Outcomes from the 2nd UNESCO-IOC Global Tsunami Symposium: Report, Outcomes, Action Plan

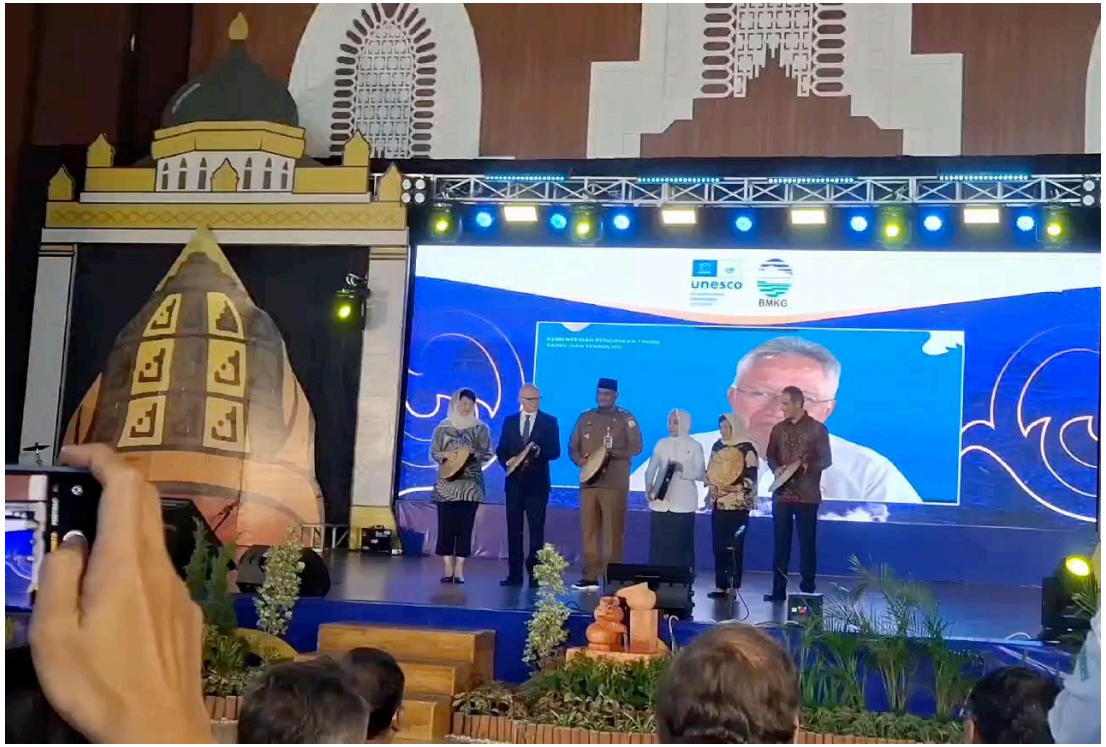
11-14 November 2024, Banda Aceh - Indonesia

Chair : Dr. Harkunti Pertiwi Rahayu (UNESCO IOC-TOWS WG-TTDMP / WG1 IOTWMS)

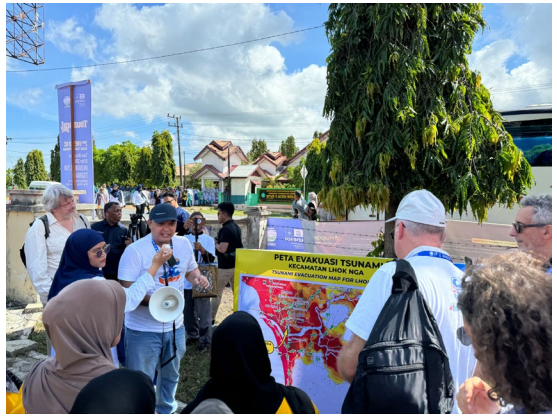
Vice Chair : Ms. Suci Dewi Anugrah (BMKG /WG3 IOTWMS)

