Physical equations for calculating fault-to-site distances used in NGA GMPEs based on earthquake source geometry

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NGA GMPEs (NGA-West1, 2008 and NGA-West2, 2014) are beginning to be widely used in seismic hazard analyses. However, these new models are considerably more complicated than previous GMPEs, and they require several more input parameters. Users are faced with the challenge of estimating unknown input parameters when implementing NGA models.

In this paper, we are interested in fault-to-site distances parameter. Scherbaum et al. (2004) (termed “SSC04”) ever developed empirical expressions for converting source-to-site distance measures using simulated source geometries. The conversion equations are in the form of polynomial functions of $M$, $R_{JB}$, and style of faulting. Kaklamanos et al. (2011) (termed “KBB11”) derived physical equations relating the three distance measures ($R_{JB}$, $R_{RUP}$, and $R_{X}$) found in the NGA 2008 models using various geometric principles. KBB11 used the Joyner-Boore distance ($R_{JB}$) as the primary distance measure to compute other distances ($R_{RUP}$, $R_{X}$) by characterizing the earthquake source by the geometric parameters down-dip rupture width ($W$), depth-to-top of rupture ($Z_{TOR}$), fault dip ($\phi$), and source-to-site azimuth ($\alpha$). When $R_{X}$ is also needed (as in the AS08 and CY08 models), KBB11 method is advantageous, because $R_{X}$ cannot be estimated using the SSC04 relationships (because $R_{X}$ had not yet been introduced as a distance measure in 2004). One other potential issue is that the SSC04 equations are technically only applicable for $R_{JB} < 100$ km, whereas KBB2011 equations are physically derived and applicable for any distance range at which the flat-earth assumption is valid (typically, several hundred kilometers).

KBB11 used the Joyner-Boore distance ($R_{JB}$) as the primary distance measure to compute other distances ($R_{RUP}$, $R_{X}$). But in one situation $R_{JB}$ is equal to zero, which means the site is located directly above the ruptured area; either $R_{X}$ or $R_{RUP}$ must be specified in order to calculate the third distance parameter using KBB11. In some other situations, when the fault trace and site location is known, we need to simulate the ground motion caused by different segment rupture of the whole entire fault. In these cases, the $R_{X}$ and $R_{XY}$ are easily measured by GIS tools but the $R_{JB}$ is dependent on the down-dip rupture width ($W$). In this paper we introduce a new distance measure $R_{XY}$ (the closest distance from top of rupture) which is used to estimate source-to-site azimuth $\alpha$ ($\sin(\alpha) = R_{X} / R_{XY}$) and $R_{X}$ ($R_{X} = R_{XY} \cdot \cos()$). Based on KBB11 we derived distance equations using the $R_{X}$ and $R_{XY}$ to compute $R_{JB}$, $R_{RUP}$, $R_{X}$, and $R_{Y0}$.

Keywords: NGA GMPEs, source-to-site distances, RJB