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Implementing the effect of the rupture directivity on PSHA maps: Application to the Marmara Region (Turkey)

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In the present study we attempted to improve the seismic hazard assessment taking into account possible sources of epistemic uncertainty and the azimuthal variability of the ground motions which, at a particular site, is significantly influenced by the rupture mechanism and the rupture direction relative to the site. As a study area we selected Marmara Region (Turkey), especially the city of Istanbul which is characterized by one of the highest levels of seismic risk in Europe and the Mediterranean region. The seismic hazard in the city is mainly associated with two active fault segments which are located at about 20–30 km south of Istanbul. In this perspective first we proposed a methodology to incorporate this new information such as nucleation point in a probabilistic seismic hazard analysis (PSHA) framework. Secondly we introduced information about those fault segments by focusing on the fault rupture characteristics which affect the azimuthal variations of the ground motion spatial distribution i.e. source directivity effect and its influence on the probabilistic seismic hazard analyses (PSHA). An analytical model developed by Spudich and Chiou (2008) is used as a corrective factor that modifies the Next Generation Attenuation (NGA, Power et al. 2008) ground motion predictive equations (GMPEs) introducing rupture related parameters that generally lump together into the term directivity effect. We used the GMPEs as derived by the Abrahamson and Silva (2008) and the Boore and Atkinson (2008); our results are given in terms of 10% probability of exceedance of PSHA (at several periods from 0.5 s to 10 s) in 50 years on rock site condition; the correction for directivity introduces a significant contribution to the percentage ratio between the seismic hazards computed using the directivity model respect to the seismic hazard standard practice. In particular, we benefited the dynamic simulation from a previous study (Aochi & Utrich, 2015) aimed at evaluating the seismic potential of the Marmara region to derive a statistical distribution for nucleation position.
Our results suggest that accounting for rupture related parameters in a PSHA using deterministic information from dynamic models is feasible and in particular, the use of a non-uniform statistical distribution for nucleation position has serious consequences on the hazard assessment. Since the directivity effect is conditional on the nucleation position the hazard map changes with the assumptions made. A worst case scenario (both the faults are rupturing towards the city of Istanbul) predicts up to 25% change than the standard formulation at 2 sec and increases with longer periods. The former result is heavily different if a deterministically based nucleation position is assumed.