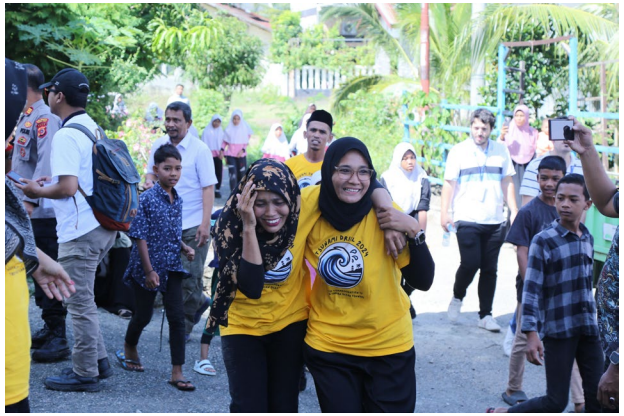
Four Days Symposium

- 8 Sessions
- 1 Day Field trip
- 32 countries
- 682 participants (offline)
- 170 participants (online)
- 1,200 viewers of YouTube

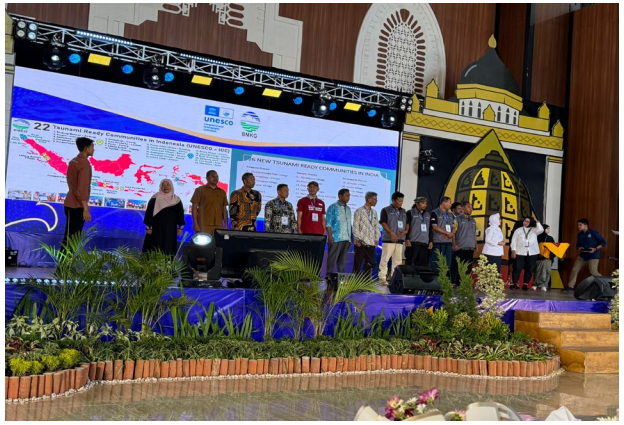


Opening





TR Communities Simulation



New TR Communities Recognition

Objectives

- To commemorate two decades after 2004 Indian Ocean Tsunami
- To reflect what has been achieved in two decades
- To identify gaps, challenges and priorities for tsunami early warning and mitigation
- To identify synergy with global challenges and coherence with global commitments
- To gather global tsunami community

Banda Aceh Statements:

- **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 Achieve 100% of Tsunami Ready Communities across the world by 2030**

Session 1

Review of the Tsunami Warning and Mitigation Systems over the past 2 decades

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- **Chair:** Dr. Idwan Suhardi & Dr. Jorn Lauterjung
- **Rapporteur:** Ms. Nora Gale
- **10 Speakers :**

Gaps (technological)

- Monitoring infrastructure for non-seismic Tsunami (Volcano, Landslide, Meteo-tsunami)
- High resolution shallow water bathymetry
- Inundation modeling and evacuation planing
- open real-time data exchange only incomplete

Future Priorities

- Develop strategies and instrumentation for the detection of non-seismic tsunamis
- Improve sampling rate (less than 1 s) for off shore monitoring, enhancement of offshore tsunami measurements (cable solutions, SMART etc)
- Utilisation of GNSS data
- Improve Real-time data exchange
- PTHA and PTRA
- Inundation modeling, Evacuation planning
- Close collaboration with volcanic observation institutions.
- Promotion of the TRRP
- SOP development for non-seismic tsunamis

Session 2

Tsunami generated by non-seismic and complex sources

- **Chair:** Mr. Bernardo Aliaga
- **Rapporteur:** Srinivasa Kumar Tummala & Denis Chang Seng
- **5 Speakers :**

Gaps (technological)

- 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, Modeling, 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 tsunamis have diverse generation mechanisms, unlike seismic tsunamis, complicating prediction and requiring specialized and dense monitoring and modeling.

