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# Testing the 2020 European Seismic Hazard and Risk Models using observations from the 2019 Le Teil earthquake

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**Résumé.** Les modèles probabilistes pour l'aléa et le risque sismique se consistent de composants, qui peuvent être testés individuellement, mais la validation de ces modèles dans leur intégralité est un défi à cause du manque de méthodes reconnues. Ici nous utilisons des observations des dommages provoqués par le séisme du Teil en 2019, des estimations de tiers pour l'intensité macrosismique, ainsi que des analyses ShakeMap pour tester des estimations faites avec des simulations des scénarios à l'aide du 2020 Euro-Mediterranean Seismic Hazard Model et du European Seismic Risk Model. Dans certains scénarios, les modèles prédisent des intensités et des dommages en accord avec les observations. Quant aux divergences majeures à partir des observations, elles sont attribuées aux facteurs non inclus dans les modèles testés, comme la position de l'hypocentre.

**ABSTRACT.** Probabilistic seismic hazard and risk models consist of components, which may be tested individually, however testing these models as a whole is challenging due to lack of recognized procedures. Estimations made with other models, and observations from past earthquakes lend themselves to testing the components for ground motion modelling and for damage estimation. Here we are using observations of damages caused by the Le Teil 2019 earthquake, third-party estimations of macroseismic intensity for this seismic event, and ShakeMap analyses in order to conduct tests on estimations made with scenario simulations using components of the 2020 Euro-Mediterranean Seismic Hazard Model and the European Seismic Risk Model. In some scenarios, the models forecast shaking and damage consistent with the observations, while major divergences from observations are attributed to factors external to the tested models, such as the location of the hypocenter.

**Mots Clés :** aléa sismique, risqué sismique, estimation des dommages, essais sur modèle

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## 1. INTRODUCTION

Earthquakes are among the disasters with most severe consequences, which include loss of human life, disruption of critical infrastructures, insured and uninsured losses, indirect economic losses, as well as socio-technical impacts in multi-risk safety contexts. As far as seismic hazard and risk in Europe is concerned, the 2020 European Seismic Hazard and Risk Models (ESHM20, ESRM20) [1,2] are the state of the art models, which were created by the European Facilities for Earthquake Hazard and Risk consortium (<http://www.efehr.org/>). The predictive accuracy of the multi-component ESHM20 and ESRM20 models, as that of all seismic hazard and risk models, and as that of all statistical and probabilistic models, should

be tested, despite the fact that the individual components consisting them have already undergone testing.

In this study, to test and compare ground motion models based on the ground motion modelling and its logic tree in ESHM20, we use observations of damage in buildings in the community of Le Teil, France, caused by the 2019 Le Teil earthquake. First, we generated samples for a set of ground motion intensity measures given by scenario simulations based on the ESHM20, as well as based on ShakeMap analyses, for different epicenters reported by different authorities. The distributions of the samples were compared to distributions given by ShakeMap analyses to select the most plausible epicenter solutions. Subsequently, we converted the ground motion intensities to macroseismic intensities using different conversion models. We used the conversions in combination with the macroseismic intensity reported by the BCSF-Réness [3] to identify the most plausible epicenter solutions. In order to test the ESRM20, we used field observations of damage in combination with a building-by-building exposure model based on the set of observations.

## 2. METHODOLOGY AND RESULTS

The scenario hazard analyses were conducted for four different ruptures using the OpenQuake Engine and a GMPE logic tree based on the ESHM20. The GMPE logic tree used consists of the “Shallow Default” branch of the model, which includes 15 branches for different configurations of the adjustable backbone GMPE used in ESHM20. Ground motion fields have been generated for peak ground acceleration (PGA), spectral acceleration at 0.3, 0.6, and 1.0 s for the parts of Le Teil on rock as well as on different soil site conditions.

Figure 2.1 shows box plots for the samples generated for the considered IMs aggregated over all exposure centroids. If we consider at first only the boxplots corresponding to the five scenarios (“CEA”, “EMSC”, “RENASS”, “Ritz et al.”, “USGS”), we see that the dispersion of the samples are equivalent. This was expected because the scenario simulations used the same GMPEs and the same GMPE logic tree. However, the differences with respect to the means of these five IM samples has to be attributed to the differences between the epicenter locations, the depth of the hypocentre, and the focal solution, because these are the parameters affecting the distance between the exposure centroids and the geometry of the rupture. Moreover, the means for the scenarios “EMSC” and “USGS” are consistently the lowest. We attribute this primarily to the hypocentral depths in these two scenarios (10.0 and 11.5 km), which are significantly larger those in the other 3 scenarios, leading to distances from the rupture between 10.0 and 25.0 km, when the corresponding distances in the other 3 scenarios are less than 5.0 km.

