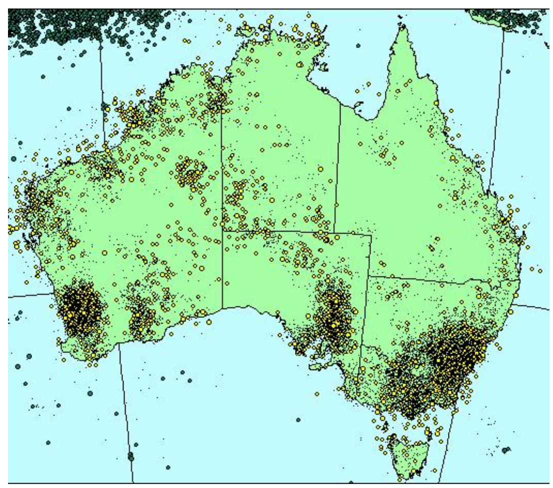


Fig. 2a Log(N)-M relation (simulated&historical) Fig. 2b spatial distribution of simulated EQs

Figure 2a shows that between Magnitude: 4.5 and 7 the historical ISC catalogue follows closely the Gutenberg Richter relation log(N) = a - bM with a b-value of 0.91. Below magnitude 4.5 the b-value is only 0.58, which means that, low magnitude events have not been detected. The b-value of 0.91 (Fig 2a) for the Magnitude range between 4.5 and 7 suggests that there are still some events of lower magnitude missing this is probably because over the last 100 years, when the EQ events were recorded, the detection threshold became gradually lower. This corresponds to the observation, that at the beginning of the observation period in 1904 an event had to reach higher magnitudes to be detected than today (The seismometer density has been increased and possibly the seismometers are more sensitive today). Because of this gradual change in sensitivity no "step" is visible the data.

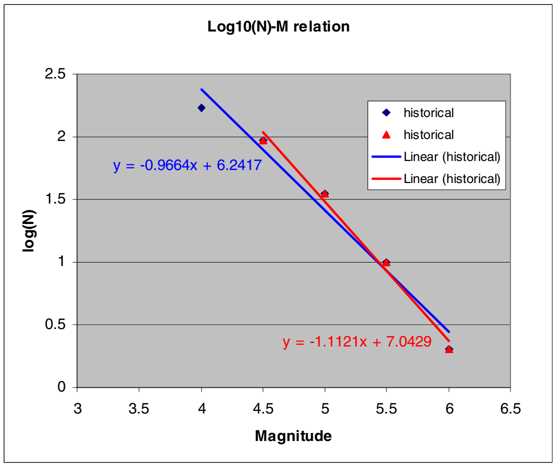


Figure 3:

The historical catalogue shows b-values of 0.96 for the magnitude range from 4 to 6 and 1.11 for the range from 4.5 to 6 in the time period starting 1970 until today. We simulated a b-value of close to 1 and accounted for the missing earthquakes by estimating the number of earthquakes that would have happened in the specified time period of 95 years of the historical catalogue by also using a b-value of 1 for the historical data.

Modeling assumptions:

1) The historical EQ catalogue is complete for M>4

2) Covered time period:	1906 to 2001
Number of EQ >4:	353
Number of years:	95
Simulation period:	10'000 years
Resulting number of simulated EQs	37'158

The simulation included all historical events contained in the ISC catalogue (also events with magnitude < 4). We assumed that the detection threshold of the ISC catalogue for the Australian continent is more or less constant, and thus the location information from the small events could also be utilized. This is important because we assume that both micro and macro-seismic events are indicating places with increased seismic hazard. On the other hand, considering all registered earthquakes will highlight areas where the detection threshold is higher because of local seismograph networks. The more sensitive a network is the smaller the events that can be localized. We assume the seismograph density is highest where earthquakes happen and also where people are living. This means, from an insurers perspective, we can cover the important areas.

We used a Gaussian kernel to simulate the new event set based on the historical seismic data. Similar procedures to estimate the long-term seismic hazard were proposed by Kagan & Jackson 1994 and 1999, by Frankel et al 1996, by Console R. 1998 and other authors.

We experimented with different degrees of spatial smoothing and finally used smoothing parameters dependent on the tectonic area. For the intraplate earthquakes on the Australian continent a standard deviation of 75 km delivered good results. Smaller values were suitable for subduction zones. Additionally it would be desirable there to use an azimuth dependent standard deviation to account for the defined tectonic structure, where the spatial variation is not the same perpendicular and parallel to the subduction zone. In our current models rather than directly modeling this anisotropy we decreased the standard deviation of the Gaussian kernel to around 15 km. This preserves the shape of the subduction zone, which is already well defined in the original data of the instrumentally recorded earthquake catalogue.