Future Priorities

- Immediate need to develop integrated SOPs at national and regional level for operational warning of tsunamis generated by non-seismic sources, using existing knowledge, methodologies and data sets, several of which are described in Technical Series 183.
- Need to establish strong linkages with agencies involved in volcano and tsunami monitoring, both at the national and international level since it is important to develop operational warning capabilities, included SOP's.
- Detailed studies related to hazard assessment of tsunamis generated by non-seismic sources need to be undertaken.
- Develop numerical modelling capabilities and scenario databases of non-seismic tsunamis to aid in hazard assessment and development of early warning capabilities.
- High resolution bathymetry is important for hazard assessment and modelling of tsunamis generated by non-seismic sources
- Optimal observing networks need to be designed and implemented for monitoring and warning of tsunamis generated by non-seismic sources, the general basis of which is described in the Technical Series 183 and in the Ocean Decade Tsunami Programme Research, Development and Implementation Plan.
- Strong international collaboration and global integration of multi-hazard warning systems is necessary for comprehensive tsunami risk management.

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Session 3

Tsunami Hazard and Risk Assessment (1)

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- **Chair:** Dr. Srinivasa Kumar Tummala
- **Rapporteur:** Mr. Rick Bailey
- **8 Speakers :**

Gaps (technological)

Evaluating seismic and non-seismic generated tsunami hazards

- Extending tsunami hazard assessments into more multi-hazard assessments and coastal vulnerability assessments.
- More background, historical statistical information on tsunamis generated by non-seismic and complex sources to extend PTHAs and real-time forecasts to include these sources.
- Require more high-resolution bathymetry data for assessments on tsunamis generated by landslides, etc.
- Need not only focus on largest impact scenarios but need also consider smaller scenarios when need to begin considering preparedness.
- Need catalogues of sources extended further back in time, such as last Holocene period
- Scale of global collaboration and assessments required is challenging

Future Priorities / Plan

Evaluating seismic and non-seismic generated tsunami hazards

- Expansion of global community utilising GTM to further enhance and expand coverage of tsunami modelling activities and risk assessments.
- Demonstration of hazard and forecasting capabilities at national level for future regional and global application.
- Utilisation of supercomputer facilities, Artificial Intelligence, and collaboration with private sector to develop new products and services to help accelerate Tsunami Ready
- Extension of PTHAs to include tsunamis generated by non-seismic and complex sources (e.g. volcanoes, landslides, meteo-tsunami, splay faulting, etc).
- More paleo-tsunami work to inform tsunami hazard assessments where required.
- Synergizing Meteo-Tsunami warning system provided by WMO.

Session 3

Tsunami Hazard and Risk Assessment (2)

- **Chair:** Dr. Srinivasa Kumar Tummala
- **Rapporteur:** Mr. Rick Bailey
- **8 Speakers :**

Gaps (technological)

Identifying Communities at Risk

- Resources and commitment to extending UNESCO-IOC Tsunami Ready Recognition Programme and similar national initiatives to meet significant global requirements
- Need hazard and risk assessments at local level and develop uniform guidelines for tsunami risk assessment
- Identify total and disaggregated numbers for populations at risk within tsunami inundation areas
- Identify and prioritise critical infrastructure
- Incorporate tsunami risk mitigation strategies and sustainable development to help achieve resilient communities
- Detailed topographical and bathymetry data needed for inundation modelling, which is even more of a challenge for many small (e.g. SIDS) and developing countries (LDCs).
- Need awareness and preparedness of communities for tsunamis generated by all sources
- Identifying disadvantaged segments of the community at higher risk

Future Priorities / Plan

Identifying Communities at Risk

- Extension of UNESCO-IOC TRRP and similar national initiatives, utilising Tsunami Ready Coalition to enhance awareness of TRRP and growth in resources required to implement.
- Review of preliminary results of coastal community at-risk quantification and consider extension to other ocean basins
- Consultation with countries about administrative level identification and application to UNESCO-IOC TRRP and similar national initiatives
- Assisting countries define priority areas for implementation of Tsunami Ready

Session 4

Tsunami Detection, Warning, Dissemination, and Response (1)

- **Chair:** Prof. Nanang Puspito and Dr. Charles McCreery
- **Rapporteur:** Ms. Ocal Necmioglu
- **8 Speakers :**

Summary

b. How do we Enhance Timeliness and Accuracy of Tsunami Warnings?

