EXPERT CONSULTATION

Scientific Tsunami Hazard Assessment of the Makran Subduction Zone

Summary Statement

8 March 2019
Kish Island,
Islamic Republic of Iran

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Printed in Australia
(IOC/BRO/2019/3)

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The Expert Consultation

The Expert Consultation on scientific tsunami hazard assessment of the Makran Subduction Zone was attended by 59 experts from 11 countries (Australia, India, Indonesia, Iran, Oman, Pakistan, Portugal, Russian Federation, Switzerland, Thailand, USA), 1 UN agency, research institutions, universities, private organisations and 3 IOC-UNESCO secretariat staff. It was organised by the Intergovernmental Oceanographic Commission (IOC) of UNESCO and hosted by the Iranian National Institute for Oceanography and Atmospheric Science (INIOAS) with support from the UNESCO Jakarta and Tehran offices. It was held on 8 March 2019, back to back with the 12th session of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (IOTWMS) held in Kish Island, Islamic Republic of Iran during 9-12 March 2019. Findings of the Expert Consultation were reported to the ICG/IOTWMS-XII session seeking to formulate a working mechanism for enhancing the collective understanding of the Makran Tsunami Hazard and strengthening the IOTWMS.

Background

The Makran Subduction Zone (MSZ) is still poorly understood even though it poses a major tsunami risk in the North West Indian Ocean. Several decades after the 1945 tsunami that caused hundreds of confirmed fatalities, there are still open questions about whether the MSZ is able to generate such large tsunamis in the future. There are also questions about tsunami triggering mechanisms in the Makran, with tectonic deformation and submarine landslides being viewed as probable sources. Access to real-time seismic data is very sparse in the region, limiting the capability to effectively monitor seismic events and forewarn of tsunamis. In the worst case, tsunami waves generated by a Makran source would reach adjoining shores within a few tens of minutes with height of several metres, posing enormous challenges to tsunami warning systems, as witnessed from the recent Palu and Sunda Strait tsunamis in Indonesia.

Realising the urgent need to strengthen the end-to-end tsunami early warning and mitigation system in the Makran region, a sub-regional Working Group for the North West Indian Ocean (WG-NWIO) was established at the 10th Session of ICG/IOTWMS (March 2015, Muscat) with India, Iran, Oman, Pakistan and Yemen as founding members. A report on “Tsunami Early Warning Systems in countries of the North West Indian Ocean Region”\(^1\) prepared by UNESCAP in association with the WG-NWIO further reiterated the immediate need to enhance the collective understanding of the Makran tsunami hazard. This will enable NWIO Member States to assess their tsunami risk, strengthen national warning systems, enhance warning chains, develop evacuation plans, build emergency response capacity and raise community awareness, preparedness and resilience with specific emphasis on a near-field tsunami threat.

Objectives

The specific objectives of the Expert Consultation were:

- To report on the current status, gaps and future priorities in the MSZ with reference to
  - Optimal observing networks for effective tsunami warning in the MSZ
  - Seismicity of the MSZ and Credible Maximum Earthquake Magnitude
  - Tsunami Hazard Assessment in the MSZ
  - Potential impact of Seismic and Secondary non-seismic effects on tsunami generation in MSZ including Red Sea and Persian Gulf

- To provide input to the 12th Session of the ICG/IOTWMS (9-12 March 2019, Kish Island) seeking to formulate a working mechanism for enhancing the collective understanding of the Makran Tsunami Hazard and strengthening the IOTWMS.

Format

The consultation was organised in four sessions, each including expert presentations followed by a moderated discussion among presenters and invited panellists focusing on the objectives of the Expert Consultation. Member States of the NWIO region (India, Iran, Pakistan

1 http://www.ioc-tsunami.org/unescap-synthesis-report-Apr17
and Oman) and other partners were given the opportunity to report on their achievements, outstanding needs, and future developments. This was followed with a concluding session that included a cross-cutting discussion on the perspective from the “last-mile”. A synthesis of each session is provided in the following sections. Details of the programme, moderators, presenters, panellists and participants are available at http://ioc-tsunami.org/msz_expert_consultation.

Session 1

Optimal Observing Networks for Effective Tsunami Warning in the Makran Subduction Zone

Moderator: Mr Peter Coburn, Operations Manager, Joint Australian Tsunami Warning Centre, Australian Bureau of Meteorology and Chair of ICG/IOTWMS Working Group-2

This session focussed on the current status, gaps and future priorities with regard to national seismic, sea-level and Global Navigation Satellite System (GNSS) monitoring networks in India, Iran, Pakistan and Oman. While several stations are available within national networks, limited data is shared globally or with the IOTWMS Tsunami Service Providers (TSPs). There is a need to determine the optimal observing networks required for effective tsunami warning in the MSZ and to encourage Member States to work towards establishing those networks.