3 Simulated Event Specification

The hazard calculation is based on individual events using standard attenuation functions to calculate the intensity of the ground motion at various distances from the sources. The events are modeled as line sources therefore the simulation included a "structural model" that describes the prevailing directions of fault traces. The azimuth of the individual events was randomly changed with a maximum deviation of 10 degrees from the main fault direction, defined in the structural model.

The fault length assigned to the earthquakes is a function of the magnitude. We used the function

I) $\text{length} = 10^{(0.67*M - 3.05)}$ Wells&Coppersmith for all slip types / continental

for all areas except for Japan where we rely on the equation

II) $\text{length} = 10^{(0.6*M - 2.9)}$ developed by The Research Group for Active Faults of Japan.

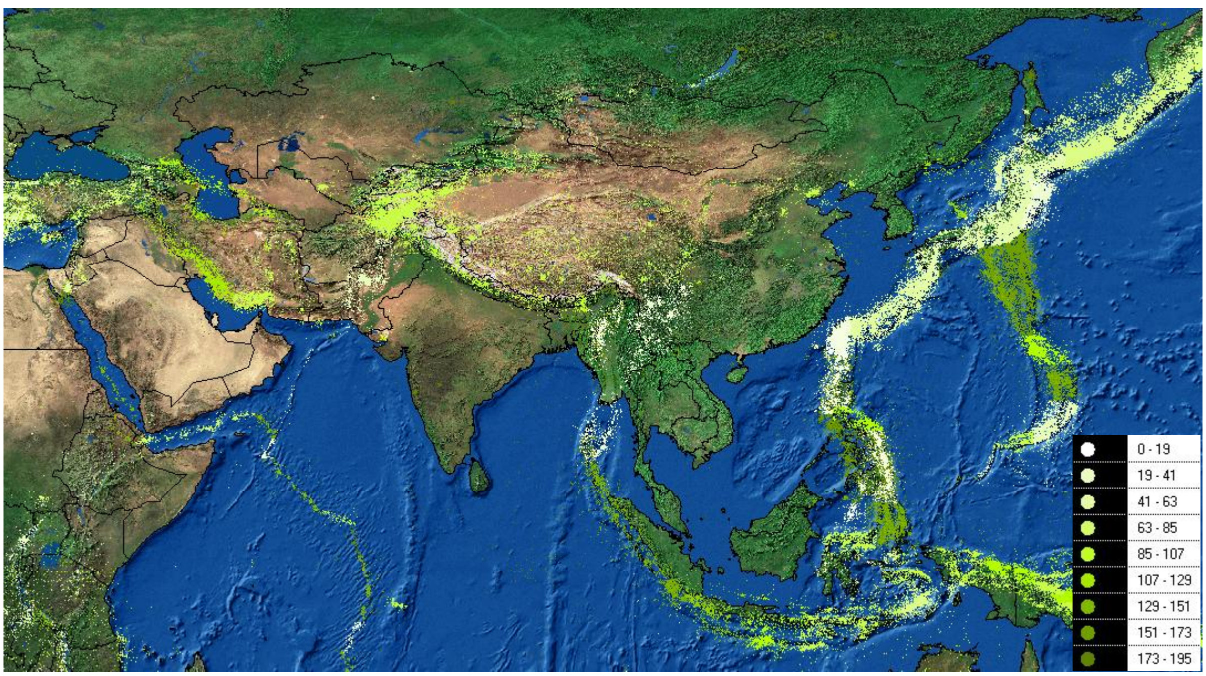


Figure 4: Epicenter map shows the locations of the simulated earthquake-catalogue. The shades of green indicate the direction of the fault trace.

4 Conclusion

It is essential for a globally operating reinsurance company to know as much as possible about the frequency and severity of earthquake occurrences anywhere on earth. The classical methodology to determine the earthquake risk is a probabilistic seismic hazard assessment . For us, the challenge is that this has to be done globally. PartnerRe has developed an in-house software shell to perform PSHAs on insurance portfolios. This software uses synthetic earthquake catalogues to define the earthquake hazard.

It is therefore mandatory to have this type of information available for all countries. The presented combined earthquake catalogue provides this information and forms the basis for PartnerRe's earthquake hazard assessment tool.

Alongside our own tools we are able to run simulations using vendor models, and with this information the CAT underwriting team can assess the required premium levels to quote/accept for portfolios of earthquake-exposed risks. There is considerable modeling uncertainty, and often parameter uncertainty inherent to all pricing models, and in this context the simplicity of the global model discussed in this paper is an advantage. We control the assumptions, understand the data inputs, and are aware of the range of the plausible results we could produce by adjusting those assumptions.

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