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Exploring uncertainties in probabilistic seismic hazard estimates for Quito

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In the present study, probabilistic seismic hazard estimates at 475 years return period for Quito, capital city of Ecuador, show that the crustal host zone is the only source zone that determines the city's hazard levels for such return period. Therefore, the emphasis is put on identifying the uncertainties characterizing the host zone, i.e. uncertainties in the recurrence of earthquakes expected in the zone and uncertainties on the ground motions that these earthquakes may produce. As the number of local strong-ground motions is still scant, ground-motion prediction equations are imported from other regions.

Exploring recurrence models for the host zone based on different observations and assumptions, and including three GMPE candidates (Akkar and Bommer 2010, Zhao et al. 2006, Boore and Atkinson 2008), we obtain a significant variability on the estimated acceleration at 475 years (site coordinates: -78.51 in longitude and -0.2 in latitude, VS30 760 m/s):

1) Considering historical earthquake catalogs, and relying on frequency-magnitude distributions where rates for magnitudes 6-7 are extrapolated from statistics of magnitudes 4.5-6.0 mostly in the 20th century, the acceleration at the PGA varies between 0.28g and 0.55g with a mean value around 0.4g. The results show that both the uncertainties in the GMPE choice and in the seismicity model are responsible for this variability.
2) Considering slip rates inferred form geodetic measurements across the Quito fault system, and assuming that most of the deformation occurs seismically (conservative hypothesis), leads to a much greater range of accelerations, 0.43 to 0.73g for the PGA (with a mean of 0.55g).
3) Considering slip rates inferred from geodetic measurements, and assuming that 50% only of the deformation is released in earthquakes (partially locked fault, model based on 15 years of GPS data), leads to a range of accelerations 0.32g to 0.58g for the PGA, with a mean of 0.42g. These accelerations are in agreement with the catalog-based hazard estimates.
4) Restricting the occurrence of magnitudes 6 to 7 to the Quito fault (a simplified geometry), applying the three initial GMPEs (Akkar and Bommer 2010, Zhao et al. 2006, Boore and Atkinson 2008) or GMPEs including a hanging-wall coefficient (Abrahamson and Silva 2008, Chiou and Youngs 2008), increases the hazard by 20 to 40% at sites located above the fault plane (range 0.42g to 0.68g at the considered site). Strong hypothesis are required to define a simple fault plane and to define the recurrence of earthquakes on this fault plane, therefore these results must be taken with great caution. However they demonstrate that taking into account faults in hazard calculations can have a major impact.

Modeling the recurrence based on the past earthquake catalog, and relying on an areal source zone model, gives a mean value around 0.4g for the PGA at 475 years in Quito. This mean value is for a site on rock and site effects need to be further taken into account. Nonetheless, based on various exercises, we show that if taking into account the fault itself in the hazard calculations, much higher values can be obtained for sites located above the fault.