- Dr. Srinivasa Kumar Tummala: > 70% of tsunamigenic events are from earthquakes, followed by confirmations from SL observations. Challenges remain for non-seismic and near-source events. Target zone is 10 min for sea-level confirmation. Main target is to issue actionable and timely warnings from all sources to 100% of coasts at risks. **The priorities** are maximizing and expand current capabilities (adding GNSS, HF Radar, Infrasound), identification of new tech (Ionospheric tomography – TEC, etc.), new forecast methods including Probabilistic methodologies design of optimal notional global networks to fulfil the requirements of the ODTP.
- Mr. Shingo Ushida: many improvements in JMA tsunami forecasting techniques after the 2011 Tohoku event, i.e. methods to quickly determine the possibility of Magnitde JMA underestimation and start evaluating the tsunami potential based on the worst-case scenario. 80 broadband & strong-motion seismographs were installed. Magnitudes are estimated by using the w-phase, more quickly than the ordinary CMT analysis, noting that the amplitude of the w-phase rarely saturates. Offshore tsunami detection capabilities have increased using tsunamimeters through cabled ocean bottom pressure gauges and GPS buoys. More recently, JMA has developed methodologies based on tsunami waveform inversion from offshore data to estimate Hmax at the coastline. These improvements significantly enhanced the tsunami warning capabilities.
- Dr. Dakui Wang: 85 percent of earthquakes occur in the ocean and highlighted the examples of Palu 2018 and HTHH 2022 and reminded the ODTP goals of tsunami confirmation within 10 min. Current gaps: as detection speed, communication delays, limited real-time data availability, accuracy gaps in estimation of location, magnitude, depth of the event. need to expand" ocean sensor networks, integration of satellite data, AI and machine learning. Modelling accuracy need to be enhanced using hr data and models. Alert can be automized, public education and trust needs to be improved, clear warning criteria should be established to avoid false alarms. He advocated to foster global and interagency collaboration.
- Mr. David Coetzee: demonstrated the steps for tsunami warning efficiency as observation capability, interpretation of hazard and risk, people-systems, communication sys-reach, impact, public action. each step can be considered as effective when the last step is effective. Speeding steps 1-5 will allow longer time for step 6. Effective public decision making involves good understanding of both natural and official warnings. Instructions should be clear, received from a trusted source, through at least 2 channels, reaching at least 75% of the people in the expected impact area. SFDRR advocates for risk-informed decision making, known as impact-based forecasting and warning. **The priorities:** need to consider vulnerability of the people and assets at the time and location of impact: warnings should include expected impact, which has been focus on the WMO High Impact Weather Research. This concept has been applied by NOAA National Weather Service since 205, part of SPCs PPREP Programme in the Pacific – Tonga & Samoa Met since 2022. **Challenges** include information about historical and future potential impacts and major problem is–where do we get the data for this purpose. Technical verifications and verifications remain as major challenges.

Session 4

Tsunami Detection, Warning, Dissemination, and Response (2)

- **Chair:** Prof. Nanang Puspito and Dr. Charles McCreery
- **Rapporteur:** Ms. Ocal Necmioglu
- **8 Speakers :**

Summary

c. How do we Ensure Tsunami Warnings Reach all in the community?

