10 Years of the North-Eastern Atlantic, the Mediterranean and Connected Seas Tsunami Warning and Mitigation System (NEAMTWS)

Accomplishments and Challenges in Preparing for the Next Tsunami

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Foreword

The Mediterranean has hosted one of the deadliest tsunamis ever, generated by the A.D. 365 Crete earthquake. Another major tsunami with more than one hundred thousand of casualties and severe damage to coastal cities occurred in 1908 (Messina, Italy). As recently as 2002 (Stromboli, Italy), and 2003 (Boumerdes, Algeria) tsunamis were generated, though fortunately these were not very damaging.

The North East Atlantic area is also an area at risk where well-known earthquake sources can generate a tsunami causing extensive loss of life and property as did the famous 1755 Lisbon earthquake, whose ensuing tsunami impacted not only the Portuguese coasts but also those of Spain, Morocco and the Caribbean.

Several countries are also exposed to inundation due to other types of sea-level related hazards, e.g. storm-surges, in particular those countries with extensive low-lying coastal land.

Since 1965 the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO) has been responsible for the intergovernmental coordination of the Pacific Tsunami Warning System (PTWS). Following the 26 December 2004 tsunami in the Indian Ocean, the IOC Member States requested at the 23rd IOC Assembly (June 2005) that similar warning systems be developed in the Indian Ocean (IOTWS), the Caribbean (CARIBE-EWS) and the North-Eastern Atlantic, the Mediterranean and Connected Seas Tsunami Warning and Mitigation System (NEAMTWS).

Therefore, 2015 marked the 10th anniversary of the establishment of the Intergovernmental Coordination Group for NEAMTWS.

After ten years of development NEAMTWS has now entered a phase where four National Tsunami Warning Centres in France, Greece, Italy, and Turkey, act as Tsunami Service Providers (TSP) and provide tsunami alerts to other NEAMTWS Member States.
In tandem with the warning system a Tsunami Information Centre for the NEAM region (NEAMTIC) was set up in 2011 with the objective of raising awareness and providing information on tsunami and other sea-level related hazards to the general public and communities.

Important achievements by NEAMTWS in the last 10 years have been possible thanks to the commitment and considerable financial investments of its Member States.

The Intergovernmental Oceanographic Commission of UNESCO is pleased to release this anniversary publication which represents an important tool for taking stock of what has been achieved so far and for identifying challenges to be met and gaps to be filled in the coming years in order to achieve full implementation of NEAMTWS.

**Vladimir Ryabinin**  
*Executive Secretary,*  
*Intergovernmental Oceanographic Commission of UNESCO*
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Executive Summary

The Intergovernmental Coordination Group for the North-Eastern Atlantic, the Mediterranean and Connected Seas Tsunami Warning and Mitigation System (ICG/NEAMTWS), formally established by the Intergovernmental Oceanographic Commission of UNESCO during the 23rd session of its Assembly in 2005 to coordinate the establishment of the tsunami Early Warning System and its activities. ICG/NEAMTWS is composed of 39 Member States1 of both Mediterranean and North-eastern Atlantic regions.

The ICG/NEAMTWS is organized around technical working groups and task teams2. There are four technical working groups (WGs):

- Working Group 1: Hazard Assessment and Modelling
- Working Group 2: Seismic and Geophysical Measurements
- Working Group 3: Sea Level Data Collection and Exchange, Including Offshore Tsunami Detection and Instruments
- Working Group 4: Public Awareness, Preparedness and Mitigation

And four task teams (TTs):

- Task Team on Communication Test
- Task Team on Tsunami Exercise
- Task Team on Operations
- Task Team on Tsunami Architecture

During the 10 years of the ICG/NEAMTWS considerable work has been provided by experts representing the Member States, both from the scientific and the civil protection communities, through these Working Groups and Task Teams. This work has focused in particular on assessing the historical tsunamis that occurred

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1 Albania, Algeria, Belgium, Bulgaria, Cabo Verde, Croatia, Cyprus, Denmark, Egypt, Estonia, Finland, France, Georgia, Germany, Greece, Iceland, Ireland, Israel, Italy, Lebanon, Libya, Malta, Mauritania, Monaco, Morocco, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, Slovenia, Spain, Sweden, Syria, Tunisia, Turkey, Ukraine, United Kingdom

2 More detailed information on the ICG/NEAMTWS and governance structure can be found at: http://neamtic.ioc-unesco.org/neamtw/icg-neamtws/what-is-the-icg-neamtws#
in the region and the potential sources of future tsunamis, designing and implementing a warning system that can support Member States, and educating and raising awareness. This publication summarizes the activities undertaken.

Knowledge of the tsunamigenic potential of a region, both in terms of historical tsunamis and the understanding of the potential sources, is a fundamental tool for studies on tsunami warnings and mitigation. The former highlights the need to compile tsunami catalogues that should be as homogeneous and reliable as possible and the latter is essential for tsunami hazard evaluation and warning. Although tsunamis in the NEAM region are not considered as a high threat as they are in Pacific, records show that many have occurred and sometimes have been destructive. In the Mediterranean, for example, there has been roughly one major event per century and there is close to 100% chance that a tsunami wave exceeding 1 metre could happen somewhere in the Mediterranean in the next 30 years\(^3\). The large coastal populations there, especially in summer, nevertheless make it relatively vulnerable to loss of life and the presence of coastal critical infrastructures enhances the associated risk.

When considering the requirements for tsunami warnings in the NEAM region it was soon appreciated that not all Member States have the means or the desire to establish their own national tsunami warning systems but would benefit from an IOC-UNESCO coordinated system. What has emerged is several national centres offering to provide a service to those Member States wishing to receive it through a subscription process. To date there are four such Tsunami Service Providers (TSPs) operating on a 24/7 basis (in France, Greece, Italy and Turkey) with a fifth (Portugal) planning to do so in the near future. The four Tsunami Service Providers were accredited at the thirteenth session of the ICG/NEAMTWS which was held from 26–28 September 2016, in Bucharest, Romania which marked an important milestone in the development of NEAMTWS. Uniquely among the four IOC coordinated tsunami warning systems, NEAMTWS has adopted a procedure whereby TSPs must be accredited, indicating that they comply with a number of requirements agreed upon by all ICG members. This is important to ensure consistency across the TSPs and to keep user confidence high.

A characteristic of the Mediterranean is that it is a semi-enclosed basin, and therefore tsunami travel times are very short. This places considerable demands on obtaining reliable seismic and sea level data as quickly as possible – within minutes at most. Thus, much effort has been expended on station coverage, on increasing

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sampling rates of tide gauges, and on transmitting the data in real time. Considerable progress in improving the observing networks has been achieved through NEAMTWS.

It is important that the TSPs and those receiving the messages maintain a high state of readiness and that the communications and protocols are robust. One way of achieving this is through tests and exercises. Regular, monthly communications tests are conducted by each of the existing TSPs and the contact points within the Member States provide feedback aimed at continuous improvements, e.g. keeping delay times to a minimum, checking integrity of the messages and that contact lists are constantly updated. Tsunami exercises (NEAMWave12, NEAMWave14) have been held in 2012 and 2014 respectively. These simulate realistic tsunami events that enable different parts of the region to work out and test their responses in a meaningful way.

The progress summarised above is insufficient in itself. It has to be complemented by educating and raising awareness within the Member States themselves. This is true not only for the civil protection authorities but also for the general public. The development of the NEAM Tsunami Information Centre is an important step for making citizens, especially youth, aware of tsunami risks and other sea-level related hazards; and identifying, sharing and disseminating good practices in plans.

However, it is vital that such activities take place also within the countries themselves. Several countries have already embarked on such programmes, such as “I don’t take risks - tsunami” in Italy, or the inclusion of tsunamis within “Disaster Prepared Turkey”. Finally, while encouraging progress has been made in the first 10 years much remains to be done.

Challenges include: better quantitative assessment of the tsunami risk in the region; improvement of the warning systems by taking advantage of the latest science; further development of the seismic and sea level observing networks; increasing the involvement of civil protection authorities and public awareness and participation; and exploring a range of opportunities of how to make the system effective and sustainable in the years to come.
Résumé Exécutif

Le Groupe intergouvernemental de coordination du Système d’alerte rapide aux tsunamis et de mitigation dans l’Atlantique du Nord-Est, la Méditerranée et les mers adjacentes (GIC/NEAMTWS), a été officiellement établi par la Commission océanographique intergouvernementale de l’UNESCO à la 23e session de son Assemblée, en 2005, afin de coordonner la mise en place du Système d’alerte rapide aux tsunamis et ses activités. Le GIC/NEAMTWS se compose de 39 États membres\(^1\) des régions de la Méditerranée et de l’Atlantique du Nord-Est.

Le GIC/NEAMTWS s’articule autour de groupes de travail techniques et d’équipes spéciales\(^2\). Il existe quatre groupes de travail techniques :

- Groupe de travail 1 : évaluation et modélisation des aléas
- Groupe de travail 2 : mesures sismiques et géophysiques
- Groupe de travail 3 : collecte et échange de données relatives au niveau de la mer, y compris les instruments de détection des tsunamis au large
- Groupe de travail 4 : sensibilisation de la population, préparation et mitigation

et quatre équipes spéciales :

- Équipe spéciale sur les tests de communication
- Équipe spéciale sur les exercices d’alerte aux tsunamis
- Équipe spéciale sur les activités opérationnelles
- Équipe spéciale sur l’architecture du système d’alerte aux tsunamis

Au cours des dix années d’existence du GIC/NEAMTWS, un travail considérable a été accompli dans le cadre de ces groupes de travail et de ces équipes spéciales par les experts représentant les États membres et issus


\(^{2}\) De plus amples informations sur le GIC/NEAMTWS et sa structure de gouvernance peuvent être consultées à l’adresse suivante : http://neamtic.ioc-unesco.org/neamtw/icg-neamtws/what-is-the-icg-neamtws#
tant du milieu scientifique que de celui de la protection civile. Ce travail a notamment porté sur l’évaluation des tsunamis historiques survenus dans la région et des sources potentielles de tsunamis futurs, sur la conception et la mise en œuvre d’un système d’alerte susceptible d’apporter une aide aux États membres ainsi que sur l’éducation et la sensibilisation. La présente publication résume les activités entreprises.

