2nd UNESCO-IOC Global Tsunami Symposium

Two Decades After 2004 Indian Ocean Tsunami: Reflection and the Way Forward

Summary Statement

Banda Aceh, Indonesia
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Banda Aceh Statement

Global Tsunami Warning and Mitigation: Building Sustainability for the next decade through Transformation and Innovation. UNESCO and its partners call on States and civil society to drastically step up their investments and efforts to strengthen Tsunami Early Warning Systems and achieve 100% of Tsunami Ready Communities across the world by 2030.

The Symposium

The symposium on 'Two Decades After the Indian Ocean Tsunami: Reflection and Way Forward' was attended by 682 in-person participants from 54 countries and 170 online participants. The symposium was hosted by the Republic of Indonesia through its Agency of Meteorology, Climatology, and Geophysics (BMKG) in collaboration with the UNESCO-IOC Tsunami Resilience Section and IUGG Joint Tsunami Commission. The symposium brought together tsunami warning specialists, disaster managers, scientists, engineers, disaster risk reduction practitioners, and policymakers from around the world to discuss the status of tsunami warning systems and the latest advances in tsunami science and engineering to help globally enhance tsunami disaster preparedness and mitigation.

The symposium also served as a global platform to review the contributions of each regional tsunami warning and mitigation system towards achieving the objectives of the UN Ocean Decade Tsunami Programme (ODTP) under the "Safe Ocean" outcome of the UN Decade of Ocean Science for Sustainable Development by 2030.

The symposium was officially opened by Minister for Higher Education, Science and Technology of the Republic of Indonesia, Prof. Satryo Soemantri Brodjonegoro. In his opening remarks, the Minister called for stronger cooperation of all stakeholders in protecting coastal communities from natural disasters such as tsunamis. In his opening remarks, the Executive Secretary of IOC-UNESCO, Mr Vidar Helgesen emphasised the importance of intergovernmental processes in coordinating the development of the global tsunami early warning and mitigation system, and called on Member States and stakeholders to leverage UN Ocean Decade as a platform for stronger collaboration to address future challenges. Prof. Dwikorita Karnawati, Head of BMKG and Chair ICG/IOTWMS highlighted the progress made in establishing ICG/IOTWMS and importance of this symposium to define a roadmap for future. Ms Maki Katsuno-Hayashikawa, Director of UNESCO Jakarta, Lt. Gen. TNI Suharyanto, Head of BNPB and Prof. Yutaka Michida, Chairperson of UNESCO-IOC also spoke during the inaugural session.

Background

The Indian Ocean Tsunami of 26 December 2004, which is also known as the Aceh Tsunami, resulted in the loss of 228,000 lives and the displacement of over 1.6 million people around the Indian Ocean, with estimated economic losses of US$10 billion. At that time, while a tsunami warning existed for the Pacific Ocean, no tsunami warning system existed for the Indian Ocean and the knowledge of tsunami risk was low. This catastrophe became a wakeup for establishment of a regional tsunami warning system for the Indian Ocean, as well as in other ocean basins in the world threatened by tsunami hazards with no existing tsunami warning system.

After years of implementation, the global tsunami warning system has been tested by tsunamis with various complexities and challenges, including the 2011 East Japan Tsunami-Earthquake, the 2018 Palu and Krakatau Non-Seismic Tsunamis, and the 2022 Hunga-Tonga Ha'apai volcano-generated tsunami.

Objectives

The objectives of the symposium were to:

- Commemorate two decades after 2004 Indian Ocean Tsunami
- Reflect what has been achieved in two decades
- Identify gaps, challenges and priorities for tsunami early warning and mitigation
- Identify synergy with global challenges and coherence with global commitments
- Gather the global tsunami community

Format

The symposium was organized into seven sessions, each including presentations followed by a moderated discussion among presenters and invited panelists focusing on key policy issues for the future of the global tsunami warning and mitigation. This was followed by a concluding session that included a discussion on the Banda Aceh statement, an eyewitness account of the 2004 tsunami, awards, and closing remarks. A synthesis of each session is provided in the following sections. Pre-conference sessions, exhibition stalls, ignite stages and field visits to tsunami ready communities provided an opportunity for productive interactions amongst the participants.