- Mr. Harald Spahn: focused on the issue as when official warnings do not reach the population. The approach they use is a visualization tool to support multi-stakeholder working process on tsunami warning chains. Warning Chain graphics have been developed for all IOTWMS states except Yemen (as of early 2024). In general, within the IOTWMS, there seems to be a consistency in warning chains, but some clarifications are needed on several aspects within the warning chain. He highlighted the call for evacuation as very important, 6 countries with near-field threat chose local level, others national. For local threat, there appears to be a good basis for timelines for tsunami evacuation issuance, but for far field the situation is different. Only 12 out of 24 countries indicated the existing on SOPs 9 from NTWCs. However, many SOPS from NDMOs are not working SOPs but more like generic guidance. Keep on analysing, discussing and testing SOPs and improve them, and to provide more training on SOPs and promote sharing best practices.
- Dr. Harkunti P. Rahayu focused on inclusive people centred early warning system in the face of near-field tsunami. 1.3 billion people are disable (16% of World population) – 22.5 million disable in Indonesia (8.5& of Indonesia) – limited access to tsunami warning. How can people with disabilities respond to tsunami warning. She highlighted the role of panic during an event and the need to consider inclusive evacuation planning, looking into social cognitive behaviour of the communities, physical/non-physical factors of urban and rural setting, character of inclusive network of information flow. There is a specific need for inclusive SOPs for disabled persons. One example is how to communicate warnings to the persons with hearing disabilities and highlighted the special cases for schools for persons with disabilities- where only teachers can hear the warning but not the students. Communal and personal warning chain tools needs to be developed. As a solution, a cross-platform for messaging has been developed and will be testes after the Symposium.
- After the speakers, a vide was presented to the actions taking by the BMKG at the time of the event. Number of the sensors were very limited, and their spatial distribution was scares. Magnitude was calculated based on 5-6 stations as 6.5 but had a major uncertainty in location. TV broadcasting demonstrate

Session 5

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

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- **Chair:** Prof. Faisal Fathani and Mr. David Coetzee
- **Rapporteur:** Ms. Nora Gale
- **10 Speakers :**

Gaps (technological)

- 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

- Scaling up the implementation of TRRP through:
  - Establishing a TTRP implementation plan for each region, including identification 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 (1)

- **Chair:** Mr. Ardito M. Kodijat and Dr. Ocal Necmioglu;
- **Rapporteur:** Dr. Laura Kong
- **10 Speakers :**

Summary

a. Social and Human Perspective in Tsunami Science and Tsunami Early Warning:

- Social perspectives of tsunami sciences, or social sciences and humanities, can pave the way for thinking differently about living on Earth and the challenges of governing it. These perspectives also facilitate discussions on the mobility, circulation, and exchange of knowledge from different countries, which help explain the development of tsunami science from the past to the present and its implications for improving the tsunami warning system.
- Through the lens of social sciences and humanities, tsunamis can be seen as having regenerative capacities, not just as threats or risks to the environment and humankind. This perspective allows us to explore the unseen relationships between humans, technologies, and the Earth. To achieve this understanding, transdisciplinary scientific work is necessary to grasp the social complexities brought by tsunamis. The discussion emphasizes the importance of disaster risk reduction, loss and damage assessments, and policies aimed at zero casualties, particularly in the context of the 2004 Indian Ocean tsunami.
- Emphasizing the importance of a knowledge management approach, especially in internalizing processes that transform explicit knowledge into tacit understanding, can prompt effective action during emergencies. Disaster education and community preparedness for tsunamis must go beyond one-off drills or socialization sessions, requiring a structured, systematic, and sustainable approach.
- Highlighting the importance of empowering women in tsunami awareness and education is essential. As a vulnerable group, women also play a crucial role on the front lines of family and community resilience-building. Equipping them with knowledge and skills strengthens disaster preparedness at all levels. Women's involvement in DRR should be not only procedural but substantial, ensuring they have opportunities in decision-making.
- Recognizing the role of higher education in community resilience, leveraging resources such as students who can serve as community agents, promoting tsunami awareness and preparedness, and building a culture of safety and preparedness.
- Attempts to cover early warning across transdisciplinary aspects were introduced under the "People-centred Tsunami Early Warning for the Indian Coastlines," working along the interaction of three pillars: understanding basic source processes and how they influence tsunami risk and hazard; new technologies within tsunami early warning for India; and improved tsunami resilience through increased awareness and inclusivity of the local population subject to tsunami early warning.