La connaissance du potentiel tsunamigène d’une région, à la fois du point de vue des tsunamis survenus dans le passé et de la compréhension de leurs sources potentielles, est un outil essentiel aux études relatives aux alertes aux tsunami et à la mitigation. Le premier aspect fait ressortir la nécessité de compiler des catalogues sur les tsunami qui soient le plus homogènes et le plus fiables possible. Le dernier aspect est essentiel pour l’évaluation des risques de tsunami et l’alerte aux tsunami. Bien que les tsunami ne soient pas considérés dans la région de l’Atlantique du Nord-Est et de la Méditerranée comme une menace aussi élevée que dans la région du Pacifique, les archives montrent qu’il s’y en est produit un grand nombre, dont certains ont été destructeurs. En Méditerranée, par exemple, on enregistre environ un événement majeur par siècle et il est quasiment certain qu’une vague de tsunami d’une hauteur supérieure à 1 mètre se produira quelque part en Méditerranée dans les 30 ans à venir. Les vastes populations côtières qui s’y trouvent, notamment en été, exposent pourtant relativement la région à des pertes humaines, et la présence d’infrastructures côtières essentielles amplifie le risque associé.

En examinant les besoins en matière d’alerte aux tsunami dans la région de l’Atlantique du Nord-Est et de la Méditerranée, il a rapidement été constaté que les États membres n’avaient pas tous les moyens nécessaires ou la volonté de mettre en place leurs propres systèmes nationaux d’alerte aux tsunami, mais qu’ils pourraient tirer avantage d’un système coordonné par la COI-UNESCO. Il a donc été proposé que sept centres nationaux offrent un tel service aux États membres intéressés par le biais d’une procédure d’abonnement. À ce jour, il existe quatre prestataires de services relatifs aux tsunami fonctionnant 24h/24 et 7j/7 (en France, en Grèce, en Italie et en Turquie) et il est prévu qu’un cinquième (au Portugal) entre prochainement en activité. Les quatre centres de service d’alerte aux tsunami ont été accrédités durant la treizième session du GIC/NEAMTWS, tenue du 26 au 28 septembre 2016 à Bucarest (Roumanie), qui a marqué une étape importante dans le développement du NEAMTWS. Le NEAMTWS est le seul parmi les quatre systèmes coordonnés d’alerte aux tsunami de la COI à avoir adopté une procédure selon laquelle les centres de service d’alerte aux tsunami doivent être accrédités, en indiquant qu’ils satisfont à un certain nombre de critères convenus par l’ensemble des membres du GIC. Cette mesure est importante pour assurer la cohérence parmi les prestataires et entretenir une confiance élevée chez l’utilisateur.

La Méditerranée se caractérise par sa nature de bassin semi-fermé et des temps de parcours des tsunamis par conséquent très courts. Il existe donc une très forte demande en matière de données sismiques et relatives au niveau de la mer fiables et disponibles le plus rapidement possible – en quelques minutes tout au plus. C'est pourquoi d'importants efforts ont été consacrés à la portée des stations, à l'augmentation de la fréquence d'échantillonnage des marégraphes et à la transmission des données en temps réels. Des progrès considérables ont été accomplis par le biais du NEAMTWS pour améliorer les réseaux d'observation.

Il est important que les centres de service d'alerte aux tsunamis et les destinataires de leurs messages maintiennent un niveau élevé de préparation et que les communications et les protocoles soient fiables. L'un des moyens de s'en assurer consiste à effectuer des tests et des exercices. Des tests de communication périodiques sont conduits chaque mois par chaque prestataire existant, et leurs interlocuteurs au sein des États membres transmettent en retour leurs observations de façon à apporter des améliorations continues, par exemple en réduisant les délais au minimum, en vérifiant l'intégrité des messages et la mise à jour régulière des listes de contacts. Des exercices d'alerte aux tsunamis (NEAMWave12, NEAMWave14) ont été organisés respectivement en 2012 et en 2014. Ils simulent de manière réaliste la survenue d'un tsunami et permettent aux différentes zones de la région de s'entraîner et de tester leurs réponses d'urgence efficacement.

Les progrès décrits plus haut ne suffisent pas à eux seuls. Ils convient de les compléter par des activités d'éducation et de sensibilisation au sein des États membres eux-mêmes. Et cela ne vaut pas uniquement pour les autorités de protection civile, mais également pour le grand public. La mise en place du Centre d'information sur les tsunamis pour l’Atlantique du Nord-Est, la Méditerranée et les mers adjacentes constitue une étape importante pour la prise de conscience des citoyens, en particulier des jeunes, à l'égard des risques liés aux tsunamis et autres aléas liés au niveau de la mer, ainsi que pour le recensement, le partage et la diffusion des bonnes pratiques sous forme de plans.

Cependant, il est essentiel que ces activités se déroulent également au sein des pays eux-mêmes. Plusieurs pays ont déjà mis en train de tels programmes, tels que la campagne « Je ne prends pas de risques – tsunami » en Italie ou la prise en compte des tsunamis dans le programme de préparation aux catastrophes de la Turquie (Disaster Prepared Turkey). Enfin, malgré les progrès encourageants réalisés durant ces dix premières années, de nombreux défis restent à relever.

Les défis sont les suivants : améliorer l'évaluation quantitative du risque de tsunami dans la région ; renforcer les systèmes d'alerte en s'appuyant sur les dernières avancées scientifiques ; développer davantage les réseaux d'observation sismique et d'observation du niveau de la mer ; encourager l'implication des autorités de protection civile ainsi que la sensibilisation et la participation du public ; étudier quelles possibilités permettraient de rendre le système efficace et durable pour les années à venir.
Resumen Ejecutivo

El Grupo Intergubernamental de Coordinación del Sistema de Alerta Temprana contra los Tsunamis y Atenuación de sus Efectos en el Atlántico Nororiental y el Mediterráneo y Mares Adyacentes (ICG/NEAMTWS) fue instituido oficialmente por la Comisión Oceanográfica Intergubernamental (COI) en la 23ª reunión de su Asamblea, en 2005, para coordinar el establecimiento del Sistema de Alerta Temprana contra los Tsunamis y sus actividades. El ICG/NEAMTWS está integrado por 39 Estados Miembros¹ de las regiones del Mediterráneo y el Atlántico Nororiental.

El ICG/NEAMTWS se articula en torno a grupos técnicos y equipos de trabajo². Hay cuatro grupos técnicos de trabajo:

- Grupo de Trabajo 1: Evaluación y modelización de riesgos
- Grupo de Trabajo 2: Mediciones sísmicas y geofísicas
- Grupo de Trabajo 3: Acopio e intercambio de datos de nivel del mar, incluyendo la detección en alta mar de tsunamis, y los instrumentos correspondientes para dichas medidas.
- Grupo de Trabajo 4: Sensibilización del público, preparación y atenuación de los efectos

Y cuatro equipos de trabajo:

- Equipo de Trabajo sobre Pruebas de Comunicación
- Equipo de Trabajo sobre Simulacros de Tsunamis
- Equipo de Trabajo sobre Operaciones
- Equipo de Trabajo sobre la Arquitectura del Sistema Regional de Alerta contra Tsunamis

En los diez años de existencia del ICG/NEAMTWS, los expertos que representan a los Estados Miembros, tanto del ámbito científico como del sector de la protección civil, han realizado una labor considerable a través de

¹ Albania, Argelia, Bélgica, Bulgaria, Cabo Verde, Croacia, Chipre, Dinamarca, Egipto, Eslovenia, España, Estonia, Federación Rusa, Finlandia, Francia, Georgia, Alemania, Grecia, Islandia, Irlanda, Israel, Italia, Libano, Libia, Malta, Marruecos, Mauritania, Mónaco, Noruega, Países Bajos, Polonia, Portugal, Reino Unido, Rumanía, Siria, Suecia, Túnez y Turquía.

² Para información más detallada sobre el ICG/NEAMTWS y su estructura de gobernanza, véase: http://neamtic.ioc-unesco.org/neamtws/icgneamtws/what-is-the-icg-neamtws#
estos grupos y equipos de trabajo. Esa labor se ha centrado, en particular, en la evaluación de los tsunamis históricos ocurridos en la región y las posibles fuentes de futuros tsunamis, el diseño y el establecimiento de un sistema de alerta que pudiera ayudar a los Estados Miembros, y la educación y sensibilización de la población. En esta publicación se resumen las actividades realizadas.

El conocimiento del potencial tsunamigénico de una región, por lo que se refiere a los tsunamis históricos y a la comprensión de las posibles fuentes de los mismos, es un instrumento fundamental para los estudios sobre alertas de tsunamis y atenuación de sus efectos. En el primer caso, pone de manifiesto la necesidad de compilar catálogos de tsunamis que deberán ser tan homogéneos y fiables como sea posible; el segundo elemento es esencial para la evaluación de peligros y la alerta de tsunamis. A pesar de que la amenaza de tsunami no se considera tan elevada en la región del Atlántico Nororiental y el Mediterráneo como en el Pacífico, los registros muestran que han ocurrido muchos y que algunas veces han sido destructivos.

En el Mediterráneo, por ejemplo, se ha registrado aproximadamente un fenómeno importante por siglo y existe una probabilidad cercana al 100% de que se produzca una ola de tsunami de más de un metro en algún lugar del Mediterráneo en los próximos 30 años\(^3\). Las grandes poblaciones costeras de la zona, en especial durante el verano, sin duda la hacen relativamente vulnerable a la pérdida de vidas, y la presencia de infraestructuras costeras esenciales aumenta el riesgo asociado.

Cuando se consideraron los requisitos para las alertas contra los tsunamis en la región, pronto se observó que no todos los Estados Miembros poseían los medios o la voluntad de establecer sus propios sistemas nacionales de alerta de tsunamis, pero que se beneficiarían de un sistema coordinado por la COI/UNESCO. Como resultado, algunos centros nacionales se ofrecen a prestar el servicio, a través de un proceso de suscripción, a aquellos Estados Miembros que deseen recibirlo. Hasta el momento hay cuatro proveedores de servicios de tsunamis que operan con una modalidad de 24 horas los siete días de la semana (Francia, Grecia, Italia y Turquía), y un quinto (Portugal) que planea hacer lo propio en el futuro próximo. Los cuatro proveedores de servicios sobre tsunamis fueron acreditados en la 13\(^a\) reunión del ICG/NEAMTWS, que tuvo lugar en Bucarest (Rumanía) del 26 al 28 de septiembre de 2016, y que supuso un hito importante en el desarrollo del NEAMTWS. De manera excepcional entre los cuatro sistemas de alerta contra los tsunamis coordinados por la COI, el NEAMTWS ha adoptado un procedimiento por el cual los proveedores de servicios de tsunamis deben acreditarse e indicar que cumplen una serie de requisitos acordados por

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todos los miembros del Grupo Intergubernamental de Coordinación. Esto es importante para garantizar la homogeneidad entre los proveedores y mantener alta la confianza de los usuarios.