Session 1

Review of the Tsunami Warning and Mitigation System over Past 2 Decades

Chairs: Dr Idwan Suhardi & Dr Jörn Lauterjung

The session covered the experiences and key lessons learned from the two megatsunamis: 2004 Indian Ocean Tsunami (Banda Aceh, Indonesia) and 2011 Tohoku Tsunami (Japan). The four existing Intergovernmental Coordination Groups (ICGs, see below) reported on the status of their work, identified gaps, and future developments and plans. The session ended with a panel discussion on the history of the Indian Ocean Tsunami Warning and Mitigation System (IOTWMS) noting the main milestones and achievements.

Current Status

- Regional Intergovernmental Coordination Groups are established in the Pacific Ocean (ICG/PTWS), Indian Ocean (ICG/IOTWMS), North-Eastern Atlantic, Mediterranean and connected seas (ICG/NEAMTWS), and Caribbean and adjacent regions (ICG/CARIB-EWS).
- Regional Tsunami Service Providers produce tsunami threat information and forecasts based on seismic and sea-level data, which is made available to National Tsunami Warning Centres.
- Regular ocean-wide tsunami exercises test the functionality of the end-to-end warning systems.
- The UNESCO-IOC Tsunami Ready Recognition Programme is underway.

Gaps

- Monitoring infrastructure for non-seismic tsunami (i.e., volcano, landslide, meteotsunami) is needed.
- High-resolution shallow water bathymetry is needed for more accurate tsunami forecasts, inundation modelling, and evacuation planning.
- The provision of freely available tsunami forecasting data that is shared in real-time.

Future Priorities

- Monitoring and forecasting for non-seismic tsunamis.
- Increased accuracy and dissemination time for tsunami threat information.
- Adoption of the UNESCO-IOC Tsunami Ready Recognition Programme (or similar initiative) in at-risk coastal communities

Session 2

Tsunami Generated by Non-seismic and Complex Sources

Chair: Mr Bernardo Aliaga

The session addressed progress, gaps and emerging challenges in detecting and warning for tsunamis generated by non-seismic and complex sources. These events are less frequent than earthquake induced tsunamis, but also potentially devastating, as demonstrated by the 2018 Anak Krakatau and 2022 Hunga Tonga eruptions. Presentations by experts in this session focused on the recent UNESCO-IOC report on Monitoring and Warning for Tsunamis Generated by Volcanoes (IOC Technical Series, 183), as well as national and regional developments.

Current Status

- The 2018 Anak Krakatau and 2022 Hunga Tonga

(HTHH) volcanic eruptions have exposed critical gaps in existing tsunami warning systems, which was primarily designed for seismic activity.

- The 'Monitoring and Warning for Tsunamis generated by Volcanoes' UNESCO-IOC publication is a useful reference on tsunamigenic volcanoes that could trigger tsunamis, and monitoring and warning for these events.
- Recent developments in monitoring and warning for tsunamis generated by non-seismic and complex sources include the automatic sea level anomaly detection algorithm (Indonesia), Stromboli Volcanic Tsunami Warning System (Italy), and ocean-air coupling analysis to detect volcanic induced tsunamis (Japan, New Zealand).

Gaps

- While several efforts are underway to develop warning protocols for tsunamis generated by non-seismic sources, such capabilities in the current regional tsunami warning systems are limited to a very few volcanoes.
- Observing, modelling, evaluating and early warning for non-seismic tsunamis, which often arise from volcanic eruptions or landslides, require distinct approaches, emphasizing the complexity and challenges they present.
- Volcanic and landslide induced tsunamis have diverse generation mechanisms, unlike seismic tsunamis, complicating prediction and requiring specialized and dense monitoring and modeling.

Future Priorities

- Integrated standard operating procedures for operational warning of tsunamis generated by non-seismic sources including linkages with both volcanic and tsunami monitoring agencies.
- Development of optimal observing networks, numerical modelling, and scenario databases of non-seismic tsunamis to aid in hazard assessment and early warning capabilities.
- Strong international collaboration and global integration of multi-hazard warning systems is necessary for comprehensive tsunami risk management.

