Risk Assessment

Probabilistic Tsunami Hazard of Splay and Normal Faults in the Western Makran/Iran

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ABSTRACT

The Makran subduction zone (MSZ), with 1000-km in length, is located offshore of southern Iran and Pakistan. The oceanic crust of the Arabian plate has been subducted beneath the Eurasian plate along the MSZ since the Early Cretaceous. The MSZ is a typical two-dimensional (2D) and one of the most extensive subduction zones with a very wide accretionary prism (~ 400 km) and a very thick sediment section of up to 7 km. It is seismically segmented into a western and an eastern part. The eastern Makran hosted two instrumentally recorded tsunamis in 1945 and 2013 and few historical tsunamis. However, only one possible tsunami from a local earthquake in 1008 is reported for the western Makran. Although the western Makranis very seismically quiet compared to the eastern Makran, the lack of major seismicity and other kinds of evidence (e.g. GPS measurements and theterraced topography of western Makran) can be results of the locking state of the western Markan. Assuming its locking, it can be assumed to have a potential of producing future great tsunamigenic earthquakes. Compared to the eastern Makran, the western Makran region has received less attention as a potential tsunamigenic zone.

The aim of this study is to assess probabilistic tsunami hazard along the shorelines of Iran, Pakistan and Oman for fault sources in the western Makran.The scenarios in this study consist of detected faults using the interpretation of seismic reflection data in the western Markan region. The structural restoration technique is used for validation of the seismic interpretation of faults in the western Makran. The interpreted faults are a series of east-west splay and normal faults. Splay faults branch upward from the subduction interface and may reach the seafloor. They can cause localized large tsunamis in the near-field, such as the 1944 Tonankai, Japan and the 2010 Maule, Chile events. Splay faulting has been considered a possible cause of the large run-up of 11-13 meters during the 1945 tsunami in Makran.

Although the deterministic approach for tsunami hazard assessment provides useful results, it is not proper for an effective risk-based decision making. A probabilistic tsunami hazard assessment (PTHA) considering multiple scenarios and a range of uncertainties gives a better understanding of the hazard level of source zones and possible future events. Thus, it is a better approach for risk-based decision making. A Probabilistic tsunami hazard assessment is carried out in this paper using a logic-tree approach and the results of annual rate estimation and tsunami numerical modeling of earthquake scenarios. The initial condition of tsunami simulations is obtained by computing the field of seabed deformation for rupture scenarios. Numerical simulation of tsunamis is performed using modeling of the nonlinear shallow water equations.

The results reveal that the splay faults in the western Makranpose a greater hazard than normal faults. The hazard level at the coastline of Pakistanis considerably lower than Iran and Oman.According to the results of PTHA in this study, the area between Jask and Beris along the Iranian coastline and the area between

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Muscat and Sur along the coastline of Oman are the most hazardous zones. The exceedance probability along the southern coasts of Oman is much lower compared to the northern coast of Oman.The probability that tsunami wave height exceeds 3 meters along the coastlines of Iran and Oman in 10, 50 and 250 years reaches about 30%, 70% and 90% respectively (Fig. 1). The estimated probability of tsunami wave exceeding 1 meter along the Iran-Pakistan and Oman coastlines in 50 and 250 years is up to 100% (Fig. 1).The annual probability of exceeding 1, 2 and 3 meters along the Iran-Pakistan shoreline is 45%, 16% and 6%, respectively. The same values for the coast of Oman are 35%, 10% and 6%. Short-term tsunami hazards along the Makran coastlines are not very significant due to the current low seismicity of MSZ. However, the tsunami hazard probability increases with time and reaches its highest level in mid-term (250 years). Our tsunami probability maps can be used by local authorities for spatial planning in coastal regions, especially for the south-eastern coast of Iran and the northern coast of Oman. In addition to tsunami probability maps, we also compute probabilistictsunami hazard curves which facilitatethe evaluation ofprobabilities in a specific area or sitefor different tsunami height thresholds and different time periods. Such curves can be useful in developing tsunami protection barriers. Our analysis does not represent the maximum tsunami hazard in the western Makran region. Future works should consider other possible near-field and far-field tsunami sources along with our presented sources for tsunami hazard assessment inthe western Makran region.

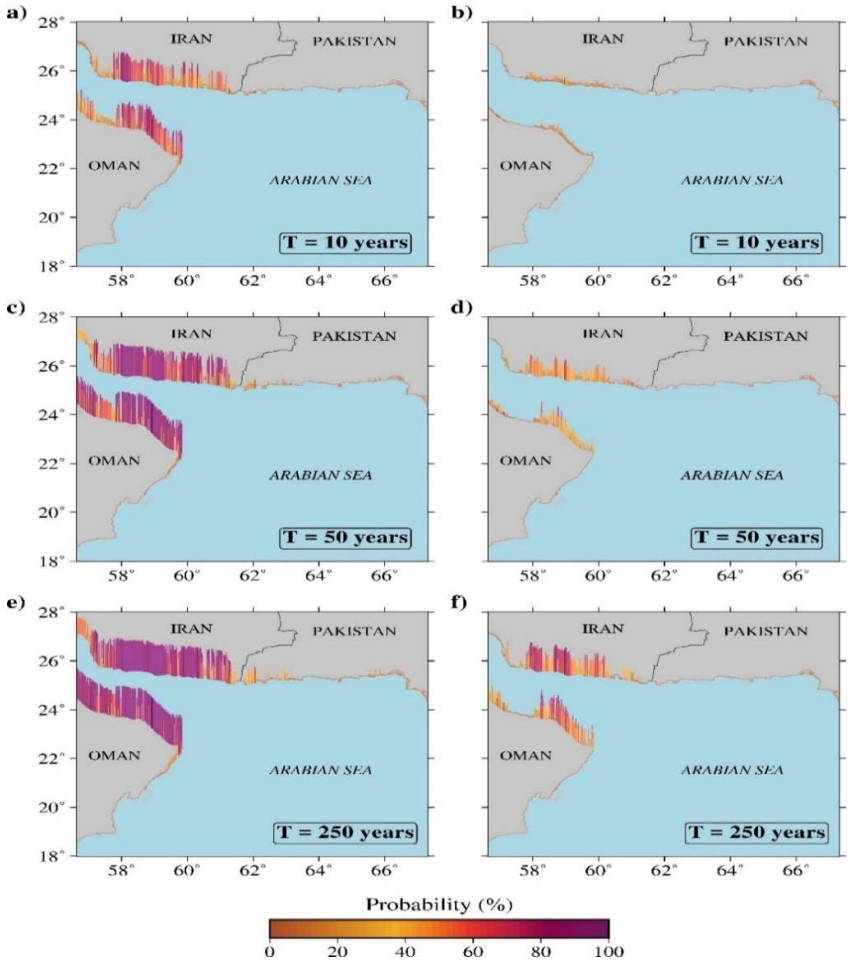

Fig. 1. Probability of exceeding 1 meter (a, c, e) and 3 meters (b, d, f) in time periods of 10, 50, and 250 years along the coastlines of Iran, Pakistan, and Oman.

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