Una característica del Mediterráneo es que es una cuenca semicerrada y, por lo tanto, los tiempos de propagación del tsunami son muy breves. Esto plantea el reto importante para obtener datos fiables, sísmicos y de nivel del mar, lo más pronto posible, como mucho en minutos. Por lo tanto, se ha dedicado gran esfuerzo a la cobertura de las estaciones, la disminución de los tiempos de muestreo de los mareógrafos y la transmisión de datos en tiempo real. A través del NEAMTWS se han realizado progresos considerables en la mejora de las redes de observación.

Es importante que los proveedores de servicios de tsunamis y los que reciben los mensajes mantengan un alto grado de disponibilidad, y que las comunicaciones y los protocolos sean sólidos. Un modo de lograrlo es mediante la realización de pruebas y simulaciones. Cada proveedor de servicios de tsunamis realiza pruebas de comunicación periódicas mensuales, y los puntos de contacto en los Estados Miembros realizan aportaciones para su mejora continua; por ejemplo, minimizar los tiempos de demora, verificar la integridad de los mensajes y la actualización permanente de las listas de contactos. Se han realizado ejercicios de simulacro de tsunamis en 2012 y 2014 (NEAMWave12, NEAMWave14). En ellos se simulaban tsunamis reales, de modo que las diferentes partes de la región puedan ejercitarse y verificar sus respuestas de manera eficaz.

Los progresos resumidos anteriormente son, en sí, insuficientes, y deben ser complementados con la educación y la sensibilización en los propios Estados Miembros, no solo respecto a las autoridades de protección civil, sino también para el público en general. La creación del Centro de Información de Tsunamis en el Atlántico Nororiental y el Mediterráneo es un paso importante para que los ciudadanos, especialmente los jóvenes, tomen conciencia sobre los riesgos de tsunami y otros peligros relacionados con el nivel del mar; y para determinar, intercambiar y difundir las buenas prácticas. Sin embargo, es vital que estas actividades también se realicen en los propios países. Algunos de ellos ya han iniciado programas de este tipo, como “No corro riesgo de tsunami”, en Italia, o “Turquía preparada para los desastres”, en el que se incluyen los tsunamis.

Por último, si bien se han realizado progresos alentadores en los primeros diez años, queda mucho por hacer. Entre los retos pendientes se encuentran los siguientes: mejorar las evaluaciones cuantitativas de riesgo de tsunami en la región; perfeccionar los sistemas de alerta aprovechando los últimos avances científicos; ampliar las redes de observación sísmica y del nivel del mar; aumentar la participación de las autoridades de protección civil y la sensibilización y participación del público en general; y explorar un abanico de oportunidades para que los sistemas sean eficaces y sostenibles en los próximos años.
Рабочее Резюме

Межправительственная координационная группа по Системе раннего предупреждения о цунами в Северо-Восточной Атлантике, Средиземном и прилегающих морях (МКГ/СПЦСВАСМ) была официально учреждена Межправительственной океанографической комиссией ЮНЕСКО в ходе 23-й сессии ее Ассамблеи в 2005 г. в целях координации работы по созданию системы раннего предупреждения о цунами и ее деятельности. МКГ/СПЦСВАСМ состоит из 39 государств-членов1 Средиземноморского региона и Северо-Восточной Атлантики.

Деятельность МКГ/СПЦСВАСМ осуществляется в рамках технических рабочих и целевых групп2. Были учреждены четыре технические рабочие группы (РГ):

- Рабочая группа 1: Оценка и моделирование опасных явлений
- Рабочая группа 2: Сейсмические и геофизические измерения
- Рабочая группа 3: Сбор и обмен данными об уровне моря, включая обнаружение цунами в открытом море и соответствующие инструменты
- Рабочая группа 4: Информирование общественности, обеспечение готовности и смягчение последствий

и четыре целевые группы (ЦГ):

- Целевая группа по проверке системы оповещения
- Целевая группа по связанным с цунами учениям
- Целевая группа по операциям
- Целевая группа по структуре цунами

В течение десяти лет значительный объем работы в рамках МКГ/СПЦСВАСМ был проделан представляющими государства-члены экспертами из научного сообщества и кругов гражданской

1 Албания, Алжир, Бельгия, Болгария, Германия, Греция, Грузия, Дания, Египет, Израиль, Ирландия, Испания, Италия, Кабо Верде, Кипр, Ливан, Ливия, Мавритания, Мальта, Марокко, Монако, Нидерланды, Норвегия, Польша, Португалия, Российская Федерация, Румыния, Сирия, Словения, Соединенное Королевство, Тунис, Турция, Украина, Финляндия, Франция, Швейцария, Эстония

2 Более подробная информация о МКГ/СПЦСВАСМ и структуре управления размещена по адресу: http://neamtic.ioc-unesco.org/neamtws/icg-neamtws/what-is-the-icg-neamtws#
обороны, которые участвовали в данных рабочих и целевых группах. Работа, в частности, была сосредоточена на оценке цунами, которые происходили в регионе ранее, и возможных источниках цунами в будущем, разработке и развертывании системы предупреждения, способной оказать поддержку государствам-членам, и на просвещении и повышении осведомленности. В данной публикации подытоживаются проведенные мероприятия.

Знания о цунамигенном потенциале в регионе с точки зрения как исторических данных о цунами, так и понимания потенциальных источников цунами являются ключевым инструментом для исследований в области предупреждения о цунами и смягчения их последствий. Исторические данные требуют составления максимально гомогенных и достоверных каталогов цунами, а знания о потенциальных источниках необходимы для оценки опасностей возникновения цунами и оповещения о них. Хотя в регионе СВАСМ цунами не считаются такой серьезной опасностью, как в Тихом океане, история показывает, что в данном регионе происходило много цунами, некоторые из которых были весьма разрушительными. Например, в Средиземном море в среднем случаются одно крупное цунами в сто лет, и вероятность цунами с высотой волны выше 1 метра в Средиземном море в ближайшие 30 лет составляет практически 100%3. Размещение значительного числа людей в прибрежной зоне, особенно в летний период, создает относительно серьезную угрозу гибели населения, а наличие в ней критически важных инфраструктур усиливает связанные с цунами риски.

При разработке требований для оповещения о цунами в регионе СВАСМ выяснилось, что не все государства-члены имеют средства или желание создавать свои собственные национальные системы предупреждения о цунами, но могли бы воспользоваться системой, координируемой МОК-ЮНЕСКО. Несколько национальных центров предложили оказывать услуги желающим государствам-членам в рамках подписки. На сегодняшний день существует четыре таких круглосуточно работающих поставщика услуг по цунами (ПУЦ) (во Франции, Греции, Италии и Турции), пятым кандидатом (Португалия) планирует оказывать услуги желающим государствам-членам в рамках подписки. На сегодняшний день существует четыре таких круглосуточно работающих поставщика услуг по цунами (ПУЦ) (во Франции, Греции, Италии и Турции), пятым кандидатом (Португалия) планирует оказание таких услуг в ближайшем будущем. Четыре поставщика услуг по цунами получили аккредитацию в ходе тринадцатой сессии МКГ/СПЦСВАСМ, которая прошла 26-28 сентября 2016 г. в Бухаресте, Румыния, и стала важной вехой в истории СПЦСВАСМ. В отличие от четырех других координируемых МОК систем предупреждения о цунами СПЦСВАСМ выбрала процедуру аккредитации ПУЦ, подтверждающей их соответствие ряду согласованных членами МКГ требований. Это позволяет обеспечить согласованность между ПУЦ и высокое доверие со стороны пользователей.

Отличительной чертой Средиземного моря является его полузамкнутый бассейн, в результате чего время распространения цунами крайне короткое. Это налагает дополнительные требования на получение надежных данных сейсмических наблюдений и наблюдений за уровнем моря максимально быстро, в считанные минуты. Таким образом, были предприняты значительные усилия по расширению охвата станций, повышению частоты измерений метеорологов и передаче данных в режиме реального времени. В рамках СПЦСВАСМ был достигнут значительный прогресс в совершенствовании сетей наблюдения.

Крайне важно обеспечить высокую степень готовности ПУЦ и получающих сообщения структур и надежность коммуникаций и протоколов. Одним из способов обеспечения такой готовности являются тесты и учения. Каждый из действующих ПУЦ проводит ежемесячную проверку коммуникаций, а контактные структуры в государствах-членах предоставляют направленные на постоянное совершенствование коммуникации, напр., в целях обеспечения минимального времени задержки, проверки целостности сообщений и постоянного обновления контактных данных. В 2012 г. и 2014 г. прошли учения по цунами СВАСМ-волна12 и СВАСМ-волна14. В ходе учений были смоделированы реалистичные цунами, что позволило различным областям данного региона на научной основе выработать и апробировать методы реагирования на них.

Указанные выше достижения сами по себе недостаточны. Они должны дополняться просвещением и повышением осведомленности в самих государствах-членах. Это касается не только органов гражданской обороны, но и общественности в целом. Создание Центра информации о цунами СВАСМ является важным шагом в деле повышения осведомленности граждан и особенно молодежи о рисках цунами и других опасных явлений, связанных с изменением уровня моря, и выявления передового опыта в области планирования и его обмена и распространения.

Тем не менее, необходимо обеспечить проведение таких мероприятий в самих странах. Несколько стран уже начали осуществлять такого рода программы, как, например, «Я не хочу рисковать – цunami» в Италии или включение цунами в программу «Готов к опасностям» в Турции. В заключение, хотя в первые десять лет существования системы был достигнут существенный прогресс, многое еще предстоит сделать.

Среди будущих задач: совершенствование количественных оценок риска цунами в регионе, улучшение систем предупреждения благодаря последним достижениям науки, дальнейшее развитие сетей сейсмических наблюдений и наблюдений за уровнем моря, повышение участия органов гражданской обороны и участия и осведомленности общественности и рассмотрение методов повышения эффективности и устойчивости системы в будущем.
Accomplishments and Challenges in Preparing for the Next Tsunami

Tsunamis in the NEAM region - past events and risk assessment

الملخص التنفيذي

أنشأت لجنة اليونسكو الدولية الحكومية لعلوم المحيطات رسمياً، في عام 2005، فريق التنسيق الدولي الحكومي المعنى بنظام الإخلاء المبكر بأمواج التسونامي والتحذير من آثارها في المنطقة الشمالية الشرقية من المحيط الأطلسي وفي البحر المتوسط والبحار المتصلة به من أجل تنسيق عملية إنشاء نظام الإخلاء المبكر بأمواج التسونامي والأنشطة الخاصة بهذا النظام.