Session 3

Tsunami Hazard and Risk Assessment

Chair: Dr Srinivasa Kumar Tummala

The session addressed progress, plans, gaps and emerging challenges in undertaking tsunami hazard assessments and identifying communities at-risk. These steps are essential elements in enhancing and developing community awareness in order to initiate development of preparedness, as detailed in UNESCO-IOC Standard Guidelines for the Tsunami Ready Recognition Programme (IOC Technical Series, 74). Presentations by experts in this session focused on current modelling capabilities and examples of tsunami hazard assessments being undertaken at regional scales and attempts at identifying communities at-risk.

Current Status

- Considerable progress on evaluating seismic generated tsunami hazards has been made through initiates such as the Global Tsunami Model, end-to-end impact forecast systems (e.g., TsunamiCast), probabilistic tsunami forecasts and hazard assessments, and paleo-tsunami studies.
- Community awareness of ocean basins tsunami hazards has increased since 2004 through tsunami hazard assessments with regional scale assessments identifying communities at-risk (e.g. North-West Indian Ocean and Caribbean).
- Preliminary efforts in estimating the location and quantity of coastal communities that could be impacted by tsunamis has informed the UNESCO-IOC Tsunami Ready Recognition Programme and other similar initiatives.

Gaps

- Multi-hazards, coastal vulnerability, and inclusion of tsunamis generated by non-seismic and complex sources are not included in the majority of tsunami risk and/or hazard assessments.
- Local-level hazard and risk assessment and smaller impact scenarios (in addition to the largest impact scenarios) are needed to better inform communities.
- The catalogue of tsunami sources is limited and needs to extend further back in time, such as to the last Holocene period.
- There are few uniform/standardized/official? guidelines for tsunami risk and hazard assessments available leading to uncertainty on best practices.

Future Priorities

- Extension of hazard and risk assessment to include tsunamis generated by non-seismic and complex sources (e.g. volcanoes, landslides, meteotsunami,

splay faulting, etc.) is needed to enhance tsunami generation models.

- More high-resolution near-shore bathymetry and topography data should be acquired and made freely available for tsunami propagation models underpinning hazard and risk assessments.
- Paleo-tsunami studies to better inform tsunami hazard assessments should be undertaken along at-risk coastlines with preserved sedimentary deposits (i.e., North-West Indian Ocean).

Session 4

Tsunami Detection, Warning, Dissemination and Response

Chairs: Dr Charles McCreery & Prof Nanang Puspito

The session reviewed achievement towards improving the capabilities for and execution of tsunami detection, warning, dissemination and response. The responses to notable tsunami events and corresponding lessons learned were reviewed before discussing improvements for tsunami monitoring and forecasting. Reference was made to the UN Ocean Decade Tsunami Programme's goal to develop the warning system's capability to issue actionable and time tsunami warnings from all identified sources to 100% of coasts at risk.

Current Status

- Since 2004 substantial improvements have been made to detect and warn for tsunamis generated by earthquakes, which account for 70% of the global tsunamigenic events.
- Enhancements in real-time seismic and sea-level monitoring networks, propagation models, and the provision of information through national tsunami warning chains have improved tsunami information to coastal communities.
- Events such as the 2004 Indian Ocean tsunami, 2011 Tohoku tsunami, 2018 Palu tsunami, 2020 Aegean Sea tsunami, and 2022 HTHH tsunami have provided insights and lessons learned thus enhancing future tsunami responses and best practices.
- Establishment of National Tsunami Warning Centers and warning chains to reach communities at risk has dramatically increased since 2004.

Gaps

- Forecasting for tsunamis generated by non-seismic and near-source events remains a challenge.
- Determining accurate earthquake magnitudes immediately after the event remains challenging with magnitude estimates for large events generally increasing over time and initial assessments an underestimate.
- Ensuring tsunami warning and response is all inclusive is a necessary challenge to protect the lives of vulnerable communities.

Future Priorities

- Develop tsunami warning systems capable of issuing actionable and timely warnings from all sources to 100% of coasts at risk.
- Tsunami early warning systems should be people-centred and inclusive of all genders, children, elderly and disabled people.
- Maximise and extend existing tsunami monitoring technologies and identify emerging technologies for tsunami propagation modelling and forecasting.
- Design and install optimal global tsunami monitoring networks capable of identifying all tsunamis within ten minutes of generation.

