Probabilistic Tsunami Hazard along the Coast of Oman

Outline

1. Motivation
2. Methods for tsunami hazard assessment
3. Probabilistic hazard assessment along the coast of Oman: Method, tools, and results
4. Perspectives for future work
5. Conclusions
At least the coast of Oman was heated by two tsunamis during the 20 and 21 centuries:

- The 1945 Makran;
- The 2004 Indian Ocean (Sumatra)

The 24th December 2004 Indian Ocean tsunami recorded at Salalah harbor

Sediments deposit in the Sur lagoon

Okal et al., 2006 (Earthquake Spectra)
2. Tsunami Hazard Assessment - Methods

Methods for Tsunami Hazard Assessment

- **Observations**
  - Records, Field survey, Paleo-tsunami studies, Eyewitness, historical documents
  - Tsunami Catalog

- **Numerical simulations**
  - Deterministic approach
    - Most credible earthquake scenarios + tsunami modeling
    - Tsunami impact maps (wave heights, inundation, etc.)

- **Probabilistic approach**
  - Possible earthquake scenarios + PSHA + tsunami modeling
  - Tsunami hazard: Exceedance maps, hazard curves

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3. Probabilistic tsunami hazard assessment-Oman: Method

Event-tree approach to assess the PTH along the coast of OMAN
Tsunamigenic source areas along the Makran Subduction Zone; EMSZ (red rectangle), WMSZ (yellow rectangle) and EntMSZ (white polygon)

3. Event-tree approach for PTHA at OMAN

NODES 1\&2: Earthquake Event and Source Zone

In PTHA we use all the possible scenarios of magnitudes between 7.5 and 9.1. and we apply a regular magnitude interval of 0.2 to define individual event.

Three main source zones are distinguished:

- East Makran Source Zone (EMSZ)
- West Makran Source Zone (WMSZ)
- Entire Makran Source Zone (EtMSZ)
3. Event-tree approach for PTHA at OMAN

NODES 1&2: Earthquake Event and Source Zone

PSHA: Probabilistic Seismic Hazard Assessment – Earthquakes Annual Recurrence Rates

The historical record of earthquakes in the Makran area is too short to enable a reliable evaluation of their frequency of occurrence; a much longer time spanning is required to evaluate the recurrence parameters correctly. Therefore, estimating the probabilistic tsunami hazard through the application of the recurrence interval of seismic history alone is not accurate.

Seismicity of Oman and its surrounding in the period from 1900-2009 from the ISC Bulletin
3. Event-tree approach for PTHA at OMAN

NODES 1&2: Earthquake Event and Source Zone

PSHA: Probabilistic Seismic Hazard Assessment – Earthquakes Annual Recurrence Rates


<table>
<thead>
<tr>
<th>Moment Magnitude</th>
<th>Seismic Moment (dyne/cm²)</th>
<th>Annual occurrence rate</th>
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<tbody>
<tr>
<td>7.5</td>
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**Recurrence Rate for East Makran**

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**Recurrence Rate for Entire Makran**

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<tbody>
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We associate to each magnitude range (from Mw7.5 to 9.1 with a regular magnitude interval of 0.2) a typical fault (TF) that is defined using the earthquake parameters required for tsunami modeling.

We let the TF float, with regular interval, along the trace fault in the source region in order to generate the maximum possible number of scenarios within the source zone.
3. Event-tree approach for PTHA at OMAN

NODES 5&6: Slip distribution and Numerical modeling

Uniform Slip distribution
Shallow Water Model to simulate the tsunami

Eastern Makran Max. Earthq. Mw8.7

Western Makran Max. Earthq. Mw8.5

Entire Makran Max. Earthq. Mw9.1
Framework to calculate the probability of exceeding a specific hazard stage

Assuming that \( E_j \) has a recurrence rate \( \nu_j \) that obeys a Poisson process, then its probability of occurrence is as follows:

\[
P(E_j) = 1 - \exp(-\nu_j) \tag{1}
\]

Considering the total of \( J \) tsunami events, the probability that at least one event produces exceedance of \( \eta_i \) is:

\[
P(\eta > \eta_i) = 1 - \prod_{j=1}^{J} \left[ 1 - P(E_j)P(\eta > \eta_i \mid E_j) \right] \tag{2}
\]

If the \( E_j \) is composed of \( k_j \) mutually exclusive realizations, then:

\[
P(\eta > \eta_i \mid E_j) = \sum_{k=1}^{k_j} P(\eta > \eta_i \mid E_{jk})P(E_{jk} \mid E_j) \tag{3}
\]

Equations (1) and (3) into (2) lead to:

\[
P(\eta > \eta_i) = 1 - \prod_{j=1}^{J} \left[ 1 - (1 - \exp(-\nu_j)) \sum_{k=1}^{k_j} P(\eta > \eta_i \mid E_{jk})P(E_{jk} \mid E_j) \right] \tag{4}
\]
The probabilities that the maximum wave height could exceed 1 m off-shore the coast of Oman are significant along the northern coast, reaching about 70%, and low towards the south.
3. Tsunami Hazard Assessment, Oman - Results

500-year probability of exceedance map and hazard curves

The 500-year probability that the maximum wave height could exceed 1 m off-shore the coast of Oman is up to 100% along the northern coast and remains low towards the south.

Hazard Curves presenting the probability of exceedance as a function of max. wave amplitudes at some points of interest.
4. Perspectives for future work

1. Integrate in the PTHA the effect from Far-field tsunamigenic source zones, in particular the Andaman Sumatra subduction zone.

2. Integrate the tidal uncertainties and calculate the PTH for site-specific coastal zone prone to tsunami inundation.
5. Conclusions

• An event-tree approach is developed to assess the probabilistic tsunami hazard along the coast of Oman;

• PTHA is performed for the Makran subduction considering three main sources zones: EMSZ, WMSZ, and the EtMSZ;

• Two different return periods: 100 years, 500 years were considered;

• The probabilities that the maximum wave height could exceed 1 m off-shore the coast of Oman are significant along the northern coast of the country;

• Toward the south the probabilities are low;

• Far-field sources from Andaman Sumatra subduction zone should be included in the PTHA.


This work is a collaboration between:
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Earthquake Monitoring Center, SQU Oman
THANKS !