وينطلق هذا الفريق من 39 دولة عضوًاً، مطلة على البحر المتوسط والمنطقة الشمالية الشرقية من المحيط الأطلسي.

ويتكون هذا الفريق من أفرقة عمل تقنية وأفرقة عمل خاصةً كما يلي:

أفرقة العمل التقنية الأربعة التالية:

- فريق العمل 1: تقييم المخاطر وضع نماذج لها;
- فريق العمل 2: قياس الزلزال والظواهر الجيوفيزيائية;
- فريق العمل 3: جمع وتبادل البيانات المتعلقة بمسمى سطح البحر، بما في ذلك استشعار أمواج التسونامي من البحر والأدوات ذات الصلة;
- فريق العمل 4: التوعية العامة والاستعداد وتخفيف الآثار.

وأفرقة العمل الخاصة الأربعة التالية:

- فريق العمل الخاص المعني بعمليات الإبلاغ التجريبية;
- فريق العمل الخاص المعني بالإخلاء المبكر بأمواج التسونامي;
- فريق العمل الخاص المعني بالعمليات;
- فريق العمل الخاص المعني ببنية نظام الإخلاء المبكر بأمواج التسونامي.

1. ألبانيا والجزائر وبلغاريا وبلجيكا وكرواتيا ورومانيا وصربيا والدنمارك وفرنسا وتونس وبلجيكا، وإيطاليا وليختنشتاين ومالطا وموريتانيا ونرويج وسلوفينيا وسبتامبانيا واسبانيا وسلوفاكيا وسويسرا.

2. يمكن الإطلاع على معلومات أكثر تقضياً عن فريق التنسيق الدولي الحكومي المعنى بنظام الإخلاء المبكر بأمواج التسونامي والتحذير من آثارها في المنطقة الشمالية الشرقية من المحيط الأطلسي وفي البحر المتوسط والبحار المتصلة به من خلال الرابط التالي:
http://neamtic.ioc-unesco.org/neamtws/icg-neamtws/what-is-the-icg-neamtws
ويتميز البحر المتوسط عن غيره من البحار بكونه بحرًا مغلقًا، وهو الأمر الذي يجعل أزمنة انتقال أمواج التسونامي قصيرة للغاية. ويؤدي ذلك إلى إيجاد حاجة ماسة إلى الحصول على بيانات يمكن الوثوق بها بشأن الزلازل ومستوى سطح البحر بسرعة. بل وجدت جهود كبيرة لتوسيع نطاق التغطية الجغرافية للمحطات، وزيادة معدات أخذ العينات من جهزة قياس البحيرة على السواحل، والإرسال الآلي للبيانات. وقد أجريت تقدم كبير في تحسين شبكات الرصد بفضل نظام الإصدار المبكر بأمواج التسونامي والتفحص من أثرها في المنطقة الشمالية الشرقية من البحر المتوسط وماضم البحر المتوسط المتصل به.

ومن المهم أن نظل مقدمي الخدمات الخاصة بأمواج التسونامي والأشخاص المعنيين بالتقييم الرسائل في حالة تأهب عالية، وأن تستند البلاغات والروبوتات إلى أسس صحية. ويمكن تحقيق هذا الأمر عن طريق الاستعدادات والتمارين، ويُجري كل مركز من مراكز تقديم الخدمات الخاصة بأمواج التسونامي اختبارات شهيرة متزامنة لتقييم المعلومات، وتبيان الجهود المتقدمة بالتجربة الخاصة بالإنذار بأمواج التسونامي في الدول الأعضاء آراءها في هذا الصدد من أجل مواصلة تحسينات على الخدمات الخاصة بأمواج التسونامي، ومنها على سبيل المثال تقليل الوقت الذي يستغرقه تبليغ المعلومات قدر المستطاع، والتأكد من صحة الرسائل ومن الاستعداد المتواصل لقروئها. وقد أجري تمارين على الإصدار بأمواج التسونامي (NEAMWave12 وNEAMWave14) في عامي 2014 و2012 على التوالي لمحاكاة حوادث التسونامي بطريقة واقعية تتبع مختلف دول المنطقة التسونامي والتدرب على التصدي لأمواج التسونامي واختبار التدابير المنخفضة لهذا الغرض.

ولا يمكن مع ذلك الاكتفاء بالتقدم الملموس آنفاً، بل يجب تكملة التدريب والتوعية داخل الدول والأعضاء ذاتها. ولا يقتصر ذلك على السلطات المحلية بالحماية المدنية، بل يشمل جميع الناس أيضاً. وينبغي تطوير مركز الإعلام بشأن أمواج التسونامي للمنطقة الشمالية الشرقية من البحر الأطلسي والبحر المتوسط والبحر المتوسط المتصل به خطوة مهمة لتوسيع التنوع الثقافي، ولا سيما الشباب، بمخاطر أمواج التسونامي وغيرها من المخاطر المرتبطة بمستوى سطح البحر، وكذلك للوقوف على الممارسات الجيدة في خطط التصدي لأمواج التسونامي وتشعار المعلومات الخاصة بتلك الممارسات ونشرها.

ولا بد من القيام بذلك الشبكة داخل البلدان ذاتها. وقد شرعت عدة بلدان في وضع وتنفيذ برامج لهذا الغرض، ومنها على سبيل المثال برنامج "I don't take risks – tsunami" في إيطاليا؛ أو في إنجاز مخاطر أمواج التسونامي في برنامج الوقاية من الكوارث كما فعلت تركيا إذ أدرجتها في برنامج "Disaster Prepared Turkey". وما زال هناك الكثير من الأعمال التي يجب القيام بها على الرغم من التقدم المشترك الذي أحرزه في السنوات العشر الأولى.

وتضم التحديات في هذا الصدد تحسين التقييم الكمي لخطر التسونامي في المنطقة، وتحسين نظم الإصدار بأمواج التسونامي عن طريق الاستفادة من أحدث الإنجازات العلمية، ومواصلة تطوير شبكات رصد الزلازل ومستوى سطح البحر، وتعزيز مشاركة السلطات المعنية بالحماية المدنية في الرصد وتعزيز توعية عامة الناس ومشاركتهم في الرصد، واستكشاف مختلف سبل جعل النظام فعالًا ومستدامًا في السنوات القادمة.
Accomplishments and Challenges in Preparing for the Next Tsunami

Tsunamis in the NEAM region - past events and risk assessment

Accomplishments and Challenges in Preparing for the Next Tsunami

Tsunamis in the NEAM region - past events and risk assessment

Werwall Uhr من عمل فريق التنسيق الدولي الحكومي المعني بنظام الإنذار المبكر بأمواج التسونامي والتخفيف من آثارها في المنطقة الشمالية الشرقية من المحيط الأطلسي وفي البحر المتوسط والبحر المتوسط المنحلة بها، اضطلع خبراء يمثلون الدول الأعضاء وينتمون إلى الأساطير العلمية والأوساط العنية بالحماية المدنية بعمل هائل عن طريق أفرقتهم الجهود المبذولة في تجهيز أمواج التسونامي التي شهدتها المنطقة في الماضي والصادرة المطلوبة لأمواج التسونامي في المستقبل، وعلى تصميم وضع نظام إنذار يمكن أن يساعد الدول الأعضاء، وعلى التثقيف والتوعية. وتن числе هذه الوثيقة الأنشطة التي جرى الاضطلاع بها.

وتمّت معرفة احتمالات تعرض منطقة ما لأمواج التسونامي عن طريق وسيلة تتمثل أولاً دوماً في الاستعانة بالانترنت المطلبة أمواج التسونامي التي شهدتها المنطقة في الماضي، وتتمثل ثانياً فيها في فهم المصادر المحدودة لأمواج التسونامي. أدأ دور أساسي لإجراء دراسات بشأن عمليات الإنذار البرك بأمواج التسونامي والتخفيف من آثارها. تتمثل الوسيلة الأولى ضرورة إعادة سجلات خاصة بأمواج التسونامي ينبغي أن تكون متاحة وموثقة بقدر الإمكان، وتتمثل الوسيلة الثانية وسيلة ضرورية لتقديم مخاطر أمواج التسونامي والإنذار بها. ولا تُعتبر مخاطر أمواج التسونامي في المنطقة الشمالية الشرقية من المحيط الأطلسي وفي البحر المتوسط والبحر المتوسط المنحلة به عالية كما هي عليه في المحيط الهادئ. بيد أن السجلات تبين وقوع الكثير من حوادث أمواج التسونامي التي كانت مدمرة أحياناً. وتعرض منطقة البحر المتوسط على سبيل المثال لحادثة كبرى كل مائة عام تقريباً. وتحتم الاحتمالاً كبيراً يكون بيلغ 10% أن يحدث تسونامي في مكان ما في البحر المتوسط خلال الثلاثين سنة المقبلة وأن يتزاوج ارتفاع موجة التسونامي مترًا واحدًا. وتشير مناطق البحر المتوسط به عناية بالقرون الكثير من الأرواح نظرًا لارتفاع عدد سكان المناطق الساحلية. وسياً في ظل أي الصفح، ويجدي وجود نشأة حيوية في المناطق الساحلية إلى زيادة الخطير المرتبطة بأمواج التسونامي.

