METIS PROJECT: GEM'S CONTRIBUTIONS TO THE HAZARD WORK PACKAGE

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Abstract: *In this contribution, we illustrate improvements made to the OpenQuake (OQ) Engine - the open-source hazard and risk calculation engine developed by GEM - by the GEM hazard and IT teams in the context of the METIS project. These include new approaches for the propagation of epistemic uncertainties, a new approach for the calculation of Vector-valued PSHA, the implementation of the Method 4 proposed by Lin et al. [2013] for the computation of conditional spectra and the ability to compute seismic hazard by considering the contribution of aftershocks.*
Regarding the propagation of epistemic uncertainties, we improved the capabilities of the OQ Engine to process logic trees by adding the option of using a Latin Hypercube Sampling approach in lieu of the more traditional Monte Carlo one and we included the possibility of specifying where to apply the weights assigned to the various realizations admitted. We also proposed a new way to propagate epistemic uncertainties that calculates seismic hazard for each individual source and combines the results in a post-processing phase by using discrete distributions and a convolution approach. This new method is computationally efficient, and it provides results consistent with the ones provided by more traditional approaches.
With respect to the calculation of the Conditional Spectrum, we implemented in the OQ Engine the most complete, rigorous, and complex approach available for the calculation of the spectrum, the so-called "Method 4" from Lin et al. [2013]. We also developed a new approach for the calculation of VPSHA that combines the logic used by the so-called "indirect" approach with a higher precision of the results computed.
The last topic considered is modelling seismic hazard by considering aftershocks' contributions. In this case, we implemented tools for adjusting the rates of existing main shocks based on input models for the OQ Engine to account for the contribution of aftershocks. We added to the OQ Engine functions allowing the computation of hazard using these models.

In the following we provide a brief description of the main improvements made to the OpenQuake (OQ) Engine in the context of the METIS project.

1 Uncertainty Propagation

Regarding the propagation of epistemic uncertainties in probabilistic seismic hazard analysis (PSHA) calculations we worked on two fronts. The first one was to improve the approaches available for sampling the realizations admitted by the logic tree, while in the second we implemented an original approach for efficiently processing the results produced by all the realizations admitted by the logic tree.

Regarding the first point, in addition to the traditional Monte Carlo approach used for sampling the logic tree realizations admitted by the logic tree, we added to the OQ Engine the possibility of using a more efficient approach based on Latin Hypercube Sampling. This sampling approach arrives at a robust mean using fewer logic tree samples but may not reduce the number required for other hazard statistics.

Regarding the second point, we implemented a novel approach that computes separately for each source the results admitted by the logic tree and aggregates the results in a second, post-processing phase. Before this post-processing phase, for each Intensity Measure Type (IMT) considered, the results are converted from a set of hazard curves into a set of histograms each one describing the probability of having a certain annual frequency of occurrence for a given Intensity Measure Level (IML). In the post-processing phase – in the simplest case – we combine each histogram for a given IMT and IML via convolution to obtain the final probability distribution of the annual frequency of occurrence. Using this histogram is then possible to derive of the traditional statistics used to describe hazard results (e.g., mean, median and percentiles).

2 Vector Valued Probabilistic Seismic Hazard Analysis

We added to the OQ Engine a new methodology for the calculation of Vector-Valued Probabilistic Seismic Hazard Analysis (VPSHA) that combines the rigour of the traditional ‘direct’ approach proposed by Bazzurro and Cornell (2002) and the calculation efficiency offered by the ‘indirect’ VSPHA methodology later introduced by Bazzurro et al. (2010). In particular, the new approach implemented used the same concept of aggregating contributions for discrete combinations of parameters used in a probabilistic seismic hazard disaggregation analysis to reduce the number of calculations of the multivariate Gaussian probability distribution functions. The parameters considered in this ‘disaggregation’ matrix are the logarithm of the median ground motion and the corresponding total standard deviation. The OQ Engine creates this matrix in a traditional forward PSHA calculation and uses it in a post-processing phase to obtain the mean-rate density for a combination of IMTs.

