

**INTERGOVERNMENTAL COORDINATION GROUP (ICG)
INDIAN OCEAN TSUNAMI WARNING & MITIGATION SYSTEM (IOTWMS)**

Working Group 2 on Tsunami Warning, Detection and Dissemination

25 August 2025

Meeting Report

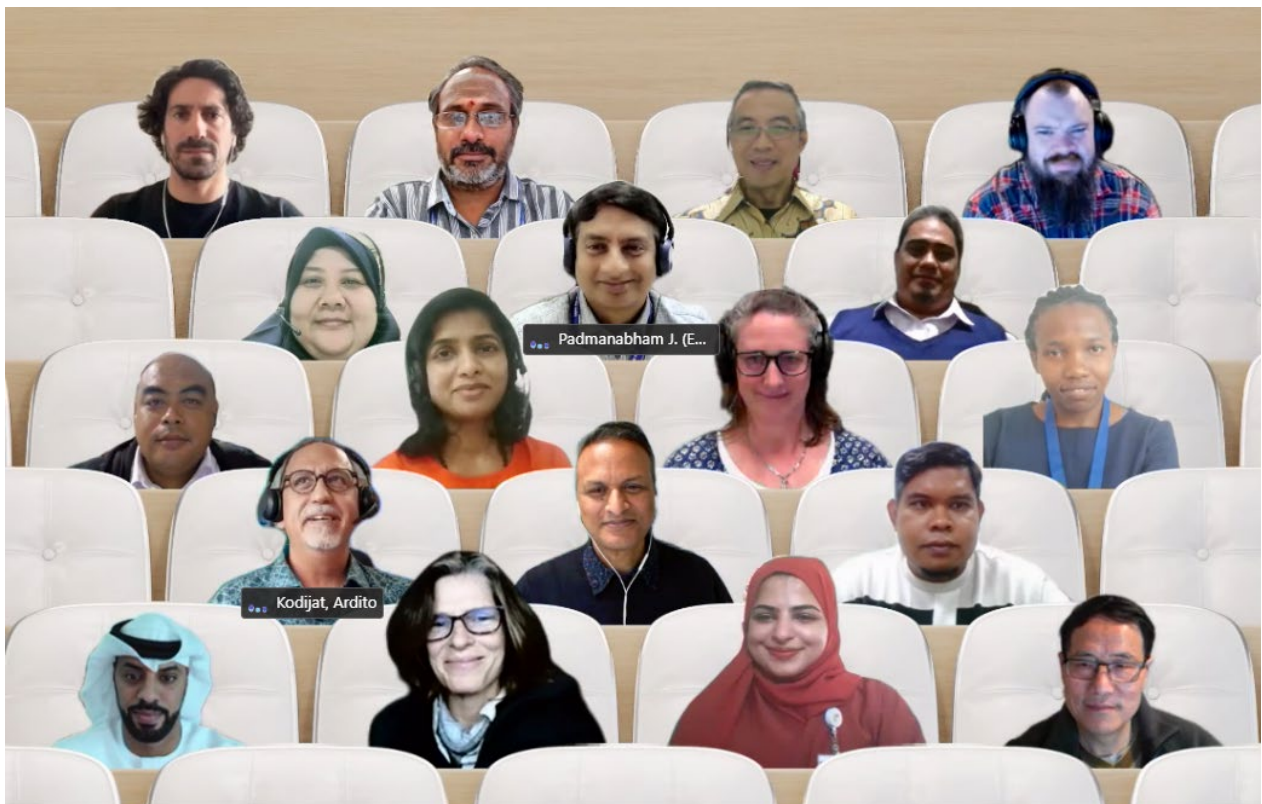


Figure 1. Participants at the ICG/IOTWMS Working Group 2 meeting held online during 25 August 2025.

Presentations and relevant documentation for the meeting can be found on the meeting website: <https://oceanexpert.org/event/4839>.

1. OPENING

1.1 INTRODUCTIONS, WELCOME AND OPENING REMARKS

Dr Srinivasa Kumar Tummala, Head of the Secretariat for the Intergovernmental Coordination Group of the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS) extended a warm welcome to all participants attending the Working Group 2 meeting on tsunami warning, detection, and dissemination.

Participants were invited to provide brief introductions. The Working Group 2 intersessional meeting attendees included:

Chair

Mr Padmanabham Jijavarapu (India)

Vice-Chairs

Dr Robert Greenwood (Australia)

Mr Yedi Dermadi (Indonesia)

Members

Ms Adrienne Moseley (Australia)

Mr M Nagaraja Kumar (India)

Mr Januar Arifin (Indonesia)

Iman Fatchurochman (Indonesia)

Ms Moza Al-Marhoobi (Oman)

Mr Anjum Nazir Zaighum (Pakistan)

Ms Rose Cheptoo Soy (Seychelles)

Mr Badr Alameri (UAE)

Ms Shamma Alneyadi (UAE)

Invited Experts

Dr Yuelong Miao, ICG/IOTWMS Vice-Chair (Australia)

Mr Ajay Kumar Bandela, TT-IOWave25 Chair (India)

Ms Sunanda Manneela, WG-NWIO Chair (India)

Ms Suci Dewi Anugrah, WG3 Chair (Indonesia)

Dr Harkunti P Rahayu, ICG/IOTWMS Vice-Chair (Indonesia)

Dr Wahyu W Pandoe, TT-New/Emerging Technologies Chair (Indonesia)

Prof Usama Kadri, Cardiff University (United Kingdom)

Observers

Mr Adam Gimes (Australia)

Dr Bayu Pranata (Indonesia)

UNESCO-IOC

Dr Srinivasa Kumar Tummala (ICG/IOTWMS Secretariat)

Mr Ardito Kodijat (IOTIC)