وقد تبيناً سريعاً. بعد النظر في متطلبات نظام الإنذار بأمواج التسونامي في المنطقة الشمالية الشرقية من المحيط الأطلسي والبحر المتوسط، أن الدول الأعضاء المعلقة لا تملك جميعها الوسائل اللازمة لإنشاء نظام واضح ومنطقة خاصة بها لإذار بأمواج التسونامي أو لا ترغب جميعها في ذلك، بل يمكن أن تستفيد من نظام تتولى تنشيط لجنة اليوونسكو الدولية الحكومية لعلوم المحيطات. وظهرت عدة مراكز وطنية تعرض خدماتها الخاصة بأمواج التسونامي على الدول الأعضاء الراغبة في الحصول عليها عن طريق الاشتراك في تلك المراكز، وتوجه حتى الآن أربعة مراكز لتقدم الخدمات الخاصة بأمواج التسونامي. تعمل على مدار الساعة طيلة أيام الأسبوع (في فرنسا واليونان وإيطاليا وتركيا)، ويوجد مركز خاص في البرتغال يتعزى تقديم هذه الخدمات في المستقبل القريب. وتتم اعتماد المراكز الأربعة لتقييم الخدمات الخاصة بأمواج التسونامي إبان الدورة الثالثة عشرة لتفتح التمثيل الدولي للنظام المعني بنظام الإنذار المبكر بأمواج التسونامي والتخفيف من آثارها في المنطقة الشمالية الشرقية من المحيط الأطلسي وفي البحر المتوسط والبحر المتوسط المنحلة به، التي عقدت في 26-27 أيلول/سبتم. 2016 في بخارست برومانيا والتي شكلت متاعبة هاماً في تطوير النظام. ويُتفرد نظام الإنذار المبكر بأمواج التسونامي والتخفيف من آثارها في المنطقة الشمالية الشرقية من المحيط الأطلسي وفي البحر المتوسط والبحر المتوسط المنحلة به، بنرمINGS نظام الإنذار المبكر الأربعة التي تتولى تنسيقها لجنة اليوونسكو الدولية الحكومية لعلوم المحيطات، بتطبيق إجراءات توجو محول مقدم الخدمات الخاصة بأمواج التسونامي. ويُعتقد هذا الأمر مهمًا لضمان الانتشار بين مقدمي الخدمات والاحتفاظ بقدر كبير من الثقة لدى المتفقين بالخدمات.

1. Tsunamis in the NEAM region - past events and risk assessment

Due to the active tectonic processes the seismicity in the Mediterranean region is high and predominantly driven by the present-day convergence between the African and Eurasian plates\(^4\). Although tsunami activity is not as frequent as in the Pacific, the Mediterranean still accounts for about 10% of all tsunamis worldwide, with on average, one large tsunami happening in the region every century. A probabilistic tsunami hazard in the Mediterranean Sea study has revealed that the probability of a tsunami wave exceeding 1 m somewhere in the Mediterranean in the next 30 years is close to 100%. In addition, the risk to coastal areas is high because of the high population density in the area -- some 130 million people live along the sea's coastline. There are many activities and some of the biggest ports in the world in the coastal areas of Europe and North-Africa. The Mediterranean is the main tourist destination in the world with tourist arriving all over the world. There is a growing risk and concern. Moreover, travel time of tsunami waves in the Mediterranean are short.

Historical documentary sources together with geological evidence, e.g. palaeotsunami sediment deposits and geomorphological features, archaeological findings, as well as instrumental data and recent observations have provided a long record of tsunami events produced by submarine or coastal earthquakes, volcanic eruptions and landslides. A few of those events were basin-wide, others, however, were either regional or local tsunamis\(^5\).

Knowledge of the tsunamigenic potential of a region, both in terms of historical tsunamis and the understanding of the potential sources, is a fundamental tool for studies on tsunami hazard evaluation, tsunami warnings and mitigation. This highlights the need of compiling tsunami catalogues that should be as homogeneous and reliable as possible.

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Accomplishments and Challenges in Preparing for the Next Tsunami

Fig 1 - A 5-ton fishing boat moved ashore in Kalymnos Isl., South Aegean Sea, by the large tsunami of 9 July 1956 triggered by M7.5 tectonic earthquake (NOA Bulletin, 1956).

Fig 2a - Tsunami leading breaking wave attacking Punta Lena Nord in north-eastern Stromboli on 30 December 2002 (photo taken by an eyewitness). The observed run-up height exceeded here 7 m, while the highest measured in the island was about 11 m (Tinti et al., 2005).

Fig 2b - Debris deposited by the 2002 Stromboli tsunami at Scari (north-eastern coast) where run-up was 4.3 m. In the background, the village of San Vincenzo on the slope of the Stromboli volcano.


The most up-to-date tsunami database for the NEAM region, the Euro-Mediterranean Tsunami Catalogue (EMTC), was recently published\(^8\), as the result of a systematic and detailed review of all the regional catalogues covering the study area\(^9\). The EMTC contains 290 tsunamis, from 6150 B.C. to the present day. The tsunamis occurred in a vast area that includes the Norwegian Sea, the North Sea, the north-eastern Atlantic, the Black Sea and the Mediterranean Sea that is divided into the western, central and eastern (including the Marmara Sea) basins. The majority of the tsunamis in the NEAM area are local and sometimes destructive. In some cases the waves propagated regionally while, from historical observations, only three regions seem to be capable of triggering powerful basin-wide tsunamis: the Hellenic Arc, the system of faults in the eastern Atlantic Ocean facing the Portuguese coast, and the Tell-Atlas thrust system (in North Africa, stretching from Morocco, through Algeria To Tunisia) (Fig. 3).

Each event in the EMTC catalogue is characterized by a reliability value, which is a parameter that has been assigned on the basis of the trustworthiness of the information related to the generating cause, the tsunami description accuracy, and also on the availability of contemporary bibliographical sources. Following these criteria, the reliability values range from 0 (“very improbable tsunami”) to 4 (“definite tsunami”). Most of the events listed in the EMTC are “definite” or “probable” tsunamis (with reliability values of 3 or 4), which makes it an essential tool for the implementation of tsunami hazard and risk assessment.

The frequency of reported events becomes stable after the 18th century, with well documented tsunami phenomena. One of the main advantages of introducing reliability as an indicator of the quality of the data, is that it avoids the loss of historical events for which the data are quite scarce and the correspondingly uncertainties are many. This is confirmed by the trend shown in Fig.4, where the number of reliable reported tsunamis increases in time to the detriment of the less reliable events.

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Fig. 3. a- Regional topographic and bathymetric map of the Mediterranean Domain with major, simplified geological structures onshore and offshore (by Papadopoulos et al., 2014, modified from Cavazza et al., 2004 and Billi et al., 2011).

Fig. 3. b- Regional map of the Mediterranean Domain with instrumental seismicity from the USGS-NEIC catalogue: http://earthquake.usgs.gov/regional/neic/). Circles are proportional to earthquake magnitude and darker colors represent deeper earthquakes.

In the NEAM region most of the tsunamis have been generated by seismic activity (83%), mainly triggered by submarine earthquakes and less frequently by earthquakes located inland. An interesting example of an inland tsunamigenic earthquake is the Levantine AD 1202 event that ruptured the Dead Sea Transform in Lebanon and Northern Israel. A small number of local tsunamis in the NEAM area were also caused by seismogenic gravitational phenomena, i.e. subaerial or submarine landslides activated by the earthquake.

As many as 9% of the EMTC events were caused by mass failures due to mere gravity load and they are mainly located in the NW part of the region, associated with slope instability in fjords, with effects amplified by the funnel bathymetry. A remarkable example is the case of the 1731 tsunami: in which more than 100,000 cubic metres of rock fell from the Rammerjell mountain (Norway) into the Storfjorden fjord, causing extensive damage and 17 casualties with a run-up height of about 70 m.

Few tsunamis, less than 5%, were related to volcanic activity, caused mostly by the Vesuvius and Aeolian islands volcanoes (Stromboli and Vulcano) in the central Mediterranean region, and some in the eastern Mediterranean as for example by the Thera (Santorini) activity. The severity of the tsunamis within the NEAM area was evaluated based on their intensity values, according to the Sieberg-Ambraseys and the Papadopoulos-Imamura intensity scales. The frequency histogram for each region is shown in Fig. 5 with the total number of tsunamis with Sieberg-Ambraseys intensity I ≥ 4 reaching 84, more than half of these events occurring in the eastern Mediterranean (M1).
The creation of the ICG/NEAMTWS group ten years ago was the starting point for the scientific community to increase public awareness of tsunami hazard and risk in the Mediterranean, NE Atlantic and Black Sea areas. It also fostered the creation of new cooperation agreements that led to the enrichment of the already existing regional catalogues as well as the compilation of a unique and useful homogeneous database.

1.1 Impact of tsunamis in the NEAM region

The catalogue includes an inventory that contains descriptions of the impact that each one of the tsunami events had. In order to secure the high reliability of the information used, only tsunami events assigned with reliability 3 or 4 were considered. It was found that 114 events had some impact either in the built environment and/or in human communities and/or in the natural environment, regardless of the extent and the type(s) of impact. The many different types of impact can be summarized as follows: human deaths (casualties) (D), damage to vessels (VD), damage to buildings and other engineering structures (SD), land impact (LI), environmental impact (EI). The land impact refers to soil erosion and to other geomorphological changes caused by the tsunamis, to destruction of cultivated land due to tsunami inundation as well as to simple land flooding. On the other hand, the environmental impact may include a variety of effects, such as fishes and shells left behind after the tsunami, changes in the sea color, death of animals, boulder replacement from offshore to onshore as well as tsunami sediment deposition. One difficulty faced in classifying the several types of impact was that the historical descriptions often are not precise enough to decide if the impact was of this or that type.
The term “impact” used so far is quite general, expressing the entire spectrum of impact extent from the very low to the highest one. Therefore, tsunami impact were classified in four levels. Level 1 corresponds to the lowest degree of impact while level 4 corresponds to the highest degree. For example, the statement “one person was killed” means impact type D of level 1 (D1), while the statement “more than 20 persons were perished” is translated to mean D4. Figure 6 shows the maximum impact level per tsunami event regardless the type of impact. Following the same geographical distribution with the distribution of tsunami intensity, the maximum impact is concentrated in the eastern Mediterranean basin, primarily along the Hellenic Arc and secondary in South Italy and in the Levantine Sea in the easternmost side of the Mediterranean Sea. However, one should not underestimate that past tsunamis had some impact also in SW Iberia, in the Strait of Dover and in western Norway.

The statistics per impact type and level is also of interest. Namely, it was found that the most common type of impact reported was on vessels (65 events). Impact on structures was reported in 40 events, while a number of 34 lethal tsunami events were reported. The numbers of events that had land and environmental impact were 28 and 27, respectively.

**Fig 6** - Distribution of tsunami sources in the European-Mediterranean region from the ancient times up to the present. Tsunami impact is in terms of 12-level Papadopoulos-Imamura (2001) intensity scale K11 (after Papadopoulos, 2016).

