Methods how to improve Japanese national seismic hazard models

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The national seismic hazard models (NSHM) of Japan has been published since 2005. It took 10 years since we started an effort to make the first Japanese NSHM after the 1995 Kobe earthquake. One of the main reasons why we needed NSHM in Japan was that a scientific knowledge that any area in Japan would experience a strong ground motion should be recognized in public.
As Japan is located in subduction zone, the seismic hazard is high in general but is poorly understood at a specific area and a city. Also there is a large uncertainty in seismic hazard estimate, including epistemic uncertainty in fault and earthquake catalogue and source models, for each region and thus requires significant research. In particular, a testing of the estimate is not well conducted and documented in Japanese NSHM. It is about 20 years since the Japanese NSHM was established and we need to focus on how to test models to improve them.

Keywords: National Seismic Hazard Map

Statistical characteristics of seismicity in the Kanto region detected by the 3D-ETAS model

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We apply the 3D-ETAS model in which the focal depth follows beta distribution to JMA catalog in the Kanto region. By stochastic reconstruction method, we find that the deep main shocks tend to trigger aftershocks at larger time and epicenter ranges than shallow main shocks. To the east of 140.5° E, the shallow main shocks are more productive, while it seems the opposite with the western part. The background seismicity increased to about 5 ~10 times in three months following the Tohoku earthquake, but recovered to pre-Tohoku level rapidly except for the shallow part of the east of 140.5° E, where the background seismicity remained about 3 times of the pre-Tohoku level. We carry out the simulation algorithm of the 3D-ETAS model, according to our results, the probability of a M7.0 event in southern Kanto region within 30 years is about 76.8 percent.

What should we be rethinking?

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The title of this session, “Rethinking PSHA,” appears to suggest that there may well be significant problems in PSHA. However, we think that this title understates the true extent of the problems. In a recently published paper (F. Mulargia, P.B. Stark & R.J. Geller, “Why is Probabilistic Seismic Hazard Analysis—PSHA—still used?,” PEPI, 2016, http://dx.doi.org/10.1016/j.pepi.2016.12.002, cited as MSG16 below) we argue that, because its basic assumptions disagree fundamentally with the observed phenomenology of earthquake occurrence, PSHA should be abandoned, rather than just “rethought.”

The case made by MSG16 rests on the following three main points. (1) PSHA makes assumptions that contradict what is known about seismicity. (2) PSHA fundamentally misuses the concept of “probability.” (3) In practice PSHA does not work; many recent destructive earthquakes occurred in regions that PSHA identified as low risk. We hope that researchers who disagree with MSG16 will present detailed arguments, based on physics and observed seismic data, to explain why they disagree.

PSHA allows all of the information provided by geologists and seismologists to be aggregated and used as the input to a “black box” procedure for providing curves that give the relation between ground motion parameters and “return periods” at a particular site. Engineers can then use these curves as the basis for choosing the design parameters of structures without having to get involved in the details of the Earth-science related issues. PSHA thus serves as a seemingly objective “due diligence” procedure, which neatly separates the roles of Earth scientists and engineers. As long as engineers design their structures to meet the specified “return periods” they are regarded as having fulfilled their obligations, as are the various stakeholders (owners, operators, government regulators, etc.). The fly in the ointment, of course, is that even though PSHA has been used for about 50 years its scientific validity has not been established, and, furthermore, as noted by MSG16, it is highly questionable.

In our opinion, what we as a community should be rethinking is not PSHA, but rather the much broader question of how, in view of the great uncertainties, society should be choosing design standards for earthquake-resistant structures. We think the answer does not lie in making minor (or even major) adjustments to PSHA as now practiced and relaunching it, as the problems go far deeper. What has to happen instead is that rather than leaving the choice of earthquake design criteria up to only geoscience and engineering consultants, all participants—including project developers and owners, risk managers, engineers, and architects—have to “take ownership” of the inherent uncertainties of earthquake hazards, rather than simply tasking everything to geoscience and engineering consultants. In recent years administrative procedures in the European Union have adopted what is called the “precautionary principle.” The implementation of this principle in individual cases is still evolving, but it may provide some guidance.

In the past 50 years PSHA has grown into a minor industry, and we recognize that there may be strong resistance to our call for its abandonment. However, the facts must be squarely faced: PSHA is based on flawed physical models, and its hazard forecasts do not agree with subsequent seismicity. That being the case, a new way forward must be sought, starting anew from square one. Given the present inability to reliably predict which regions are particularly at risk, perhaps we should start by identifying seismically weak structures everywhere and then making systematic efforts to replace or reinforce them.