Session 6

Critical issues for building community resilience (2)

- **Chair:** Mr. Ardito M. Kodijat and Dr. Ocal Necmioglu;
- **Rapporteur:** Dr. Laura Kong
- **10 Speakers :**

Gaps (technological)

b. Critical infrastructure ready for tsunami: design, implementation, and maintenance

- Critical infrastructure is defined as a structure accommodating many peoples for special purpose, i.e. school, hospital, hotel, airport, and port. Thus, the strength of critical infrastructure toward tsunami is in question.
- Airport is potential to be used for evacuation of airport stakeholders and surrounding communities.
- Tsunami Drill has been conducted in 3 airport (Yogyakarta, Denpasar, Padang) and 2 port (Benoa and Pelindo-Cilegon)

Future Priorities

b. Critical infrastructure ready for tsunami: design, implementation, and maintenance

- Critical infrastructure should be properly designed beyond the existing building code by considering seismic resistant and tsunami resistant parameters. With the consequence on the cost of the structure.
- To reduce the structure cost of large infrastructure such as airport, L1 and L2 tsunami mitigation approach is needed. L1 focuses on prevention to protect lives and reduce damage for certain critical airport facilities such as AOC (Airport Operation Center). L2 focuses on mitigation to reduce damage for evacuation shelters.
- Collaboration between critical infrastructure management and the community in tsunami-prone areas is crucial to ensure tsunami readiness. The drill should be designed by not interrupting the operation of the airport, i.e. during the curfew hour (no flight) such as after 10 p.m.
- Future target is to promote UNESCO IOC Recognition for Tsunami Ready Airport and Port

Session 6

Critical issues for building community resilience (3)

- **Chair:** Mr. Ardito M. Kodijat and Dr. Ocal Necmioglu;
- **Rapporteur:** Dr. Laura Kong
- **10 Speakers :**

Summary

c. Cascading and Compound Hazards, systemic risk

- Recent events have revealed how systemic risks challenge society's mitigation, preparedness and emergency relief to contain the impact of hazards on communities. This includes cascading and compounding events and impacts. These events have also revealed the difficulties associated with understanding and tackling hazard risk in a dynamic, inter-connected and complex risk landscape.
- After complex and disruptive disasters, such as the Palu and Sunda Strait tsunamis, and the COVID-19 pandemic, those involved in early warning have been reflecting on lessons learned to inform future mitigation and preparedness planning. However, the temptation is to reflect on past experiences as systemic risks are typically obvious in retrospect. But their complexity obscures their workings and inhibits extrapolation from the past to the future.
- Society must prepare for the next disruption, which may be very different. For example, the Crowdstrike and Microsoft Azure outages in July 2024 showed the far-reaching consequences of single point failures in computer security and cloud infrastructure. These events caused widespread disruption to aviation, healthcare and financial services around the world, all sectors that might have been expected to have robust and resilient information technology systems that could withstand such threats.
- This poses a concern as to whether a similar technology failure could undermine detection and warning efforts if a tsunami hazard event occurred simultaneously. The threat of such failure is only likely to increase as a move towards multi-hazard early warning increases demands for data sharing and inter-operability.

- How can we strengthen preparedness and governance for this more complex risk landscape? There is a need to use probabilistic analyses or scenario building to sketch out the non-linear nature of systemic risks. Methods such as counterfactual analysis can help build such complex but relatable scenarios to better understand potential hazards, underlying vulnerabilities, impacted systems, and the interconnections between them. There will be a need to treat resilience as capacity building and take a community-level, place-based approach to understand where risk is realised. There are examples like resilience hazard assessment that takes 'a holistic perspective of shocks and stresses' within a specific place or community. There is also a need to fit governance to the characteristics of the decision context and clarify roles and responsibilities f.