Session 5

Achieving 100% Communities at Risk to be Prepared and Resilient to Tsunami by 2030

Chairs: Mr David Coetzee and Prof. Faisal Fathani

The session centred around the UNESCO-IOC Tsunami Ready Recognition Programme (TRRP). It focused on the context of TRRP within the Sendai Framework and the Ocean Decade, and complementing the Early Warning for All initiative. The Symposium learnt about the experience and progress of the CARIBE-EWS as early implementers of TRRP, progress by the PTWS and NEAMTWS, and how Indonesia aligned their initiatives that were already underway, with TRRP. TRRP facilitates the inclusion of vulnerable communities. The symposium noted the introduction of ISO 223328-3 as a guideline for implementing community-based tsunami early warning systems, complementing TRRP. The Terms of Reference, structure, and objectives of the Tsunami Ready Coalition were introduced, and the Symposium learnt from the UNDRR about Tsunami World Awareness Day and other initiatives with a view on the 20th

anniversary of the 2004 Indian Ocean tsunami, and UNDRR awareness collateral complementing Tsunami Ready.

Current Status

- The TRRP is now well established, and the number of recognised Tsunami Ready communities is growing. Implementation is however subject to countries' desire to implement TRRP, vs their capacities and resources in this regard.
- Significant experience with regards to the implementation of TRRP has been established in the CARIBE-EWS, NEAMTWS, and IOTWMS.
- The Tsunami Ready Coalition has been mandated by the IOC but has not yet been formed.
- WTAD is well established, with the UNDRR extending its awareness initiatives in 2024/25 to commemorate the 2004 Indian Ocean Tsunami.

Gaps

- While progress with the implementation of TRRP has been made, the momentum is relatively slow and/or not equal across all regions and sub-regions. Capacity gaps are particularly prevalent in SIDS.
- A significantly greater global implementation rate is required to achieve the ODTP aim of 100% communities at risk are prepared and resilient to tsunamis by 2030.
- To achieve the above aim the collective support of the international community is required, including leveraging existing global and regional programmes and projects.
- The Tsunami Ready Coalition is anticipated to contribute significantly to the global effort by supporting promotion, resource mobilization, networking, influence, and providing advice. Active participation in the Coalition by traditional and non-traditional global and regional institutions is crucial for strategic and operational partnerships.

Future Priorities

- Scale up the implementation of TRRP through establishment of a comprehensive TTRP implementation plan for each region, including identification of gaps and needs.
- Promote TTRP through relevant international and regional events and conferences.
- Identify funding TRRP in the regions, and/or opportunities for leveraging existing funding and programmes to advance Tsunami Ready.

Session 6

Other Critical Issues for Building Community Resilience

Chairs: Mr Ardito Kodijat & Dr Ocal Necmioglu

The session addressed progress, gaps and emerging challenges in building community resilience for tsunamis, with specific focus on the social and human perspectives in Tsunami science and tsunami early warning, tsunami ready for critical infrastructure, and cascading and compounding hazards and systemic risks.

Current Status

- Tsunami science incorporates social and human perspectives to enhance understanding and governance of tsunami risks, yet there remains a need for holistic approaches that adequately address community preparedness and disaster risk reduction.
- Critical infrastructure, including airports, ports, schools, hospitals and hotels currently lacks adequate tsunami-resistant design, necessitating enhancements beyond existing building codes to ensure safety and swift recovery during disasters.
- Recent cascading and compound hazards have exposed significant challenges in society's ability to mitigate and prepare for systemic risks, highlighting a complex and interconnected risk landscape that complicates emergency response efforts.

Gaps

- Existing tsunami education and preparedness efforts are often episodic and lack a structured, sustainable framework, while the inclusion of vulnerable groups, particularly women, in decision-making processes remains insufficient.
- There is a significant need for designing critical infrastructure facilities to cater to specific functions during tsunamis, as well as for improved collaboration between infrastructure management and communities for effective preparedness.
- There is a lack of effective frameworks to address the non-linear nature of systemic risks, alongside inadequate integration of technology resilience in emergency management systems, which may compromise detection and warning efforts during simultaneous hazard events.

Future Priorities

- There is a critical need to promote transdisciplinary collaboration in tsunami early warning systems to grasp the social complexities, empower women in disaster risk reduction efforts, and leverage higher education resources to build resilient communities through continuous awareness and preparedness initiatives.
- The goal is to promote implementation of tailored tsunami mitigation strategies for critical infrastructure facilities including conducting effective emergency drills, and implement UNESCO-IOC Tsunami Ready Recognition Programme for critical infrastructure
- To enhance preparedness and governance in this complex risk landscape, there is a need for probabilistic analyses, scenario-building techniques, and a community-level approach to resilience that focuses on capacity building and clarifies roles within a multi-agency governance structure.