Keywords: Seismic Hazard Analysis, PSHA, Seismic Risk

Synthetic ground-motion simulation using a spatial stochastic model with slip self-similarity

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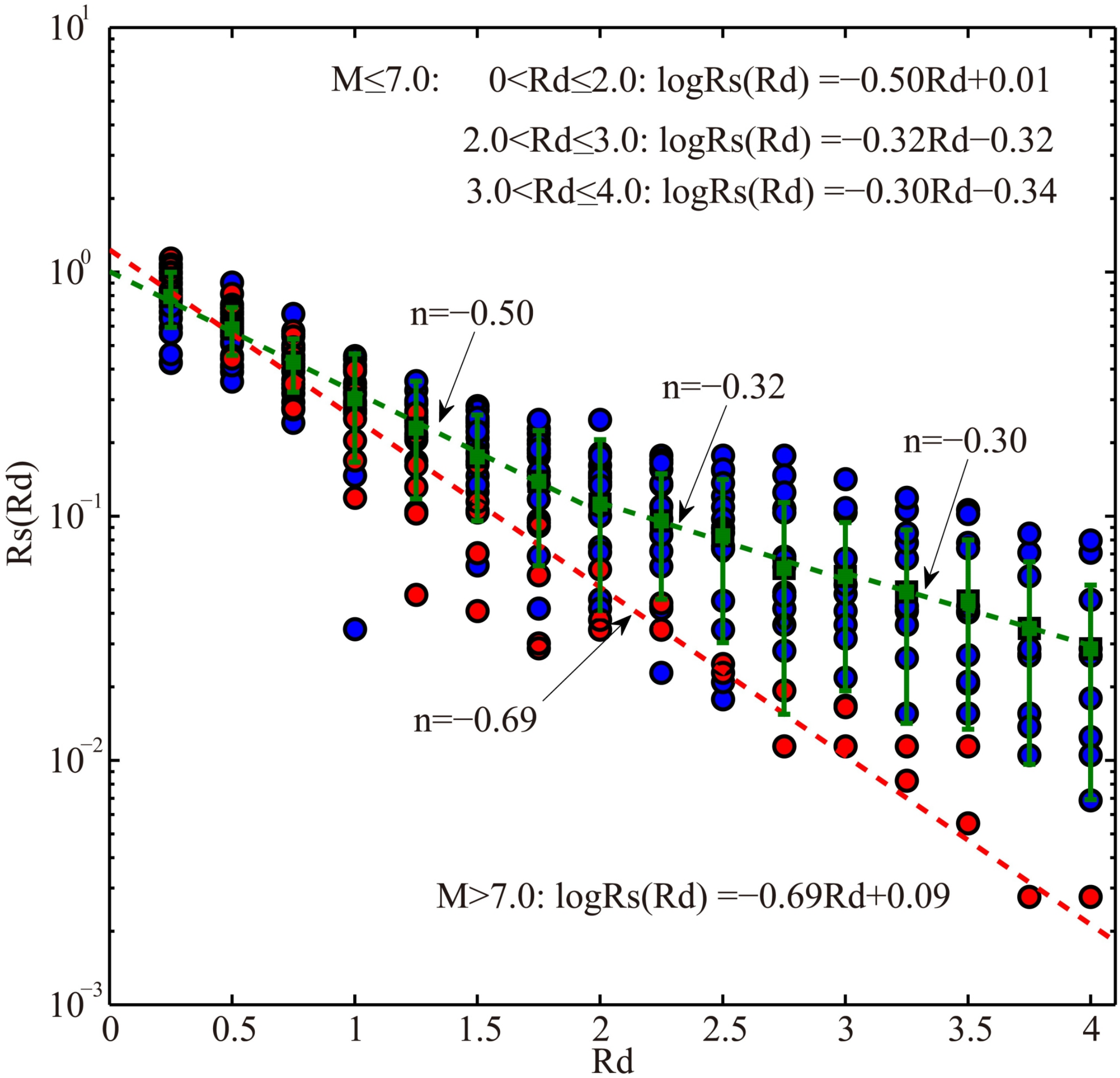
Near-fault ground motion is a key to understand the seismic hazard along the fault, and is a challenge by the approach of ground motion prediction equation. We complied finite fault slip models for earthquakes in the Taiwan orogenic belt and global earthquakes to determine the slip distribution self-similarity. Forty-one earthquakes (19 Taiwan earthquakes and 22 global earthquakes) in the Mw = 4.6 - 8.9 magnitude range were examined. The fault slip exhibited self-similar scaling between the rupture slip and area. We applied the slip-distribution scaling to develop a stochastic-slip-scaling source model, a spatial stochastic model with slipped area scaling toward the ground motion simulation. We considered the near-fault ground motion of the 1999 Chi-Chi earthquake in Taiwan, the most massive near-fault disastrous earthquake, proposed by Ma et al. (2001) as a reference for validation. Three scenario source models including the developed stochastic-slip-scaling source model, mean slip model and characteristic-asperity model were used for the near-fault ground motion examination. We simulated synthetic ground motion through the 3D finite-difference scheme and validated these simulations using observed data and the ground-motion prediction equation (GMPE) for Taiwan earthquakes. The mean slip and characteristic asperity scenario source models over-predicted the near-fault ground motion. The stochastic-slip-scaling model proposed in this study is more accurately approximated to the near-fault motion compared with the GMPE and observations. The stochastic-slip-scaling source model can generate scenario earthquakes for predicting ground motion.