Ms Nora Gale (ICG/IOTWMS Secretariat)

Mr Padmanabham Jijavarapu, Chair of Working Group 2 on Tsunami Detection, Warning and Dissemination, welcomed members, Tsunami Service Provider (TSP) representatives, and ICG/IOTWMS colleagues, expressing appreciation for their continued commitment to tsunami warning and mitigation in the Indian Ocean. He emphasized the importance of the meeting in consolidating progress and preparing for future challenges, including Exercise Indian Ocean Wave 2025 (IOWave25). He noted that discussions would focus on service updates, progress on Working Group 2 initiatives, advancing NAVAREA bulletins, and procedures for non-seismic tsunami scenarios. He underscored the group's role in developing practical tools and fostering collaboration with global. The Chair reaffirmed support for the Ocean Decade Tsunami Programme and emphasized continued collaboration with international initiatives that align with the goals of ICG/IOTWMS. He thanked the Secretariat for their coordination and the Member States for their valuable contributions, encouraging constructive input to help shape clear actions and recommendations for future work.

Dr Yuelong Miao, Vice-Chair of the ICG/IOTWMS, welcomed participants, expressing appreciation for the timely convening of Working Group 2 following the successful and collaborative Working Group 1 meeting and preparatory Tsunami Service Provider meeting. He emphasized the importance of meaningful discussion, especially as the group navigates a critical phase in the UN Ocean Decade. He highlighted the need for collective contributions to refine procedures, launch new services, and clarify roles and responsibilities. With confidence in the Working Group members and invited experts, he looked forward to

productive updates and discussions, including those related to Exercise IOWave25. He encouraged active participation to ensure a successful meeting.

1.2 ADOPTION OF AGENDA AND MEETING LOGISTICS

Mr Jijavarapu presented the agenda for adoption. The agenda was adopted with the following amendments to Item 3.1: (a) Mr Ardito Kodijat will deliver a presentation on UNESCAP and FUST, replacing the previously scheduled topic on People-Centred Tsunami Early Warning for the Indian Coastlines (PCTWIN) which will be delivered by Ms. Sunanda; and (b) the Task Team on New and Emerging Technologies presentation was rescheduled to the end of the agenda item to better accommodate Dr Wahyu Pandoe's availability. The final agenda is available in Annex 1.

2. ACTIVITY UPDATES

2.1 CHAIR REPORT

Mr Padmanabham Jijavarapu, Chair of Working Group 2, presented the Chair's report. The report provided an overview of the working group's terms of reference, membership, recent activities, and key recommendations.

The terms of reference are to liaise with other working group(s) and task team(s) within the ICG/IOTWMS and with working groups from the other ocean basins through the TOWS-WG to:

1. Coordinate and strengthen the operational implementation of tsunami detection, warning, and dissemination, including for tsunamis generated by non-seismic and complex sources, and multi-hazard framework.
2. Support the Tsunami Service Providers (TSPs) delivery of interoperable regional tsunami threat information products to Member States.
3. Support Member States in the development of their national tsunami warning capabilities.
4. Monitor the performance of key observational, warning and communication system components.
5. Support implementation of IOWave Exercises.
6. Identify areas of priority for action following assessments, communications tests, exercises, and real tsunami events.
7. Provide advice to and collaborate with the UNESCO-IOC Indian Ocean Tsunami Information Centre (IOTIC) on capacity development on warning system and services including for non-seismic and complex sources.
8. Provide special attention to the needs of SIDS, LDCs, Africa in the work program.
9. Develop WG2 work plans in line with the broad objectives of ODTP RDIP, Ocean Decade Challenge 6, EW4ALL.
10. In collaboration with UNESCO-IOC IOTIC and UNESCO-IOC Secretariat for ICG/IOTWMS, help strengthen the capacity and capability of Member States.

The current membership of Working Group 2 includes 20 experts from nine Member States: Australia, India, Indonesia, Malaysia, Myanmar, Oman, Pakistan, Seychelles, and the United Arab Emirates. The Task Team on New and Emerging Technologies, chaired by Dr Wahyu Widodo Pandoe of Indonesia, reports directly to Working Group 2. The Working Group also engages with international experts, including Prof Usama Kadri of Cardiff University and Prof Fatemeh Jalayer of University College London.

Working Group 2 is tasked with coordinating and strengthening the operational implementation of tsunami detection, warning, and dissemination systems, including those for non-seismic and complex sources. The group supports TSPs in delivering interoperable regional threat information, assists Member States in developing national warning capabilities, monitors system performance, and contributes to IOWave exercises. Working Group 2 also collaborates with the UNESCO-IOC Indian Ocean Tsunami Information Centre (IOTIC) on capacity development and prioritizes support for Small Island Developing States (SIDS),

Least Developed Countries (LDCs), and African Member States. Its work aligns with the objectives of the Ocean Decade Tsunami Programme (ODTP) and the Early Warning for All (EW4All) initiative.

Mr Padmanabham reported that during the intersessional period, TSPs enhanced their capabilities to provide threat information for non-seismic tsunamis, such as those generated by volcanic activity. TSP-Australia has already implemented this, with India and Indonesia planning to follow. Maritime products for NAVAREAs are scheduled for trial and implementation during the IOWave25 exercise. A draft Standard Operating Procedure (SOP) for tsunamis generated by volcanic events (TGVs) is under development and will be tested during the exercise. TSP operations remain ISO-compliant, with certifications including ISO 9001 and ISO 22328-3.

Communication tests are conducted biannually, bringing the total to twenty-nine tests and seven IOWave exercises to date. A pre-IOWave25 webinar for NAVAREA Coordinators will be held prior to IOWave25 to strengthen maritime tsunami alerting mechanisms.