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The examination of individual tsunami events showed that most significant impact comes from extreme
tsunamis, such as the ones of AD 365 and 1303 generated to the west and east of Crete, respectively, and the
1755 Lisbon tsunami, all caused by high magnitude earthquakes on the order of 8 or more. However, high
impact also occurred from events of lower magnitude (~7-7.5), such as the 1908 tsunami in Messina straits
and the 1956 tsunami in the South Aegean, which underlines the strong dependence of the impact on the
community exposure. Another important finding is that the cumulative impact of relatively moderate or
even small, local tsunamis, produced by earthquakes, landslides or volcanic activity, is quite important and
that such distributed tsunami impact should not be neglected in actions undertaken for the tsunami risk
mitigation.

Tsunami Risk Assessment in the NEAM region

Increasing our knowledge through assessments is a first step to setting up effective emergency measures
when the event occurs and to mitigate its adverse effects through suitable and wise prevention policies, in the
period between event occurrences. Though the assessment is cross-cutting and essentially interdisciplinary,
the real development in the past has been mostly sectorial such as seismologists for earthquakes, hydrologists
for floods, meteorologists for hurricanes, etc. They have introduced their own methods, approaches, point of
view and even glossaries to address the problem. Experts in tsunamis have come to this field only in the last
twenty years following a series of disastrous tsunami events.

There are several aspects to be considered when performing tsunami risk assessment: hazard, exposure, and
risk. Tsunami hazard is often meant as the probability of occurrence of a tsunami in a given area within a
given interval of time. Therefore, assessing tsunami hazard means estimating such a probability. By tsunami
exposure of an element (which can be a building, a person, a port, a town, a community…) one means
the probability that the element be faced by a tsunami in a given period of time. The vulnerability of an
element to a tsunami is the degree of degradation or damage that the element can incur under the attack
of a tsunami and strongly depends on the element properties. For example, the vulnerability of a building
is influenced among others by the material from which it is built, its shape, architecture and foundation.
The risk is the estimate of the loss expected from tsunamis in a given region and within a given period of
time and applies to both human and property losses, and in a broader sense also to environmental and
social community losses. From the above, it is clear that assessing the hazard is the first link in a chain, while
assessing the risk is the last link that cannot be accomplished before the rest of the chain is completed.

Owing to the non completeness of tsunami catalogues, as tsunamis are relatively infrequent events, a
computational approach addressing the potential sources and numerical modeling of the tsunamis they
may generate, is often used as a complement to catalogues to define the hazard. At the global scale, the most up to date and complete Probabilistic Tsunami Risk Assessment effort is the tsunami component of the GAR 2015\(^{12}\), promoted by the United Nation Office for Disaster Risk Reduction. A more detailed homogeneous assessment would be needed also at the regional scale. As a starting point, a homogeneous Probabilistic Tsunami Hazard Assessment (PTHA) for earthquake-generated tsunamis will be developed in the next one and a half year within the TSUMAPS-NEAM project (http://tsumaps-neam.eu), recently funded by the European Commission through the DG-ECHO.

**Tsunami Hazard Assessment**

Assessing the probability of tsunamigenic earthquakes is one of the most important aims of seismology research which combines historical data (e.g. earthquake catalogues), seismotectonic data and models, short and long-term crustal and surface deformation data to compute the probability that an earthquake of a given magnitude may occur on a given fault, or in a given region, within a given period of time. Seismologists have produced a number of seismic hazard maps worldwide covering also the NEAM region.

Tsunami hazard can be assessed through two main approaches, Probabilistic Tsunami Hazard Assessment (PTHA) and Scenario-based Tsunami Hazard Assessment (STHA). In the first case the focus is put on the probabilities for earthquakes from offshore or coastal sources while the second case focuses on the largest events without evaluating the probability of their occurrence refered to as the Worst-Case Credible Tsunami Scenario Analysis.

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**Figure 7** - Inundation area computed through the PTHA technique for the town of Sines in Portugal corresponding to 500 years. Calculations by IPMA, Lisbon

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Figure 8 - Probability of exceedance of 1 m (left) and 5 m (right), obtained through the PTHA technique for coasts of Southern Italy. The different statistics (mean, median, percentiles) represent the epistemic uncertainty. Calculations were made by INGV, Rome\textsuperscript{13}.

Some examples of PTHA exist only at the very local level. An example of PTHA result for the town of Sines in Portugal is given in Figure 7 where the probability of inundation in a period of 500 years is given through a colour code from blue (probability 0.01) to red (probability 1). Computations were performed in the framework of the ASTARTE EU FP7 project (http://astarte-project.eu) by the partner IPMA, Lisbon. Another example is given in Figure 8 where the maps represent the probability of exceedance of 1 and 5m for the coasts of Southern Italy, with epistemic uncertainties regarding the model of the potential tsunamigenic earthquakes mapped into tsunami hazard. Figure 9 provides instead an example of the STHA method applied to the bay of Siracusa, Sicily. Computations were performed in the framework of the ASTARTE project by the partner UNIBO, Italy.

Figure 9- Maximum tsunami sea elevation calculated by aggregating credible worst scenarios for the bay of Siracusa, Sicily, produced by the ASTARTE partner UNIBO (University of Bologna, Italy).

**Tsunami Vulnerability Assessment**

The vulnerability of an element to tsunami waves or currents can be assessed in a hydraulic laboratory if the element is simple (a building, a jetty, a bridge pillar, a fence, etc.) or only in the field if the element is indeed a system of interconnected elements (port facilities, coastal towns, route system, transportation system, lifeline systems, coastal communities...). Field data are data collected in the field after the occurrence of a damaging tsunami. Since, in recent years only two tsunamis caused inundation and damage in the
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western Mediterranean: the Boumerdes tsunami in 2003\(^{14,15}\) and the Stromboli tsunami in 2002\(^{16}\), most of the observations are hence from the effect of tsunamis in the Indian and the Pacific Oceans.

The attempts made so far have not been able to cover fully all the elements that need to be brought together to give a holistic picture of the vulnerability of a coastal site, but have put the focus only on some specific elements (mostly buildings, but also specific industrial plants or facilities). What is lacking is some general theoretic framework and a consistent and complete set of data. The dispersion of databases of the threatened elements among different (usually public) institutions and management systems at national and country level with various degree of accessibility makes assembling and homogenizing the needed data an enormous challenge. In addition, since vulnerability and damage analysis is the second step of the chain leading from hazard to risk, all weakness and deficiencies in the hazard analysis reflect also on the vulnerability analysis. Therefore, the lack of a systematic tsunami hazard analysis on the coasts of the NEAM region also implies that a systematic vulnerability analysis is missing, and should be adressed in the future NEAM region.

**Tsunami Risk Assessment**

Tsunami risk assessment is the last link in the assessment chain. It implies the assessment of the value of the losses produced when a tsunami strikes, which is traditionally distinct between losses on properties, man-made structures, and the physical environment (ambient, ecosystems) on one side and human beings, communities and societies on the other side. Tsunami risk assessment is a subject of intensive research worldwide, still requiring an agreed theoretical framework inclusive of all the risk components and, as a consequence, of an agreed system of concepts, definitions, and standards. Research projects like the European Commission Assessment, STrategy And Risk Reduction for Tsunamis in Europe (ASTARTE) are expected to contribute to tsunami risk analysis with progress in the theory and methods and by extending the applications to other coastal areas. However, it is unlikely that a complete systematic risk analysis for the NEAM region coasts can be accomplished in the next few years and therefore it has to be seen as a long-term objective.

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2. Tsunami Warning Systems

A tsunami warning system (TWS) is used to detect tsunami sources and tsunami waves in advance and issue warnings to communities at risk to prevent loss of life and to reduce damage. A typical tsunami Early warning System has four main elements: risk knowledge, monitoring and warning, dissemination and communication, and response capability. An early warning system with all these elements is referred to as an “end-to-end” system.

Setting up an end-to-end TWS is an effort that requires collaboration and coordination among different institutions and organizations at national and international level, including those responsible for seismic and sea-level monitoring, the civil protection authority as well as the communities at risk to tsunami. Moreover, it requires considerable financial investments to maintain and up-grade and build comprehensive detection networks in particular sea-level, support research activities in tsunami science, and to raise awareness and prepare communities at risk to tsunami. In addition, a clear legal framework has to be developed for each country where roles and responsibilities of institutions and organizations involved are clearly defined.

In the NEAM region it was decided to support and promote the development of National Tsunami Warning Centres (NTWCs) that could also act as Tsunami Service Providers (TSP) for all Member States of the ICG interested in subscribing to the service. This is because not all the countries have the resources and the possibility to develop their own NTWC. In the NEAM region there are currently four NTWCs which are acting as TSPs and these are briefly described below. The ICG/NEAMTWS also decided, and this is unique to the NEAM region, that those NTWCs willing to act as TSPs should be accredited, i.e. be assessed by a group of experts who will verify that the NTWCs comply with the essential functions and characteristics agreed by the ICG. Until accreditation is achieved such centres are known as TSPs. All four TSPs have officially applied for accreditation.

It is evident that in such an international and intergovernmental context an additional layer of complexity is added. That is the one linked to the need of cooperation among the different TSPs. This type of cooperation entails the definition of common procedures and standards of operations, the sharing of seismic and sea-level data, and the formulation of tsunami warning messages that can be sent, and therefore understood, by a variety of end-users.

Over the last ten years Member States from the NEAM region, under the coordination of the IOC of UNESCO, have worked together in an effort to provide tsunami warning service for the countries bordering the Mediterranean and the Black Sea as well as those of the North-eastern Atlantic.
The activities undertaken, both on a national and on an international level, included:

- Strengthening the international tsunami research community in the NEAM region
- Up-language of detection networks
- Set-up of technical working groups and task teams
- Enable dialogue between the scientific community and the civil protection authorities

From an operational point of view it was agreed that the functioning of the system begins with the detection of an earthquake of sufficient size to trigger an alarm at the TSP. Generally, this will occur within a few minutes of the occurrence of any earthquake in the NEAM region for earthquakes with a magnitude above 5.5. Duty personnel respond immediately and begin the analysis of the event. The analysis includes automatic and interactive processes for determining the earthquake’s epicentre, depth, and origin time, as well as its magnitude. Based on these parameters, a decision is made concerning further action (Fig 10).

