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Earthquake physics and seismic hazard (invited)

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The ever-increasing population density in large metropolitan areas near major active faults (e.g., Tokyo, Istanbul, Los Angeles, cities in the San Francisco bay area), and recent catastrophic earthquakes in Japan, Haiti and Indonesia (loss of life > 500,000, economical damage > $US 100 billion), highlight the need for developing improved seismic hazard estimates. Progress can be made using non-generic estimates tailored to the locations of interest. Research in this direction has been limited traditionally to characterization of site conditions (e.g., rock type, topography, etc) near the earth surface. Here we focus on improved understanding of earthquake physics that allows deriving information reflecting key properties and processes of fault zones and the crust in the region. This is illustrated with the following two examples.

(i) Ruptures on faults that separate different elastic solids (bimaterial interfaces) are predicted to propagate for wide ranges of conditions in the direction of tectonic motion of the block with lower seismic velocity at depth (e.g. Weertman 1980; Ben-Zion 2001; Ampuero & Ben-Zion 2008). Since rupture directivity can amplify the ground shaking in the propagation direction by a factor of 3 or more, it is important to estimate the possible existence of preferred rupture direction on large faults. This can be done with observed asymmetry of rock damage across the fault (e.g. Dor et al. 2006; Mitchell et al. 2011), along-strike asymmetry of ongoing seismicity (Zaliapin & Ben-Zion 2011), directivity of ongoing seismicity (Lengline & Got 2011), and reversed-polarity secondary deformation structures near stepovers (Ben-Zion et al. 2012).

(ii) The degree of seismic coupling in a region (fraction of stored elastic energy released by earthquakes), and hence seismic hazard, is predicted to be proportional to the effective rock viscosity related primarily to heat-flow and fluid-content (Ben-Zion & Lyakhovsky 2006). Direct estimates of the seismic coupling require long records of seismic and geodetic data not available in most locations. However, this can be done indirectly by analyzing properties of low magnitude seismicity in the region. Relatively high coupling associated with highly-brittle behavior leads to burst-like clusters of seismicity with distinguishing sets of spatio-temporal and internal topological properties, while low coupling associated with mixed brittle-ductile behavior leads to swarm-type clusters with a different set of properties (Zaliapin & Ben-Zion 2012a,b).

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