Mr Jijavarapu reviewed the actions and recommendations arising from key meetings: the fourteenth session of the ICG/IOTWMS (Banten, Indonesia 16-19 November 2025), 19th ICG/IOTWMS Steering Group Meeting (Jakarta, Indonesia, 17–19 June 2025), the 18th session of the TOWS-WG (Paris, France, 24–25 February 2025), and the 33rd IOC Assembly (Paris, France, 25 June – 3 July 2025). These meetings emphasized the need for harmonized SOPs for non-seismic events, enhanced collaboration between NMHSs and TSPs/NTWCs, and the development of impact-based tsunami forecasting methods. The IOC Assembly encouraged Member States to deploy detection systems in underserved regions.

2.2 SECRETARIAT REPORT

Dr Srinivasa Kumar Tummala, Head of the ICG/IOTWMS Secretariat, presented the Secretariat’s report, highlighting continued progress in the development of the IOTWMS as an interoperable “system-of-systems” coordinated by UNESCO-IOC, with NTWCs receiving forecast information from TSPs in Australia, India, and Indonesia. While significant advances have been made in monitoring, modelling, and preparedness, challenges remain in addressing non-seismic and near-field tsunami sources, SOP gaps, and last-mile dissemination. The Tsunami Ready Recognition Programme has expanded to 48 communities in India and Indonesia. Exercise IOWave25 will be conducted from 25 September to 5 November 2025, with four scenarios including a volcanic event. Pre-exercise workshops in August 2025 engaged 400 participants from 23 countries. Biannual communication tests continue, with email proving most reliable, followed by GTS, and SMS.

The 2024 Capacity Assessment noted that while detection, warning, and dissemination systems have largely plateaued since 2018, there has been clear progress in community preparedness. Growth in evacuation SOPs, school and city drills, and tsunami signage is linked to the expansion of the UNESCO-IOC Tsunami Ready Recognition Programme. The Secretariat also reported on endorsed initiatives (e.g. PCTWIN) and new proposals (e.g. UNESCAP & FUST for promoting TRRP). In conclusion, Dr Tummala outlined the 2025–2026 roadmap including IOWave25, SOP workshops, TRRP training, regional webinars, and the next ICG/IOTWMS session to be held in Muscat, Oman during 2026.

Dr Robert Greenwood (Australia) inquired about plans for a volcanic PTHA. Dr Tummala responded that non-seismic sources are starting to be considered under Phase 3 of the UNESCAP project.

2.3 TSP REPORTS AND SERVICE UPDATES

TSP Australia

Dr Robert Greenwood reported on the activities and developments of Tsunami Service Provider Australia (TSP-Australia), operated by the Joint Australian Tsunami Warning Centre (JATWC), a collaboration between Geoscience Australia (GA) and the Bureau of Meteorology (BoM). The Bureau’s tsunami warning services remain ISO 9001 certified through 2026, with GA progressing toward complementary accreditation. Recent system improvements include updates to the TOAST platform, restoration of two

DART stations in the Tasman Sea, and testing of seismic array processing for real-time operations. GA has also upgraded to SeisComp6, currently under evaluation.

TSP-Australia trialled NAVAREA products during the 29th IOTWMS Communications Test on 11 June 2025. Although initial dissemination issues occurred, these were resolved through configuration adjustments, and further trials are planned during IOWave25. Performance metrics for January–June 2025 showed strong results across key indicators, with minor issues in bulletin issuance addressed through system fixes and staff training. Notably, ten incorrect bulletins were issued across 2024 and 2025 due to software and human errors, both of which have since been mitigated.

Future developments include adapting tsunami products to align with the Australian Warning System, transitioning to a new public-facing website, and contributing to a national project focused on volcanically generated tsunami scenarios. The report also reviewed JATWC's response to the 29 July 2025 M8.8 Kamchatka earthquake, which involved 13.5 hours of active monitoring. The event highlighted challenges in public communication due to conflicting messages from PTWC and underscored the need for improved decision support tools and internal sea level visualization capabilities.

TSP India

Mr M Nagaraja Kumar of INCOIS presented the status report for Tsunami Service Provider India (TSP-India), highlighting significant advancements in detection, monitoring, warning dissemination, and preparedness. TSP-India maintains a robust national observation network comprising 17 seismometers, 32 accelerometers, 32 GNSS stations, 36 tide gauges, and 7 bottom pressure recorders, all supported by a 24/7 monitoring centre. A key development was the inauguration of the Synergistic Ocean Observations Prediction and Services Lab (SynOPS) in February 2024, which enables immersive visualization and supports multi-hazard early warning services. Additionally, the TARANG High-Performance Computing facility was established, featuring 1 Petaflops of compute power and 15.5 Petaflops dedicated to AI and machine learning applications.

TSP-India has implemented a multi-channel, multilingual warning dissemination system, including SMS, email, fax, web, and GTS, and uses the SACHET platform to deliver alerts via the Common Alerting Protocol (CAP). The SAMUDRA mobile app further enhances public access to real-time oceanic disaster alerts and forecasts. TSP-India has begun generating NAVAREA messages in accordance with Service Definition Document v5.0 and contributed to the development of the NAVAREA User Guide. Efforts are underway to enhance capabilities for issuing non-seismic bulletins, particularly for tsunamis generated by volcanic activity, with a draft SOP for Tsunamis Generated by Volcanic Events (TGVs) in progress.

In the area of disaster risk knowledge, TSP-India is actively participating in the UNESCAP-led Probabilistic Tsunami Hazard Assessment (PTHA) project for the Makran Subduction Zone, with simulations completed for the Arabian Sea, Persian Gulf, and Red Sea. Preparedness activities included a national tsunami mock exercise in November 2024, drills in the Andaman Islands, and various awareness programs for World Tsunami Awareness Day. INCOIS also hosted workshops and training sessions, including the Tsunami Ready Recognition Programme (TRRP), Tsunami Evacuation Maps, Plans and Procedures (TEMPP), and the PCTWIN project.