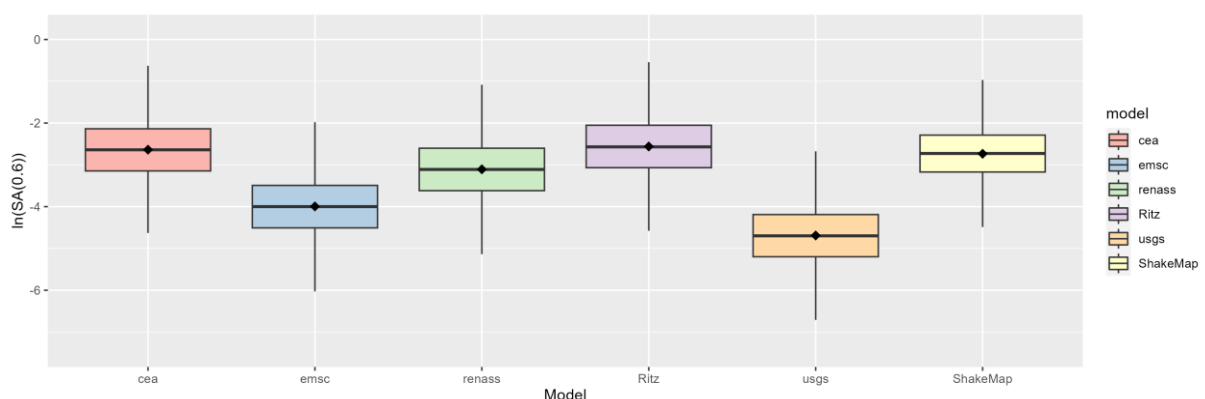


Figure 2.1: Distribution of  $S_a(0.6 \text{ s})$  from the scenario simulations and based on the ShakeMap analysis for rock site conditions

For the comparisons with estimated damage, we used data from the forms in which observations of building damage were recorded during inspections by the AFPS's emergency unit. Using a proposed classification rule, we recoded these observations from a green, yellow and red tagging scheme to EMS98 damage grades. It is the recoded damage observations, which we will be referring to as observations hereafter.

Subsequently, to test the risk model, we compared the damage observations to the damages estimated by damage simulations. The simulations were performed using the OpenQuake Engine, in which the rupture was modelled according to the hypocentral location and focal mechanism, which were identified as the most plausible, while information for the local site effects [4] was taken into account. The exposure model was created based on the subset of the damage observations, for which the damage grade as well as the building type could be determined. Based on the building types, we selected lognormal fragility curves from the set of fragility curves made available by the ESRM20. For each logic tree branch, 1000 simulations were performed to compute average damages per building type, which were then used to compute the weighted average according to the weights in the GMPE logic tree. Figure 2.2a shows aggregate damage probabilities over all building types for one of sets of fragility curves. Finally, we discuss what drives the estimated damage probabilities by using the damage probabilities disaggregated by building type and logic tree branch (e.g. Figure 2.2b).

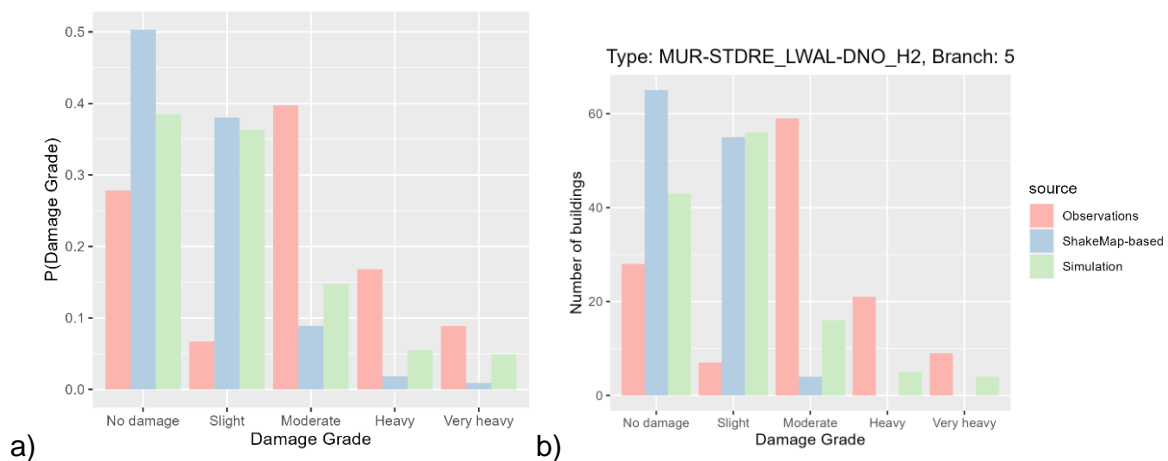


Figure 2.2: Probabilities of damage states according to the observations, the scenario simulations, and based on the ShakeMap analysis a) for all buildings b) for a single branch and for buildings of a single type

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