**Fig 10- NEAMTWS Tsunami Service Provider decision-making flow. Image from Öcal Necmioglu, Turkey TSP**
If the event meets the criteria defined by the appropriate decision matrix or other approved approaches, such as those based on tsunami modeling, then a tsunami message is issued. The decision matrix is the agreed decision-making tool for the ICG/NEAMTWS, although other approaches based on evolving and adapted best practice are allowed. The decision matrix approach is based on the focal parameters of the earthquakes, that is the location of the earthquake epicentre (offshore or inland), the focal depth (shallow or intermediate depth) and the earthquake magnitude and it defines the probability that an earthquake with a certain magnitude and at a certain location can or not generate a tsunami. Considering the specific characteristics and the complexity of the tectonic structure of the Mediterranean, and the complexity of tsunami generation and propagation processes, other more sophisticated tools are under preparation in order to have a more reliable warning message generation system for the region.

In order to test the readiness, NEAMTWS communication tests and tsunami exercises (so-called NEAMWave exercises) are regularly organized. During the tsunami exercises all the phases of the tsunami warning generation and dissemination are simulated in an attempt to verify and learn which elements of the system works and those ones that need to be improved. So far two NEAMWave exercises (NEAMWave12, NEAMWave14) have been carried out and the next NEAMWave exercise will be conducted in 2017.
Tsunami Warning Systems

perform daily internal tests of the Tsunami Warning System based on scenarios.

CENALT was the Message Provider at two Enlarged Communication Test Exercises (ECTE2 and ECTE5) in 2012 and 2015, and has also participated as TSP in the two Tsunami Exercises NEAMWave12 and NEAMWave14 providing and performing a scenario in the Western Mediterranean Sea.

CENALT has promoted and is financing data sharing telecommunication modes with neighbour TSPs and seismological institutes. CENALT has developed a series of innovative techniques and tools, in particular specific tools that monitor the seismic and sea level networks and their detection capacities and continuously reports the network's performance and whether each station is operating optimally, delayed or is out of order. A methodology was also developed to determine an optimum tide-gauge network for tsunami detection and warning. CENALT has developed its own modeling and forecasting tools, one of them using a pre-computed scenario data base to refine the alert level and inform the French authorities on the location of the most threatened regions.

Since the start of the operation phase of the centre on July 2012, 15 messages have been sent to the tsunami focal points and tsunami centres of the NEAM region and to the French civil protection authorities.
The National Observatory of Athens (NOA), the Greek TSP

The NOA centre became operational as a NTWC on a 24/7 basis in August 2012. Since then it has also become one of the four TSPs. From the technical point of view the standards that the Hellenic (HL)-NTWC follows at the national level are the same as those at the level of NEAMTWS, including the operation on a 24/7 basis of national seismograph systems and tide-gauge networks as well as expertise in seismic and sea-level monitoring and in tsunami science.

The HL-NTWC, as a specific unit of the Institute of Geodynamics at NOA, is closely associated with, and supported by, the research and infrastructure components of the institute. In addition, the educational and training activities play an increasingly important role in the HL-NTWC’s daily activities. These three dimensions of research, training and operation are facilitated through a network of collaborative schemes with national and international organizations.

To increase the data sets that are available to HL-NTWC, NOA has linked to seismic stations and ocean-bottom seismometers in Cyprus and tide-gauge stations in Egypt and Italy. Agreements to access other data sources in the region are also being negotiated.

In line with the position adopted by the ICG, the Decision Matrix is a key tool which is still the preferred choice of the HL-NTWC, but an alternative option - the use of scenario data bases - is also available. The JRC computer Tsunami Analysis Tool (TAT), which incorporates a data base of pre-simulated tsunami scenarios is freely available to national tsunami centres. HL-NTWC uses TAT regularly for its tsunami operations. In addition, the Tsunami Travel Times software (TTT) by Geoware (kindly provided by NOAA, USA) has also been installed. It gives the operator the possibility of estimating tsunami arrival times either by using scenario travel time or those calculated by TTT.

Since August 2012 the HL-NTWC has issued and sent to a large number of recipients 11 tsunami messages after the occurrence of relatively strong (M≥5.5) submarine or coastal earthquakes occurring in Greece and its adjacent regions.
Istituto Nazionale di Geofisica e Vulcanologia (INGV), the Italian TSP

INGV started operating as TSP on October 1st 2014 within the NEAMTWS framework for its competence zone (the whole Mediterranean Sea including the Marmara Sea). As part of its activities, INGV receives in (quasi) real-time sea level data recorded by hundreds of tide-gauges distributed worldwide through the Sea Level Monitoring Facility of IOC. In addition, ISPRA - the institution managing and operating the Italian National Mareographic Network - sends continuously to INGV the sea level data recorded by about 35 stations distributed along the coast of Italy. These data can be analyzed by the tsunamologist on duty to confirm (or cancel) warning messages issued previously. All the above mentioned operations are managed through JET (Java Estimation Tsunami), an in-house software specifically developed to assist the work of the tsunamologist through the implementation of a Decision Support System and other analysis tools.

The IT-TSP is located in the “seismic monitoring centre” at the INGV headquarters in Rome benefitting from its existing physical infrastructure and human resources consisting of about 100 well trained scientists and technicians that have been operating for a long period. The real-time availability of seismic, geodetic and sea level data is of primary importance for rapid and reasonably accurate earthquake source determination and tsunami assessment. Thus, INGV is promoting bilateral agreements with other TSPs and institutions in the NEAM region to share data, the benefits being twofold: on one hand, it will improve the azimuthal station coverage, on the other hand each centre will mutually serve as partial data backup.

INGV is about to complement (and possibly replace in the future) the “decision matrix” used currently (last modified July 1st, 2015), with pre-calculated tsunami scenario databases, and with Faster Than Real Time tsunami simulations performed with the Graphics Processing Unit-based code HySEA developed by the University of Malaga. The aim is to increase the accuracy of tsunami forecast by assimilating the largest possible amount of data in quasi real time, and performing simulations in a few minutes.
KOERI, the Turkish TSP

KOERI, was established in 1868 as the Imperial Observatory. It has a long tradition of earth observation and science and is a unique organization in Turkey encompassing earthquake observation, research, education and application services within a single, integrated body. KOERI’s Regional Earthquake and Tsunami Monitoring Center (RETMC) is a 24/7 operational center operating 128 Broadband (BB) and 88 Strong Motion sensors at the national level and utilizing seismic data from global and various regional networks. Sea-level data from 7 tide-gauges operated by General Command of Mapping is integrated in the system in real-time. Real-time data transmission from selected primary and auxiliary stations from the International Monitoring System is in place based on an agreement concluded with the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO) in 2011. Duty officers of the RETMC perform internal tests of the Tsunami Warning System on a daily basis based on pre-determined set of scenarios. In addition, KOERI performs monthly Communication Test Exercises with the Turkish Civil Protection Authority (AFAD) and other TSPs and participates in NEAMTWS Communication Test Exercises. KOERI was the Message Provider of the 1st NEAMTWS Enlarged Communication Test Exercise (ECTE1) in 2011 with the involvement of all the Tsunami Warning Focal Points (TWFP) with 139 end-users in 31 countries of the NEAM region. KOERI has also successfully participated in NEAMWave12, the first Tsunami Exercise in NEAM region, as a TsunamiWatch Provider with a scenario based on Mw=8.4 worst-case interpretation of the 8 August 1303 Crete and Dodecanese Islands earthquake resulting in destructive inundation in the Eastern Mediterranean. In the second Tsunami Exercise in NEAMTWS (NEAMWave14), KOERI acted as the Message Provider for a Black Sea Scenario, where Black Sea was covered for the first time in a NEAMTWS Tsunami Exercise. As a result of a collaborative agreement with the European Commission - Joint Research Centre (EC- JRC), several Tsunami Scenario Databases (MOD1, MOD2 and MOD2-TR) are available for RETMC for operational use. In cooperation with the Turkish State Meteorological Service, KOERI has its own GTS system and is connected to the GTS via its own satellite hub for message dissemination.
**Detection networks of possible tsunami events and confirmation of tsunami generation**

The second objective included in the ICG/NEAMTWS Terms of Reference is “To organize and facilitate, as appropriate, the exchange of seismic, geodetic, sea-level and other data in real or near real-time and information required for interoperability of the ICG/NEAMTWS”.

As mentioned in the previous sections both seismic and sea level data are essential for the operations of a TWS. Effective tsunami early warning for coastlines at regional distances (>100 km) from a tsunamigenic earthquake requires notification within 15 minutes after the earthquake origin time. This is especially true for the restricted Mediterranean basin where this time delay may often be insufficient to issue timely tsunami early warnings, and almost always for local tsunamis (i.e. for coastlines within tens of kilometers from the seismic source). It appears evident that the availability of good station coverage, the proper type of data (i.e., regional scale broadband and strong motion near the source uncontaminated by instrument and/or transmission problems), and fast and reliable data transmission vectors are all primary input for carrying out the data analysis and issuing reliable tsunami alerts.

**Seismic Network**

In Europe, there are currently more than 1000 broadband seismic stations operating. At least 50% of these are available in real-time through various transmission means (e.g., public and private satellite, internet, dedicated lines, etc.) and protocols (e.g., SeedLink, Nanometrics). The seismic networks provides data for earthquake location and magnitude estimation with the purpose of notifying the civil protection authorities of earthquakes and the area affected by strong ground shaking and also for use in research. This amalgam of strictly operational duties and research has been effective in progressively improving the standards of data acquisition, data analysis and the overall quality of the services offered and, on the research side, the continuous quality control of the data acquired and then archived. In the Mediterranean particularly, the seismic stations are the primary and almost unique tool for this purpose, given the absence of a network of deep sea tsunami sensors available in real-time to the NEAMTWS TSPs.

In spite of the availability of a large number of seismograph station data, it should be noted that for the purpose of NEAMTWS it is important to ensure the availability of geographically balanced station coverage. The current station coverage for NEAMTWS is shown in Figure 11. In the Mediterranean there is a striking asymmetry between the number of stations on the northern shores, in Europe, and those in the countries in North Africa. For the north-eastern Atlantic, the coverage is dictated by the relative positioning of the land areas (continent(s) and of the islands (e.g., Azores) where the installation of seismograph stations is possible.
This asymmetry affects the accuracy of the earthquake locations especially for the estimation of the source depth that is one of the critical factors in assessing the level of tsunamigenic potential of a given earthquake. To a lesser but still significant extent, it also delays the timing of the initial locations. An improvement could be obtained with the inclusion of ocean-bottom seismometers.