Current Status:

- National monitoring networks including broadband, sea-level and GNSS stations are installed in India, Iran, Oman and Pakistan.
- Limited data is shared globally or with the IOTWMS Tsunami Service Providers (TSPs).
- Some data is shared between IOTWMS Member States through bi-lateral agreements.

Gaps:

- Current networks of seismic stations and sea-level stations in the Makran region, and their data sharing with the TSPs, are inadequate for effective tsunami warning.
- Dense coastal GNSS networks are required for real-time data inversion to determine displacement parameters for tsunami warning.
- There is a need to determine the optimal [number and location] network of seismic, GNSS and sea-level stations in the MSZ region for effective tsunami warning.

Future Priorities:

- Form a group of experts to define the optimal [number and location] network of seismic, GNSS and sea-level stations in the MSZ region, including co-located monitoring equipment.
- Enhance networks and exchange seismic, sea-level and GNSS data among MSZ Member States and with IOTWMS TSPs.
- Utilise GNSS and strong motion accelerometer data inversion for rapid estimates of displacement and earthquake source parameters in real-time.
- Invite high-level policy makers to future science meetings to convince them of the importance of real-time seismic, sea-level and GNSS data sharing for saving the lives of their citizens.

Session 2

Seismicity of the Makran Subduction Zone and Credible Maximum Earthquake Magnitude

Moderator: Dr Jörn Lauterjung, Head of Data, Information and IT Services, GFZ German Research Centre for Geosciences, Germany

This session focused on seismicity of the MSZ and credible maximum earthquake magnitude. It included presentations from international experts working in the region on tectonics, active seismic data acquisition and paleo tsunamis. Mechanisms of deformation along the eastern Makran are better understood than in the western Makran. Member States require guidance on a credible maximum earthquake magnitude for tsunami hazard maps and inundation models.
Current Status:

- Low seismicity in Western Makran with increasing activity towards Eastern Makran.
- Geological evidence is consistent with the seismic record and indicates deformation increasing eastward.
- Paleo-tsunami research points to the occurrence of a past large earthquake (M9+) in the MSZ region.

Gaps:

- Lack of consensus on maximum earthquake magnitudes and seismic source parameters in the MSZ.
- The geological structure of western MSZ has not been sufficiently studied.
- Mechanisms of deformation along the plate interface are not well-constrained (e.g. slow strain release, lateral stress transfer, locked plate interface).
- More seismic profiling is required off-shore along north-south transects and on-shore in Oman.

Future Priorities:

- Off-shore active seismic profiling is essential for constraining mechanisms of deformation along the MSZ and constraining fault rupture models.
- Inversion of present-day deformation measured by GNSS to quantify strain accumulation and earthquake potential of the MSZ.
- Consider the occurrence of more probable, smaller-magnitude events (>M8.0) rather than less probable, large-magnitude event (>M9.0) for hazard and risk assessment in the MSZ.
- Form a group of experts to define a strategy for estimating the credible maximum earthquake magnitude.

Session 3

Tsunami Hazard Assessment in the Makran Subduction Zone

Moderator: Dr Issa El-Hussain, Director of Earthquake Monitoring Center, Sultan Qaboos University, Oman

This session focussed on recent initiatives in tsunami hazard assessment in the Makran region including Geoscience Australia’s Probabilistic Tsunami Hazard Assessment and the Global Tsunami Model. It is clear that a unified tsunami hazard map is critical for constraining the extent of potential inundation in the region. Such a map would enable more confident tsunami response planning including development of detailed tsunami evacuation maps, plans and procedures.

Current Status:

- There have been several recent advances in Makran tsunami hazard assessments giving a clearer picture of the region. However, there remain many areas of uncertainty including the Iranian coast and Persian Gulf.
- Tsunamis generated by landslides have occurred multiple times in the Makran historical record (e.g. 1945; 2013).
- The Global Tsunami Model provides a platform for science-based understanding of tsunami hazard and risk.