Keywords: self-similarity, stochastic-slip-scaling source model,, ground-motion simulation


M≤7.0: 0<Rd≤2.0: logRs(Rd) =−0.50Rd+0.01
2.0<Rd≤3.0: logRs(Rd) =−0.32Rd−0.32
3.0<Rd≤4.0: logRs(Rd) =−0.30Rd−0.34
n=−0.50
n=−0.32
n=−0.30
n=−0.69
M>7.0: logRs(Rd) =−0.69Rd+0.09
Rs(Rd)
Rd
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Investigating Physical Explanations for Path Effects to Reduce Uncertainty in Ground Motion Prediction Equations

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Reducing uncertainty in ground-motion prediction equations (GMPEs) is important for constructing reliable seismic hazard maps, as well as for the safe and cost-efficient design of critical structures. One way to reduce uncertainty is to move from a "global," average GMPE to a region-specific GMPE. Including information regarding physical or seismological processes into GMPEs may allow a model to be tailored to a particular region, thereby reclassifying some of the aleatory uncertainty as knowable features of the region. We present work on our approach to include path-specific information into GMPEs, and demonstrate the feasibility of this method for future application in GMPEs.

To do this, we employ a database of ~100,000 recordings of earthquakes recorded on four seismic networks including the ANZA network. The ANZA network has been in operation since 1981, resulting in redundancy in source-to-station paths. To obtain a regional GMPE for the Anza region, we inverted the recordings with both simple and mixed effects regressions, and used this GMPE to decompose the residuals between observed and predicted ground motions into source, site and path terms. For each recording, we computed raypaths with the regional tomographic model of Fang et al. (2016). We sampled regional seismic velocity and attenuation models along these raypaths and formed indices representative of the variation in material properties along each recording's raypath. We then compared these indices with the path terms from our residual decomposition, and find a correlation between the path integral of the gradient of velocity and the path term. We present analyses that may be used to further investigate the effects of material properties on the path effect, and how these relationships may be incorporated into GMPEs. Finally, we demonstrate the resulting reduction in uncertainty from incorporation of this path-specific knowledge, which can result in reduced estimated hazard in certain cases.

Keywords: Path Effect, GMPE, Seismic hazard , ANZA network

Is modern PSHA too precise?

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For the last 20 years, the New Zealand National Seismic Hazard Model (NSHM) has been constructed using standard probabilistic seismic hazard assessment techniques. In this algorithmic approach the model is constructed by first combining models developed from earthquake catalogue data and active fault data; these models are assumed to be Poissonian in nature. The combined source model is then coupled with ground-motion prediction equations (GMPEs) to estimate the potential shaking at desired locations. In recent years, there has been considerable progress and improvement in understanding of the uncertainties inherent to GMPEs. In our current work, we are exploring some of the fundamental assumptions of the NSHM and investigating how uncertainties in the earthquake source and ground motion modelling propagate through to the end uses of the model. In New Zealand, a major end-use is the development of the national building design standards. Some uncertainties are not quantified in the present model. These include uncertainties resulting from a paucity of earthquake occurrence data and from different methods that can be used to model the seismic sources. Additionally, seismic sources are generally assumed to be a stationary Poisson process and earthquake clustering is ignored. Here we will explore the impact of including these uncertainties in the NSHM on downstream risk-based applications of the model. Including these uncertainties will likely lead to more robust estimates of risk for use by industry and in the development of design standards.

Keywords: seismic hazard, PSHA, uncertainty