Looking ahead, TSP-India plans to sustain and expand its observational networks, including the installation of 14 new tide gauges and a cable-based multi-parameter observatory near the Andaman subduction zone. It will continue contributing to IOTWMS activities, including IOWave exercises, communication tests, SOP workshops, and capacity-building initiatives such as training for Oman NTWC operators and hosting a national SOP workshop in late 2026.

TSP Indonesia

Mr Yedi Dermadi reported on significant developments at Tsunami Service Provider Indonesia (TSP-Indonesia), operated by the Agency for Meteorology, Climatology and Geophysics (BMKG), since the 14th Session of the ICG/IOTWMS held in Jakarta from 17–19 November 2024. Two new operational centres for

the Indonesian Tsunami Early Warning System (InaTEWS) were inaugurated in Jakarta and Bali in mid-2025. Both facilities incorporate base isolator technology to enhance structural resilience against earthquake shocks, marking a major step forward in disaster-resilient infrastructure.

System upgrades include the integration of 4,000 new tsunami scenarios into the TOAST platform, the deployment of AI-based earthquake processing tools, and the development of a new magnitude formula (M_{BMKG}) tailored to local and regional strong motion data. These enhancements aim to improve the accuracy and speed of tsunami threat assessments.

Monitoring capacity has been strengthened with the installation of 20 new seismic stations and the replacement of 24 existing ones. Additionally, BMKG has shared data from 21 broadband seismic stations and successfully installed 100 tsunami gauge stations in 2025. Real-time data from an additional 20 gauges is now available via the IOC Sea Level Monitoring Facility, contributing to regional and global sea level observation networks.

TSP-Indonesia continues to support regional capacity building, including on-the-job training for National Tsunami Warning Centre (NTWC) operators from Oman and Timor Leste. Future plans include expanding the pre-calculated tsunami scenario database, enhancing the WRS-TSP real-time alert system for NTWCs, and maintaining active participation in IOWave25 and regular IOTWMS communication tests. Ongoing efforts also focus on advancing research into non-seismic tsunami sources, refining SOPs, and developing maritime products for NAVAREAs.

Discussion on TSP Presentations

Dr Tummala noted that both JATWC (Australia) and InaTEWS (Indonesia) have transitioned to using SeisComp6 and TOAST, enhancing their seismic and tsunami processing capabilities. Dr Greenwood welcomed this update, emphasizing the value of non-homogeneous solutions among TSPs to ensure independent assessments.

Mr Jijavarapu shared that TSP India employs in-house tools, including a sea level inversion decision support system, to support detection of non-seismic tsunamis. Mr Dermadi reported on Indonesia's development of an algorithm for detecting sea level anomalies, contributing to automated tsunami detection.

Ms Moseley raised a concern regarding DART buoy anomalies where no known source could be identified, highlighting the challenges in interpreting sea level data and the need for robust validation mechanisms.

The discussion underscored the importance of technological diversity, innovation in detection methods, and collaboration among TSPs to improve early warning capabilities for non-seismic tsunami events.

2.4 IOWave25 Report

Dr Ajay Kumar Bandela of INCOIS, Chair of the IOWave25 Task Team, presented an overview of preparations for the upcoming Indian Ocean-wide tsunami exercise, IOWave25, scheduled between 25 September and 5 November 2025. The exercise aims to evaluate and strengthen the effectiveness of the Indian Ocean Tsunami Warning and Mitigation System (IOTWMS), including its Tsunami Service Providers (TSPs), National Tsunami Warning Centres (NTWCs), Disaster Management Organisations (DMOs), and community-level preparedness. The exercise will test operational communication lines, validate Standard Operating Procedures (SOPs), and promote public awareness and readiness.

IOWave25 will feature four scenarios:

1. Sunda Trench (25 Sept) – M9.0 earthquake near Indonesia
2. Makran Trench (15 Oct) – M9.0 earthquake off Pakistan
3. Fani Maore Volcano (25 Oct) – volcanic eruption in the Mozambique Channel
4. Sumatra Trench (5 Nov) – M9.2 earthquake near Northern Sumatra, coinciding with World Tsunami Awareness Day

Each scenario includes detailed tsunami travel times and expected wave amplitudes for participating countries. The exercise objectives span nine key areas, from validating community-level warning dissemination and evacuation procedures to testing NTWC access to TSP bulletins and readiness for non-seismic tsunami sources.

Pre-IOWave25 hybrid workshops were held in August 2025 for Eastern and Western Indian Ocean Member States, with over 400 participants. Based on feedback, 18 Member States have confirmed participation in at least one scenario, with several planning community evacuations. The IOWave25 Exercise Manual is complete, and supplements containing TSP bulletins are being finalized. All materials will be available on the official exercise website.

A detailed checklist outlines preparatory activities, including national coordination, SOP updates, stakeholder engagement, and post-exercise evaluations. The Task Team encourages Member States to align their efforts with the UNESCO-IOC Tsunami Ready guidelines and indicators.

A discussion was held regarding the issuance of NAVAREA bulletins during the IOWave25 exercise. Mr Jijavarapu recommended trialling the NAVAREA products using a single scenario to streamline coordination. Dr Tummala suggested selecting one of the later scenarios, noting that discussions related to the workshop preparations with relevant contacts in IHO/WWNWS-SC were still ongoing. As a result, he also indicated that the associated workshop may need to be postponed allowing better preparations. Dr Bandela supported the use of Scenario 4, highlighting its broad coverage across Member States. Additionally, a draft User's Guide for NAVAREA Coordinators is under preparation to support the exercise.