Gaps:

- Consensus on the occurrence of large historical earthquakes in the western Makran.
- Reliable measurements from the 1945 tsunami such as run-up, flow depth, inundation distance and timing of reported telegraphic cable breaks.
- Understanding of the probability of a mega-event at the southern limit of Zagros along the Iranian shore of the gulf.
- Geological and sedimentary records along the Makran coast are sparse, especially in Iran.

Future Priorities:

- Produce a probabilistic tsunami hazard assessment for the Makran region.
- Undertake tsunami risk assessments in coasts bordering the Makran region incorporating available data on vulnerability and exposure.
- Constrain the run-up and inundation using the 1945 event and produce a database.
- Reach a consensus on the seismic character of the Western Makran subduction zone.
Encourage field studies in the Makran (and Persian Gulf) region including geophysical (e.g. seismic and geodesy) and geological (e.g. paleo-tsunami studies).

Session 4

Potential impact of Seismic and Secondary Non-Seismic Effects on Tsunami Generation in Makran Subduction Zone including the Red Sea and Persian Gulf

Moderator: Prof Emile Okal, Professor Emeritus, Department of Earth and Planetary Sciences, Northwestern University, U.S.A.

This session discussed the possibility of tsunamis in the Makran region from landslides, onshore earthquakes and meteorological events in the backdrop of the recent Indonesian tsunamis in Palu and the Sunda Strait. Atypical mechanisms have repeatedly demonstrated their capability to cause tsunamis. However, such mechanisms are not currently integrated into the tsunami warning systems, which were designed to detect earthquake-generated tsunamis. Advancements in the tsunami monitoring network design are critical for progressing this important issue.

Current Status:

- Tsunami Early Warning is based on real-time earthquake and sea level monitoring, model scenarios, and warning dissemination systems.
- A number of studies of atypical tsunami sources including submarine landslides, onshore earthquakes, and meteo-tsunamis have been conducted in the Makran (and Persian Gulf) region.

Gaps:

- Limitation of the current tsunami early warning system (only for tectonic earthquakes) that are not adapted to atypical tsunami sources.
- Complexity of bathymetry and topography and other data/information (e.g. bedrock topography) in most of the coastal areas.
- Reviews of past atypical tsunami events from the historical and pre-historical records.

Future Priorities:

- Research and studies to improve the understanding of tsunami hazard in Makran including the possibilities of atypical tsunami sources, such as submarine landslides, onshore tsunami sources and meteo-tsunamis.
- Studies to determine if tsunamis can impact Red Sea and Persian Gulf coastlines.
- Strengthen monitoring networks to help better understand and forecast atypical tsunami events and incorporate necessary procedures into operational tsunami early warning systems.

Concluding Session

“Last Mile” Perspective

Moderator: Dr Mohammad Mokhtari, Director of National Center for Earthquake Prediction, International Institute of Earthquake Engineering and Seismology, Iran

This session summarised the outcomes of the earlier sessions and included a crosscutting discussion on the views and priorities from a “last-mile” [community] perspective. While immediate efforts need to be made to address priorities identified by the earlier Expert Consultation sessions, discussions in this session focussed on the urgent need to use existing knowledge on the MSZ to guide in-country decision makers on development of science-based inundation maps to support community response.

Current Status:

- Significant gaps have been noted in regard to the understanding of Makran tsunami hazard. These are related to a lack of observing networks, seismicity studies, tsunami hazard assessments, and large uncertainties regarding the tsunami generation from atypical sources.
- Disaster manager and decisions maker working on the last-mile do not know how to adequately determine the Makran tsunami threat due to differences in expert findings and lack of consensus.
Gaps:

- Expert consensus on credible seismic sources for tsunami propagation models, which underpin inundation and evacuation maps.
- Challenges in the governance of tsunami warning systems at the national level including inter-institutional roles and responsibilities.
- All near-field tsunami-prone communities require education on recognising natural tsunami warning signs and responding appropriately.
- The reaction to atypical tsunami events needs to be incorporated into tsunami early warning systems including community evacuation and emergency plans.

Future Priorities:

- Recommendations, especially for local decision maker, to guide in-country tsunami hazard assessments and inundation mapping based on the current understanding of the MSZ.
- Review tsunami early warning strategies against the background of the current experiences with near-source tsunami sources in Palu and Sunda Strait [Anak Krakatau], including atypical sources, with special consideration of the downstream process.

Speakers and Panellists


Organising Committee

Mohammad Mokhtari, Srinivasa Kumar Tummala, Ardito Kodijat, Nora Gale

Acknowledgements

Behrouz Abtahi, Ali Khoshkholgh, Fahimeh Foroughi