Session 7

Critical Contributions of TEWS to global initiatives:

- **Chair:** Mr. Tony Elliott and Dr. Andi Eka Sakya
- **Rapporteur:** Prof. Richard Haigh
- **7 Speakers :**

Gaps (technological)

- 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 per se, but about building upon and synergising with existing initiatives.
- The global initiatives discussed during the session are not hazard specific and therefore are inclusive of tsunami.
- However, coordination and partnership are crucial to achieving alignment in practice. The national roadmap in EW4ALL might be a way of facilitating coordination at the national level. The Ocean Decade also provided an example of where dedicated implementation plans can be developed that address specific challenge associated with tsunami. It is also evident from the presentations made, that the leaders of the EW4ALL pillars have a lot of the linkages and networks to facilitate building those. However, the specific mechanisms for coordination are less clear.

Future Priorities

- Global initiatives and EW must be made meaningful at the community / local level, such as risk knowledge and early warning technology and messaging
- 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-event 1

Special Session -Tsunami sciences after, the 2004 Sumatra earthquake

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- **Chair:** Prof. Yuichiro Tanioka
- **Rapporteur:** Prof. Yuichiro Tanioka
- **10 Speakers :**

Science Advancement

- Monitoring infrastructure for non-seismic Tsunami (Volcano, Landslide, Meteo-tsunami)
- tsunami forecast system using DART system is advanced for far-field tsunami after the 2004 Sumatra event. observed tsunami from 2022 Tonga eruption was well modeled.
- digital twin technique using the Super-computer or GCPU computer (Amazon) was developed and could forecast the tsunami inundation, building damage and human losses about 10 minutes in Japan.
- tsunami waring system in New Zealand was developed using DART buoy data and the original hazard map was also developed. New Zealand is also working towards utilization of sea level and atmospheric pressure data to detect non-seismic tsunamis associated with volcanoes and air sea coupling.
- New forecast method for the volcanic tsunami like the 2018 Krakatau tsunami was developed using a Lader system and a ship tracing system. New method for the optimal design of ocean bottom pressure sensors was also developed.
- tsunami forecast system using the depth dependent rigidity was developed to accurately forecast tsunami from tsunami earthquakes such as the 2010 Mentawai earthquakes. New tsunami forecast system for the volcanic tsunami for future Krakatau eruption was developed using the database of tsunami wavefield and 6 tsunami waveforms near the source region.
- complicated tsunami sources are found in the most complicated tectonic region near Banda Sea and Molucca Sea areas.
- 2022 Tonga tsunami was studied using the tsunami waveforms observed by tide gauges around the world.

Future Priorities

- Need more observation data (such as SMART cable) to improve the accuracy of tsunami forecast. A breakthrough of tsunami forecast using data assimilation and Machine learning techniques will occur.
- The small historical tsunami should be collected more systematic way.
- Pre-historical events are important to understand the future mega-tsunami events

Pre-event 2

Roundtable Discussion #2 on Reflection of IABI toward achieving 100% Communities a risk to prepared and resilience to tsunami

- **Chair:** Dr. Triarko Nurlambang
- **Rapporteur:** Mr. Roby
- **4 Speakers :** Harkunti P Rahayu, PhD, Dr. Lilik Kurniawan, Mr. Sugeng Triutomo, Mr. Jefrizal Revanche

Recommendation:

Encourage the development of a global strategy to ensure the effectiveness and sustainability of various advances in the development of early warning systems and building the character of community preparedness and resilience, through:

- Focusing on maintaining sustainability: Immediately outline the DNA of the word "sustainability" to re-orient the progress that has been achieved by global tsunami warning systems, technological development, infrastructure strengthening, as well as strengthening the character of community preparedness and safety.
- Focusing on strengthening communication strategies and agenda setting that reaches all levels of society
- Communication strategies with effective agenda setting are aimed at strengthening the character of community preparedness and security, especially in the areas of tsunami early warning and infrastructure technology and strengthening community character in facing tsunami disasters.

- Immediately establish or form an organization that has a special mandate to manage and utilize various conventional and popular communication means to carry out campaigns and promote various research and engineering results that have been tested.

Thank you …