3 Conditional Spectrum Calculator

The feature added to OQ Engine in this case is a calculator for the conditional spectrum. We opted for the methodology proposed by Lin et al. (2013) and – more specifically – for the one defined as “Method 4”. With this approach it is possible to compute the most precise and rigorous conditional spectrum.

4 Aftershock Hazard Modelling

The methodology considered to account for the aftershock contribution into a classical PSHA analysis (Cornell, 1968) assumes that all the aftershocks occur on existing ruptures within the seismic source model. Therefore, any existing seismic hazard model suitable for classical PSHA in the OQ Engine can be run with aftershocks considered as well. In addition, we assume that aftershocks follow a Gutenberg-Richter distribution and aftershock productivity follows a model like the one proposed by Feltzer et al. (2004). With these assumptions, for every rupture in the seismic source model we identify the ruptures in its surroundings that describe its possible aftershock ruptures, and we modify the magnitude-frequency distribution of the seismic source involved to account for the occurrence of these additional events otherwise omitted in a main-shock based hazard analysis. Once this pre-processing phase is completed, the hazard analysis proceeds as a traditional one. Figure 1 shows the results computed for the METIS case study, which is a hazard analysis for an idealized site located in the southern part of Tuscany (Italy).

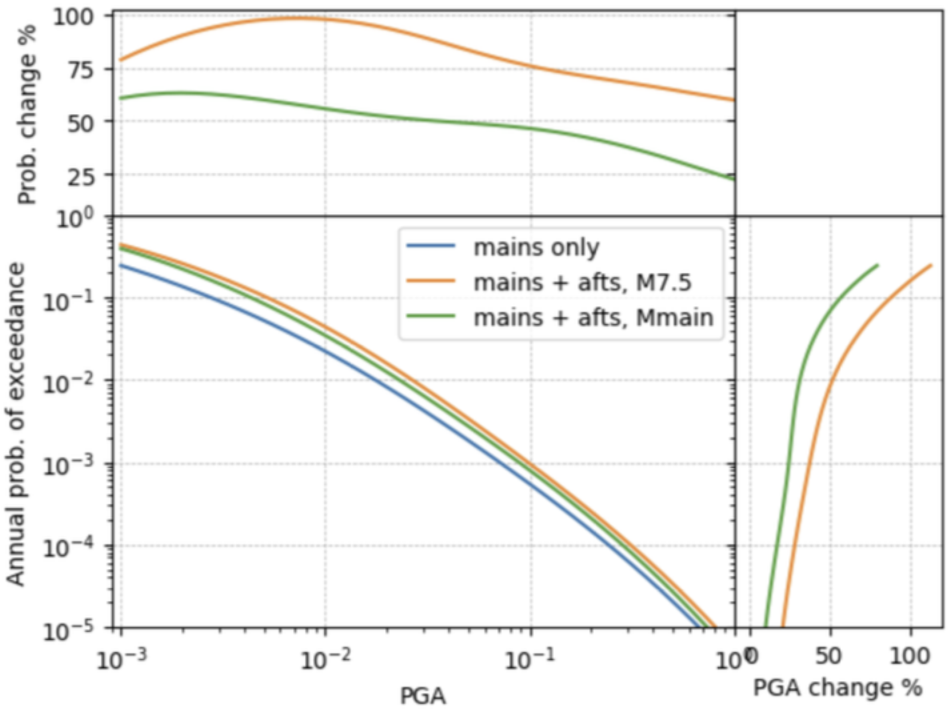

Figure 1. Hazard curves for the METIS test site, considering three scenarios: The mainshock-only hazard curve is shown in blue. The scenario with the aftershock M_{max} = 7.5 for all sequences is shown in orange. The scenario with the aftershock M_{max} = M_{main} is shown in green.

5 References

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