Session 7

Contributions of Tsunami Early Warning to Global Initiatives

Chairs: Mr Tony Elliott & Dr Andi Eka Sakya

This session explored the integration of Tsunami Early Warning Systems (TEWS) into broader global initiatives, highlighting synergies with Multi-Hazard Early Warning Systems (MHEWS), UN Secretary General Early Warning for All (EW4All) and other frameworks such as the SDGs, COP28, the Sendai Framework for Disaster Risk Reduction (SFDRR), and the UN Ocean Decade. Presenters also examined specific programmes like UNESCO-IOC Tsunami Ready, WMO Weather Ready Nations, and Making Cities Resilient (MCR 2030), emphasizing their contributions to disaster resilience.

Key Takeaways

- There is already alignment and coherence across many global initiatives at the framework level. For example, EW4ALL was launched at COP 27, and is not a new initiative as such, but builds upon and synergises with existing initiatives.
- The global initiatives are not hazard-specific and are inclusive of tsunami. However, the Ocean Decade also provides an example of where dedicated implementation plans can be developed that address specific challenges associated with tsunami.
- Coordination and partnership are crucial to achieving alignment in practice. It is also evident that the organisations leading EW4ALL pillars have many linkages and networks to facilitate building these partnerships. However, the specific mechanisms for coordination are less clear. The national roadmaps in EW4ALL are a way of facilitating coordination at the national level.
- A recurring theme of the session was about the global initiatives and Early Warning being meaningful at the community / local level, such as risk knowledge and early warning technology and messaging. Tsunami Ready and MCR2030 are vehicles for achieving this.
- Overall, partnership and coordination will be central to aligning tsunami with the global initiatives. However, further work is required to identify and / or establish the most suitable platforms to achieve this, especially at the sub-national level.

Pre-conference events

Chairs: Dr Yuichiro Tanioka & Dr Triarko Nurlambang

Two pre-events were organised preceeding the conference centred around: (i) scientific advancements made since the 2004 Sumatra earthquake, with a focus on forecasting techniques, technological innovations, and understanding complex tsunami sources, and (ii) importance of building community preparedness and sustaining advancements in early warning systems and infrastructure. These discussions brought together leading experts and stakeholders to address challenges, explore innovations, and outline priorities for future work in tsunami science and risk management.

Key Takeaways

- Advances in DART observations, modelling, source characterisation, high-performance computing and digital twin technologies have improved real-time impact tsunami predictions not only from far-field earthquakes, but also from complex tectonic regions such as the Banda and Molucca seas.
- Tools such as lidar systems, ship tracking, integration of sea-level and atmospheric pressure data and source modelling have demonstrated promising capabilities for forecasting of tsunamis from volcanic sources such as the HTHH & Anak Krakatau.
- To enhance accuracies of tsunami warning,

immediate priority should be accorded to increase observational data (e.g., SMART cables), data assimilation and machine learning, as well as systematic collection of historical tsunami records, including small tsunamis.

- Develop a clear framework to ensure the sustainability of tsunami warning systems, technological advancements, infrastructure improvements, and community preparedness efforts.
- Strengthen communication strategies and agenda-setting to engage all societal levels, promoting disaster preparedness, early warning systems, and infrastructure resilience.
- Establish a strong institutional framework to manage outreach campaigns and promote research and engineering advancements for enhanced community resilience.

Conclusion

The conference was regarded as high successful in reviewing the status, identifying gaps and coming up with a robust roadmap for enhancing the end-to-end tsunami early warning and mitigation system. The conference adapted the Banda Aceh Statement:

"Global Tsunami Warning and Mitigation: Building Sustainability for the next decade through Transformation and Innovation. UNESCO and its partners call on States and civil society to drastically step up their investments and efforts to strengthen Tsunami Early Warning Systems and achieve 100% of Tsunami Ready Communities across the world by 2030"

Conference Speakers, Panelists, Rapporteurs

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Side Event Speakers, Panelists, Rapporteurs

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