***Action:** Trial NAVAREA bulletins during IOWave25 using Scenario 4 (Sumatra Trench) on 05 November 2025 to ensure broad coverage and allow time for coordination with NAVAREA stakeholders. The NAVAREA coordinators webinar may also be postponed to 09 October 2025.*

2.5 WG-2 ONGOING INITIATIVES

NAVAREA SOP, Implementation, User Guide

During the ICG/IOTWMS Working Group 2 meeting, Mr Padmanabham Jijavarapu presented the draft Standard Operating Procedures (SOP) and User Guide for NAVAREA tsunami messaging. This initiative responds to a request from the International Hydrographic Organization's (IHO) World-Wide Navigational Warning System (WWNWS), conveyed through the UNESCO-IOC TOWS-WG. The objective is to ensure that TSPs in all ocean basins support NAVAREA Coordinators by providing timely and consistent maritime tsunami products.

The Indian Ocean region is divided into five NAVAREAs: VII (South Africa), VIII (India), IX (Pakistan), X (Australia), and XI (Japan). Each NAVAREA is managed by a designated coastal state responsible for issuing navigational warnings to ships at sea. The NAVAREA Coordinators collect and validate information, coordinate with relevant authorities, and issue maritime safety broadcasts.

Mr Jijavarapu explained that NAVAREA bulletins will only be issued for Type-II (Potential Threat) and Type-III (Confirmed Threat) bulletins. These messages will continue until a Final or Cancellation bulletin is issued. For the IOWave25 exercise, countries will be listed under threat based on two criteria: a) an estimated wave amplitude of 0.5 metres or greater, as assessed by the TSPs, or b) the threat status reported by National Tsunami Warning Centres (NTWCs), in line with IOTWMS public bulletin policy.

Dissemination of NAVAREA messages will be conducted exclusively via email to NAVAREA Coordinators. In response to a question from Ms Suci Dewi Anugrah regarding alternative dissemination methods, Mr Jijavarapu confirmed that email is the method requested by the IHO. Mr Yedi Dermadi inquired whether the bulletins should be posted on TSP websites. Mr Jijavarapu noted that while archiving the messages on TSP websites could be good practice, Dr Tummala advised that, at this stage, dissemination should be limited to email only to avoid public confusion.

Dr Tummala also recommended that references to “CFZ threat level” in the bulletin templates be replaced with “country threat level” to better reflect the purpose of the messages. He further emphasized that the SOP and dissemination protocols should be reviewed against the IOTWMS service policy and formally submitted to the Steering Group for adoption before any implementation beyond the testing phase.

Dr Robert Greenwood asked whether the NAVAREA SOP would be incorporated into the broader NTWC User Guide. Mr Jijavarapu confirmed that it would be included as an annex to both the NTWC User Guide and the Service Definition Document.

***Action:** Review and refine the NAVAREA bulletin dissemination against IOTWMS service policy and submit to the Steering Group for adoption prior to any implementation beyond the testing phase.*

***Action:** Finalize and circulate the NAVAREA User Guide as an annex to the IOTWMS Standard Services Documentation (SDD) and NTWC User Guide. Feedback on the draft, if any may be sought from the IHO/WWNWS-SC before finalisation.*

Generic TSP SOP for Non-seismic Tsunami

Dr Robert Greenwood (Australia) presented a framework for developing standard operating procedures (SOPs) for non-seismic tsunami events, noting that 85–90% of tsunamis are generated by earthquakes, with volcanic eruptions being the second most common cause. SOPs for non-seismic events should mirror those for seismic events as closely as possible, with tailored procedures for near-field and far-field scenarios.

Key elements of the tsunami warning process were outlined:

1. Source Identification – via direct observation (e.g. volcanic ash reports, observatory alerts) or sea-level data (e.g. tide gauges, DART buoys).
2. Threat Assessment – using tsunami travel time contours, pre-computed model runs for known sources, or real-time modelling with adjusted inversion techniques.
3. Product Generation and Dissemination – modifying standard bulletin templates to reflect non-seismic sources while maintaining consistency with seismic formats.

The updated IOTWMS Service Definition Document (Version 5.0) now includes a clause stating that Service Level 2 products may be issued for non-seismic and complex source events, acknowledging the limitations in timely detection and the need for future development.

Prof Usama Kadri contributed insights on impact-generated tsunamis, such as those caused by meteorites, noting that the angle of impact is a critical factor and that modelling such events is relatively straightforward due to their geometric simplicity.

Dr Tummala asked whether the proposed SOP framework would be adopted by all three TSPs. Dr Greenwood responded that while each TSP may use different tools and techniques, they should follow common principles to ensure consistency in threat assessment and messaging.

***Action:** Develop a generic SOP flowchart for non-seismic tsunami events (volcanic, landslide, meteor impact) to support NTWCs and TSPs (WG2 Chair and Vice-Chairs).*

***Action:** Clarify bulletin issuance intervals, particularly the use of hourly updates and criteria for transitioning between bulletin types.*

IOTWMS Optimal Observing Networks – Seismic and Sea-level

Mr Januar Arifin (Indonesia) presented an overview of the seismic, sea-level, and GNSS monitoring networks operated by the three Tsunami Service Providers (TSPs): Australia, India, and Indonesia. The presentation included a comparison of the IOTWMS observational network coverage in 2004 and 2017, highlighting improvements and persistent gaps.

Key points included:

- TSP Australia shares real-time seismic, GNSS, and sea-level data via IRIS, IGS, and IOC portals.
- TSP India operates seismic, tide gauge, tsunami buoy, and GNSS networks, with partial data sharing.
- TSP Indonesia manages a large network of seismic stations, tsunami gauges, GNSS units, and auxiliary sensors, with consolidated monitoring via the InaTNT platform.

