A Physics-based Earthquake Simulation for Eastern Iran

A. Khodaverdian [1], H. Zafarani [2], K. W. Schultz [3], M. Rahimian [4]

1 ETH Zurich, Swiss Seismological Service, Switzerland, **2** IIEES, Iran, **3** University of California Davis, California, **4** University of Tehran, Iran.

Introduction

Return periods of major earthquakes and their statistical distribution is a key factor for time-dependent or time-independent probabilistic seismic hazard assessment. Beauval et al. (2008) indicated that a minimal of 12000 years of observation is needed to estimate PGA for 475-year return period with 20% uncertainty.

However, 80-year instrumental catalogs and several thousand-year historical evidences are either too short or too inaccurate and incomplete to reliably provide a statistically significant data set for earthquake prediction. The situation becomes worse in eastern Iran where few recorded historical seismic data are available.

Although the eastern part of Iran experienced few infrequent large earthquakes during the observation time covered by instrumental and historical catalogs, paleoseismological studies (Foroutan et al., 2014, Foroutan et al., 2012) showed that average recurrence times of large earthquakes is more than several thousand years. On the other hand, large earthquakes severely alter the size and recurrence time of earthquakes on other adjacent faults by changing the state of static stress (Stein, 1999). This interaction between individual faults is important and should be taken into account when studying seismic behavior of faults characterized by large-magnitude ruptures. Hence, the evidences of large earthquakes from the instrumental, historical or paleoearthquake records are too short and physics-based numerical simulation is one of the reliable approaches to produce a long history of all probable earthquakes.

Active Deformation

The general geodynamic processes in Iran result from the Arabia-Eurasia collision and the overall differential motion between the central parts of Iran and western Afghanistan results in N-S righ-lateral shear in central-eastern Iran (Vernant et al., 2004). A large portion of this deformation is localized on a series of parallel N-S oriented dextral faults bounding the Lut desert block (Figure 1). This block is devoid of seismicity and acts as rigid block in the present-day kinematics of Iran.

Recently, Khodaverdian et al. (2015) compiled all the newest data sets, including geological slip rates, geodetic velocities and principal stress directions, and proposed the most comprehensive kinematic model for the Iranian fault systems. Concentration of strain rate within narrow zones along the previously known faults showed that all the major active faults in the region are fairly well identified.

Slip rates, which were suggested from the comprehensive model at scale of individual faults, not only are consistent with previous geological and geodetic studies, but also are more accurate since the velocity field was obtained based on the all available data. Hence, a more reliable picture of deformation in the study area is now provided and these estimates can be used to generate a long-term catalog of earthquakes.

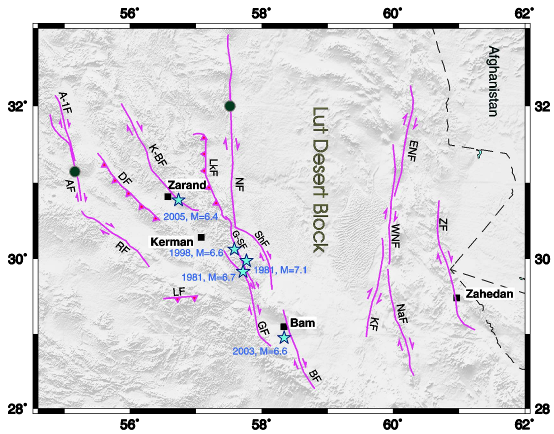

Figure 1. Traces of active faults in the study area

VQ Simulation

VQ is a boundary element code that simulates topologically realistic, driven fault systems using stress interactions (Rundle 1988a, Rundle 1988b, Rundle et al. 2006a, Rundle et al. 2006b).

VQ simulator consists of three components: a fault model, simulation physics, and an event model. The fault model is the most important input for simulation as all geometric and kinematic characteristics of active faults is defined on that. The basic simulation physics is fault stress accumulation via building a slip deficit. VQ employs both static and dynamic friction laws for simulated earthquakes. During a simulated earthquake, an element begins to slip when its stress reaches the failure threshold (static failure). The Coulomb Failure Function (CFF) is used to determine when faults reach their failure stresses.

Verification

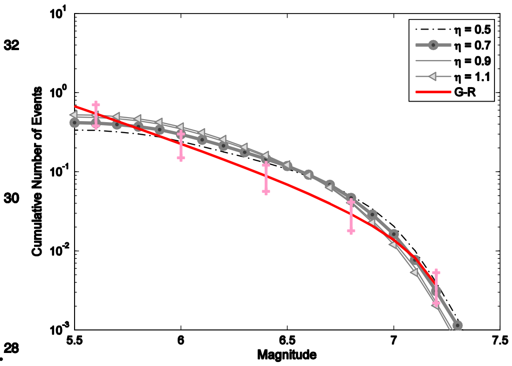

Figure 2. FMD plot for different models compared with the empirical (G-R) relation.

Results

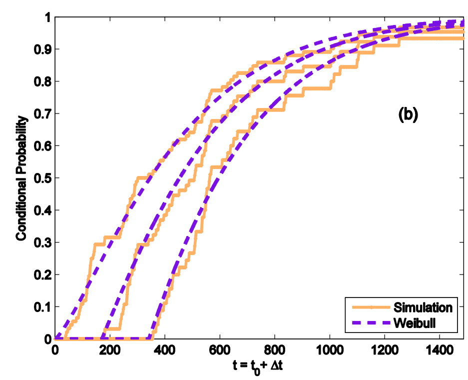

Figure 3. Conditional probability of a m>6.9 earthquake on the Golbaf-Sirch fault.

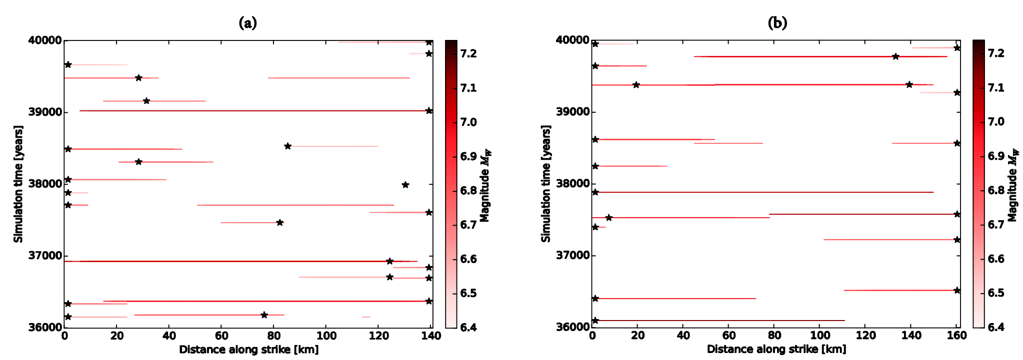

Figure 4. A catalog of m>6.5 earthquakes on (a) the Kahurak and (b) the Nosratabad faults during 4000 years.

Conclusion

A physics-based synthetic seismicity model is developed for the fault system in eastern Iran and tuned based on evidence of previous earthquakes. We find that the Poisson (time-independent) distribution is the best model when all large earthquakes in the study area are considered together, while large earthquakes on the individual faults show quasi-periodic behavior, and can be well represented by the Weibull distribution, for most faults. Long-term simulations indicate that waiting times for large earthquakes on specific faults are strongly dependent on the fault system configuration.

Schweizerischer Erdbebendienst Service Sismologique Suisse Servizio Sismico Svizzero Swiss Seismological Service ETH zürich

Contact:
Alireza.khodaverdian@sed.ethz.ch