The presentation emphasized the ODTP goal of delivering confirmed tsunami warnings within 10 minutes of origin. Challenges to achieving this include proximity of tsunami sources to coastlines, sparse sensor coverage and data latency, and limitations in real-time modelling.

Dr Tummala noted that the stations currently used by TSPs provide a useful baseline for defining the optimal observing network. Ms Adrienne Moseley suggested using color-coded mapping to distinguish stations used by all TSPs versus those used by one or two.

To advance this work, the following actions were agreed:

***Action:** TSPs provide the Secretariat with updated lists of their current monitoring stations (seismic, sea-level) to support the creation of consolidated network maps.*

***Action:** Form a small expert team comprising members from Working Group 2 and the Task Team on New and Emerging Technologies (TT-NET) to a) Define the baseline network b) Identify gaps, c) Propose an optimal observing network aligned with ODTP goals and d) Recommend practical approaches to enhance data sharing from existing stations - amongst the 3 TSPs, between Member States and TSPs and with broader networks such as IOC Sea level Monitoring Facility.*

IOTWMS SDD V5.0 & NTWC User Guide V3.0

Mr Padmanabham Jijavarapu presented the latest updates to the IOTWMS Standard Definition Document (SDD) Version 5.0, highlighting key additions related to NAVAREA messaging and non-seismic tsunami sources. The revised document includes updated procedures and templates for maritime safety bulletins, as well as guidance on issuing bulletins for tsunamis generated by volcanic eruptions, landslides, and other complex sources.

Updates were clearly marked in red font for ease of review. Mr Jijavarapu noted that the NTWC User Guide has been updated in parallel to reflect these changes, resulting in Version 3.0.

These updates aim to ensure consistency across Tsunami Service Providers (TSPs) and enhance the clarity and usability of products issued to National Tsunami Warning Centres (NTWCs) and NAVAREA coordinators.

***Action:** Secretariat to circulate the IOTWMS SDD V5.0 and NTWC User Guide V3.0 to Working Group 2 members for review and approval.*

3. EMERGING TECHNOLOGIES, PROJECT COLLABORATIONS, OCEAN DECADE TSUNAMI PROGRAMME

Task Team on New/Emerging Technologies for Observation and Forecasting

Dr Wahyu W. Pandoe, Chair of the ICG/IOTWMS Task Team on New and Emerging Technologies for Observation and Forecasting, presented an overview of recent technological advancements relevant to tsunami detection and early warning. The presentation covered seven key areas:

1. **Ina-CBT (Cable-Based Tsunami Sensors)** – Indonesia’s second-generation system deployed in the Flores Sea since February 2022. It integrates hydrostatic pressure gauges, accelerometers, and temperature sensors, offering high sampling rates and rapid data transmission. The system is designed for long-term operation with minimal maintenance and is resistant to vandalism.

2. **SMART Cables** – A collaborative initiative led by ITU, WMO, and UNESCO-IOC to integrate environmental sensors into submarine telecommunication cables. These cables can measure seafloor temperature, pressure, and seismic motion, contributing to real-time disaster monitoring and mitigation.
3. **Distributed Acoustic Sensing (DAS)** – A technique that uses existing fibre-optic cables to detect vibrations and acoustic signals. DAS has applications in earthquake and tsunami monitoring, oceanography, marine mammal tracking, and traffic monitoring. It offers extensive coverage, high data density, and low installation costs.
4. **Acoustic Sensing ("Listening to Earthquakes")** – Research collaborations are underway to explore the use of hydrophones for detecting T-waves generated by seismic events. These acoustic signals propagate efficiently in ocean water and can be detected over long distances.
5. **Hybrid Systems** – Combining cable-based and acoustic technologies, hybrid systems are being explored for deployment in tropical waters. Examples include the DONET system in Japan and NSF-supported projects in Indonesia.
6. **Numerical Models** – The Task Team reviewed tsunami modelling tools used globally, including COMCOT, MOST, Tsunami-HySEA, TUNAMI-N2, and ANUGA. These models support real-time forecasting, hazard assessment, and scenario simulation.
7. **Physical Models** – A tsunami simulation device has been developed to replicate wave generation and impact in scaled laboratory settings. It supports educational and experimental studies on coastal defences, vegetation, and infrastructure resilience.

Action: Task Team on New and Emerging Technologies to prepare a report on its work for submission ahead of the next ICG/IOTWMS Steering Group meeting.

PCTWIN Project Initiatives relevant to WG2

Ms Sunanda Manneela of INCOIS presented an update on the PCTWIN project, which has been underway since 2024 and is now in its second year. Co-led by INCOIS and University College London (UCL), the project involves a broad consortium of international and national partners. PCTWIN is structured around three work packages that align with the IOTWMS Working Groups:

- WP1: Knowledge Hub (Lead: NGI) focuses on improving baseline hazard and risk information through probabilistic tsunami hazard and risk analysis.
- WP2: Early Warning (Lead: INCOIS) aims to enhance detection, forecasting, and impact estimation capabilities at both national and regional levels.
- WP3: Resilience Hub (Lead: UCL) promotes inclusive, participatory approaches to increase community awareness and preparedness.

The project is expected to contribute to several key outcomes, including a reduction in tsunami source characterization time (from 10 minutes to 3 minutes), the integration of inclusivity markers into the UNESCO-IOC Tsunami Ready Recognition Programme, and strengthened support for pilot communities. Stakeholder workshops have been held, featuring participatory evacuation mapping and community storytelling.

PCTWIN's long-term impact pathways include saving lives, sharing knowledge, and enhancing resilience. It is funded by NERC UKRI and the Indian Ministry of Earth Sciences and continues to support regional efforts to build inclusive and effective tsunami early warning systems.

Global Real-time Early Assessment of Tsunamis

Dr Usama Kadri from Cardiff University provided an overview of the Global Real-time Early Assessment of Tsunami (GREAT) system, which leverages acoustic-gravity wave detection for rapid tsunami

assessment. He explained that hydrophones are capable of recording acoustic-gravity wave signals generated by submarine earthquakes, offering a promising avenue for real-time tsunami detection. The system integrates data from hydrophones, tide gauges, and other sources, and has been operational since June 2024.

The GREAT software performs end-to-end analysis in under 8 minutes on average, provided that acoustic-gravity waves are recorded by a hydroacoustic station located within approximately 1,000 km of the source. It generates outputs such as alertness level and estimated tsunami height at any global location, and can integrate data on evacuation time, population density, tsunami risk areas, and road access, that can help optimising the evacuation process. Real-time assessments have shown strong agreement with observational data. Historical event data has also been used to generate pre-calculated inverse models for risk assessment and scenario planning, enabling use in situations where no nearby hydrophones are available.

Dr Kadri emphasized the importance of accessing CTBTO hydroacoustic stations, noting that only partial access is currently available (4 out of 6 hydroacoustic stations) and that full access to all stations is essential for global coverage. He recommended that UNESCO-IOC liaise with CTBTO and national data centres to facilitate this. The system currently checks for new earthquake data via the USGS API every five minutes, but delays in data updates highlight the need for more direct data connections.

Looking ahead, Dr Kadri proposed deploying hydrophones at approximately 30 stations globally, specifically designed for tsunami warning, with an estimated cost of USD 70,000–100,000 per deployment station. A small project funded by EPSRC (Sept 2025–March 2026) is underway to advance hydroacoustic deployment and regional policy integration, in collaboration with UPM Malaysia. A larger five-year grant proposal is also in preparation, with opportunities for external partners to join.

UNESCAP, FUST

Mr Ardito M Kodijat, Head of IOTIC, provided an update on two key projects supporting tsunami preparedness in the Indian Ocean region: UNESCAP Phase 3 and the FUST–Flanders FIT project.

UNESCAP Phase 3 focuses on strengthening community capacities for tsunami preparedness and response in alignment with the UNESCO-IOC Tsunami Ready Recognition Programme (TRRP). This phase builds on previous efforts and expands implementation to Maldives and Sri Lanka, in addition to the existing pilot countries in the North-West Indian Ocean: India, Iran, and Pakistan. Oman and the United Arab Emirates are participating through self-funded initiatives. Key outputs include capacity building for inundation modelling and mapping, strengthening local SOPs, supporting the establishment of National Tsunami Ready Boards (NTRBs), and advancing research on non-seismic tsunami sources in the Makran Subduction Zone.

The FUST project adopts a similar approach, aiming to implement the TRRP in Madagascar and Seychelles. In Seychelles, IOTIC conducted national training in 2023 and supported the establishment of the NTRB in 2025. In Madagascar, capacity building activities will be conducted in-country, including training on tsunami inundation modelling and mapping, and support for community-level implementation of the 12 Tsunami Ready indicators.

The projects are coordinated by IOTIC, the ICG/IOTWMS Secretariat, Sub-regional Working Group for the North-West Indian Ocean, and Working Group 3, with funding and oversight provided by the Trust Fund for Tsunami, Disaster and Climate Preparedness under UNESCAP. The initiatives aim to enhance end-to-end early warning systems and promote sustainable, community-based tsunami resilience across the region.

Action: *WG-2 to continue strong engagement with PCTWIN, GREAT, UNESCAP, FUST and other upcoming initiatives such as SMART cables to strengthen ICG/IOTWMS and contribute to the goals of the UN Ocean Decade Tsunami Programme.*

4. WORKPLAN, ACTIONS AND RECOMMENDATIONS

Working Group 2 reviewed its upcoming plans, timelines, and progress on Steering Group-assigned actions. Key upcoming activities include a NAVAREA webinar in October 2025 (jointly organized by Working Group 2, IOTIC, and the Secretariat), and a webinar on tsunamis generated by volcanic events (TGVs) in December 2025. Working Group 2 meetings will continue on a quarterly basis, with an in-person SOP workshop planned for July/August 2026 in Hyderabad, India.

Working Group 2 will advance work on the Optimal Observing System to support ODTP goals, forming a dedicated team within the group to lead this effort. Additional priorities include developing Common Alerting Protocol (CAP) guidelines, collaborating with the Task Team on New and Emerging Technologies, and initiating work on Probabilistic Tsunami Forecasting and Impact-Based Tsunami Information.

Progress on Steering Group actions was also reviewed. Highlights include:

- Completion of the Standard Services Documentation (SDD v5.0) and NTWC User Guide, led by Mr Padmanabham Jijavarapu with support from Ms Nora Gale.
- Continued development of products for non-seismic and complex tsunami sources by TSP-India and TSP-Indonesia, following the model of TSP-Australia.
- Successful NAVAREA product trials during the June 2025 COMMS test by all three TSPs.
- Ongoing efforts to develop training materials for NAVAREA operators, and CAP-based dissemination training for NTWCs.
- Inclusion of SIDS, LDCs, and African Member States as a priority in the WG2 work programme.
- Agreement to prepare a comprehensive WG2 report for submission to ICG/IOTWMS-XIV.

Cyber protection policy development was discussed, with recognition that TSPs may already have national policies in place, making a unified approach challenging.

Actions Arising

1. Trial NAVAREA bulletins during IOWave25 using Scenario 4 (Sumatra Trench) on 05 November 2025 to ensure broad coverage and allow time for coordination with NAVAREA stakeholders. The NAVAREA coordinators webinar may also be postponed to 09 October 2025.
2. Review and refine the NAVAREA bulletin dissemination against IOTWMS service policy and submit to the Steering Group for adoption prior to any implementation beyond the testing phase.
3. Finalize and circulate the NAVAREA User Guide as an annex to the IOTWMS Standard Services Documentation (SDD) and NTWC User Guide. Feedback on the draft, if any may be sought from the IHO/WWNWS-SC before finalisation.
4. Develop a generic SOP flowchart for non-seismic tsunami events (volcanic, landslide, meteor impact) to support NTWCs and TSPs (WG2 Chair and Vice-Chairs).
5. TSPs provide the Secretariat with updated lists of their current monitoring stations (seismic, sea-level) to support the creation of consolidated network maps.
6. Form a small expert team comprising members from Working Group 2 and the Task Team on New and Emerging Technologies (TT-NET) to a) Define the baseline network b) Identify gaps, c) Propose an optimal observing network aligned with ODTP goals and d) Recommend practical approaches to enhance data sharing from existing stations - amongst the 3 TSPs, between Member States and TSPs and with broader networks such as IOC Sea level Monitoring Facility.
7. Secretariat to circulate the IOTWMS SDD V5.0 and NTWC User Guide V3.0 to Working Group 2 members for review and approval.

8. Task Team on New and Emerging Technologies to prepare a report on its work for submission ahead of the next ICG/IOTWMS Steering Group meeting.
9. WG-2 to continue strong engagement with PCTWIN, GREAT, UNESCAP, FUST and other upcoming initiatives such as SMART cables to strengthen ICG/IOTWMS and contribute to the goals of the UN Ocean Decade Tsunami Programme.

5. CLOSING REMARKS

The meeting concluded with appreciation for the active participation and contributions from Member States, Tsunami Service Providers (TSPs), and invited experts. Dr Tummala emphasized the importance of continued collaboration across Working Groups and Task Teams to strengthen tsunami early warning and mitigation efforts in the Indian Ocean region.

Key reflections included:

- Recognition of progress made in implementing NAVAREA bulletins and the need for careful coordination with NAVAREA coordinators.
- Agreement to trial NAVAREA messaging during **Scenario 4** of IOWave25, with dissemination limited to email to avoid public confusion.
- Encouragement to harmonize non-seismic tsunami SOPs across TSPs, while allowing methodological flexibility.
- Acknowledgement of advancements in observational networks and the need for improved data sharing and integration.
- Support for ongoing and emerging projects such as PCTWIN, GREAT, and SMART cable initiatives, which align with the goals of the UN Ocean Decade Tsunami Programme.

The Chair, Mr Padmanabham Jijavarapu, thanked all participants and reaffirmed the commitment of Working Group 2 to deliver actionable outcomes, including updated SOPs, user guides, and enhanced coordination mechanisms. The meeting ended with a call to maintain momentum in preparation for IOWave25 and upcoming intersessional activities.

Annex 1 – Final Agenda

Meeting of ICG/IOTWMS Working Group 2- Tsunami Detection, Warning and Dissemination on 25th August 2025 (online)

#	UTC Time	Agenda Item	Lead / Speakers
1	05:30 – 05:50	Opening	
1.1	05:30 - 05:45	Introductions, Welcome and Opening Remarks	Secretariat / ICG Chair / Vice Chairs / WG2 Chair
1.2	05:45 – 05:50	Adoption of Agenda & Meeting Logistics	JP / NG
2	05:50 – 08:20	Activity Updates	
2.1	05:50 - 06:10	Chair Report (Terms of Reference, Membership, Activities, TOWS- WG/TT-TWO/IOC Meeting Updates, etc)	JP
2.2	06:10 - 06:20	Secretariat Report	SK / NG
2.3	06:20 – 07:10	TSP Reports and Service Updates <ul style="list-style-type: none"> • TSP – Australia (10 min) • TSP - India (10 min) • TSP - Indonesia (10 min) Discussion (20 min)	RG NK YD
2.4	07:10 – 07:20	IOWave25 Report	AK
2.5	07:20 - 08:20	WG-2 Ongoing Initiatives <ul style="list-style-type: none"> • NAVAREA SOP, Implementation, User Guide (10 min) • Generic TSP SOP for Non-seismic Tsunamis (10 min) 	JP RG

#	UTC Time	Agenda Item	Lead / Speakers
		<ul style="list-style-type: none"> IOTWMS Optimal Observing Networks - Seismic and Sea-level (10 min) IOTWMS SDD V5.0 & NTWC User Guide V3.0 Discussion (20 min) 	JA JP
	08:20 - 08:30	BREAK & Group Photo	
3	08:30 – 09:10	Emerging Technologies, Project Collaborations, Ocean Decade Tsunami Programme	
3.1	08:30 - 09:10	<ul style="list-style-type: none"> PCTWIN Project Initiatives relevant to WG2 (10 min) Global Realtime Early Assessment of Tsunamis (10 min) UNESCAP, FUST (05 min) Task Team on New/Emerging Technologies for Observation and Forecasting (10 min) Discussion (05 min)	MVS / FJ UK AK WP
4	09:10 – 09:40	Workplan, Actions and Recommendations	WG-2 Chair
5	09:40 – 09:45	Closing Remarks	WG-2 Chair / Secretariat

JP – Padmanabham Jijavarapu; NG – Nora Gale; SK – Srinivasa Kumar; RG – Robert Greenwood; MNK – Nagaraja Kumar; YD – Yedi Dermadi; JA – Januar Arifin; AK – Ajay Kumar; WP – Wahyu Pandoe; FJ – Fatemeh Jalayer; MVS – Sunanda Manneela; UK – Usama Kadri; AK – Ardito Kodijat