Since experience has shown that not every strong earthquake generates a tsunami, and keeping in mind that earthquake parameters are not a direct measure of the ensuing tsunami and may constrain the expected tsunami impact to a limited extent, one of the key elements of a tsunami warning system is the availability of data that enable real time confirmation and characterisation of tsunami wave generation, once an earthquake having its epicentre on the ocean floor or near the coast is detected and the first data arrive from the seismic network. This has been recognized as a crucial element to avoid false tsunami alerts that may diminish the confidence of the population on the system; or as an important tool for reducing the uncertainty of tsunami forecasting. On the other hand, these data can also be used in delayed mode for validation of tsunami propagation models. However, real time sea level information both at the coast and in the open ocean was scarce until the occurrence of the Indian Ocean tsunami in December 2004.
**Sea Level Network**

Tsunami detection and confirmation is achievable first of all, of course, by using existing tide gauges in harbours. Although of interest for measuring the magnitude of the tsunami when it impacts the coastline, and also useful for warning when individual tide gauges are integrated in a large network covering several countries, however, one would not consider this to be enough for an ideal effective warning system; incorporation of offshore measurements of sea level from buoys or offshore observatories would be desirable to detect the tsunami wave well in advance. Offshore instrumentation such as the Deep-ocean Assessment and Reporting of Tsunami (DART) buoys, operating in the Pacific and Indian oceans as well as in the western Atlantic, are very expensive and difficult to maintain. On the other hand, tsunamigenic sources in NEAMTWS are rather close to the coasts, so the benefit of investing in such equipment must be carefully considered.

Many Member States have invested a lot during the last decade for the up-grade of their sea-level network and its enhancement with the implementation of numerous new sea level stations to get faster and better tsunami detection network. A new activity is the implementation of twenty new Inexpensive Device for Sea Level (IDSL) Measurements in the NEAMTWS region funded by joint Research Center (JRC) / European Commission.

**Figure 12** - a, b shows the stations compiled on this inventory up to July 2015; information has been added from several stations further away from our region that could however be important for the NEAMTWS Tsunami Warning Centres, such as the West coast of Africa, remote islands in the middle of the Atlantic or Greenland.

**Figure 12 a** - Stations included in the new NEAMTWS Tide Gauge Inventory, following the information provided by the Member States since March 2014. Green dots: sampling rate claimed to be ≤ 1 min.
An important activity is to collate and regularly update an inventory of sea level measurements and to enhance the capability of existing systems such as the European Sea-Level Service (ESEAS) and MedGLOSS so that data of sufficient accuracy and sampling can be made available in a timely fashion for tsunami warning system purposes and to ensure that such data are made freely available to the TSPs.
3. Awareness raising and education

Introduction

Although it remains impossible to predict when and where an earthquake will occur, the impacts of earthquake disasters can be reduced by taking a variety of personal and community safety measures\textsuperscript{17},\textsuperscript{18},\textsuperscript{19} to complement effective warning systems. Indeed, the catastrophic losses resulting from the Indian Ocean Tsunami of December 2004 were largely due to the absence of warning systems, lack of knowledge, and lack of preparedness among the populations at risk\textsuperscript{20}. By contrast, in Japan’s Tohoku earthquake on 11 March 2011, the effectiveness of local emergency warning systems and disaster preparedness among Japanese citizens saved many lives, despite the short time between the quake and the tsunami.

There is an ongoing need to better educate communities about tsunami threat and the associated risk and impacts to help manage expectations about the role of tsunami warning systems and communities at risk\textsuperscript{21}.

Awareness and population response are crucial issues in the NEAM region because tsunami travel times are very short, and there is a real possibility that the tsunami will hit before the population can be properly alerted by the TWS or too soon after the TWS has issued warnings to take action. It is important therefore that national and local emergency response plans be prepared for coastal regions and that regular preparedness exercises and drills be undertaken in all countries starting from the coastal areas most exposed to tsunami hazard.

Moreover, public awareness of tsunami risk can be enhanced by promoting the inclusion of coastal hazard and risk reduction knowledge in relevant sections of school curricula at all levels and the use of other formal and informal channels to reach and inform youth and children. Additional benefits can be

\textsuperscript{17} Turner, R., Nigg, J., and Heller Paz, D.: Waiting for Disaster, University of California Press, Los Angeles, CA, USA, 1986.
gained by developing training and learning programmes in disaster risk reduction targeted at specific sectors (development planners, emergency managers, local government officials, etc.) and at the coastal communities of the areas most exposed.

**NEAMTIC**

North-Eastern Atlantic and Mediterranean Tsunami Information Center (NEAMTIC) was fully established in 2011 with the support of the European Commission Directorate General for Humanitarian Aid and Civil Protection (EC DG ECHO) with the following objectives:

i. Making citizens, especially youth, aware of risks of floods from the sea in coastal areas, such as tsunamis, storm surges and strong swells and acquiring knowledge on and practicing safe behaviour;

ii. Identification, sharing and dissemination of good practices in plans, methods and procedures to strengthen preparedness for sea-level related hazards, including mitigation through integrated coastal zone management approaches;

iii. Fostering linkages between the European Commission and the IOC on intergovernmental and transnational actions to develop the NEAMTWS.

In order to fulfil these objectives in the context of NEAMTIC a number of multilingual education, awareness and preparedness materials were developed.

The main NEAMTIC tool is the web portal on tsunamis and other sea-level related hazards.

Through the NEAMTIC web portal it is possible to access a variety of information on tsunami warning and related institutions in every NEAMTWS Member State. It is also possible to download a number of multilingual educational products for students and for both a specialized and general public.

Some examples are:

- An educational and awareness poster on tsunamis and other sea-level hazards,
- An online course on tsunami and other sea-level related hazards for middle school students.
- An interactive educational board game.
- Video on tsunami risk in the NEAM region and on NEAMTWS for the general public.
Moreover, with the aim of providing civil protection authorities, coastal managers and planners with reference materials on preparedness for tsunamis and other coastal inundation, as a platform to strengthen cooperation and coordination, two publications were developed:

(1) Good practices in tsunami and coastal inundation preparedness (for emergency managers, civil protection authorities)

This document has been developed primarily for Civil Protection authorities in the NEAM region. The apparent low frequency of tsunamis can result in low interest and preparedness among population and authorities. However, recent events in the Pacific and Indian Oceans have led to an increased awareness of the importance of tsunami hazard in NEAM coastal areas. A set of guidelines are provided in this report to help civil protection authorities and coastal communities understand their exposure to tsunami hazards and to mitigate the resulting risk through awareness, preparedness information and land use planning.
Case studies and good practices for coastal management approaches for sea level related hazards

This compendium aims to provide examples of good practice in preparedness for, and awareness of, tsunami and other sea-level related hazards, selected from the case-studies presented at a NEAMTIC workshop in Paris in December 2012, complemented by experience gained from countries outside the NEAM region. It presents examples on how to prepare, respond to or mitigate such hazards. Short descriptions of these initiatives are given, highlighting interesting and innovative elements, approaches, tools, etc., that could be replicated, given similar conditions, or to provide a basis for the development of new approaches more appropriate for other areas.

In the following sections some examples of educational and awareness raising activities undertaken in some of the NEAMTWS Member States are presented.

**Turkey**

A large part of the loss of life and property in the disasters that have happened to date in Turkey is mainly due to the lack of knowledge of how to prepare for and act during disasters. Based on the fact that disasters are inevitable, and aiming to reduce damages and losses from disasters by taking measures and mitigating their impacts, the Disaster and Emergency Management Authority (AFAD) has set its mission as “Building a disaster resilient society”.

Earthquakes, floods, landslides, rock falls, droughts, storms, tsunamis and many other disasters have devastating effects on people, the environment and the economy. However, it is possible to increase the resilience (i.e. ability to withstand and quickly recover from these devastating effects) of people and places. Increasing this resilience will minimize the impact and damage caused by disasters, as well as the time required for the society to recover after disasters. AFAD has set its mission based on this viewpoint. Within the framework of AFAD’s mission, AFAD’s motto is: “We are prepared for the Unexpected”.

In order to become prepared for disasters as individuals, organizations and as a nation, an education mobilization campaign was launched. It contains basic disaster awareness topics that should be learned as a priority. For this purpose, disaster awareness and education programs have been implemented in Turkey.

In 2013, AFAD launched disaster awareness training followed by sensitization training under the title of “Disaster-Prepared Turkey” with the purpose of informing Turkish society about natural, technological and environmental hazards.
man-made disasters, protection from disasters and minimization of loss of lives and properties, so as to build a “culture of disaster sensitive living” at all levels of the society. On the other hand, in-service training is being organized for capacity building, with training programs being implemented for personnel of public agencies and organizations.

Disaster-Prepared Family Project: The aim is to build disaster preparedness culture with training for preparedness for the first 72 hours of disasters, raise awareness, share basic precautions for living spaces, ensure that families learn and implement the right behaviour, and prepare individuals to educate the society for disasters.

Disaster-Prepared School Project: The aim is to provide school employees and students with appropriate training for their age groups to become prepared for the first 72 hours of disasters in order to adopt disaster preparedness culture, raise awareness, share basic precautions they can take in their living spaces, ensure that they learn and implement the right behaviour, inform them on preparing disaster and emergency plans, and ensure preparation of school disaster and emergency plans (Figure 14).

Disaster-Prepared Business Project: The aim is to provide trainings for preparedness for the first 72 hours of disasters and to create a disaster preparedness culture, raise awareness, share basic precautions they can take at workplaces, ensure that they learn and implement the right behaviour, inform them on preparing disaster and emergency plans, and ensure the preparation of disaster and emergency plans for workplaces.

Figure 14- A view of the education activities for school children by AFAD staff (Photo from AFAD’s Strategy Document).
Disaster-Prepared Volunteer Youths Projects: The aim is to provide training to ensure that young people are ready for the first 72 hours of disasters, build a disaster preparedness culture, raise awareness, share basic measures they can take, ensure and implement the right behaviour and gain awareness on volunteering, ultimately form sustainable youth teams.

Disaster-Prepared Media Project: Within the scope of the Project planned to be carried out with relevant stakeholders, the aim is to ensure participation of printed and visual media into disaster preparedness and mitigation works, and ensure that they provide the right guidance to the public.

Tsunami preparedness and training activities are included in the “Disaster Prepared Turkey” campaign implemented by AFAD. However, before the NEAMWave14 exercise, AFAD organized public awareness activities at Tsunami Exercise pilot provinces in advance of the exercise.

During these exercises a wide range of the community participated to the event including decision makers, officials of government and municipality, academics, school children and representatives of NGOs. These one-day activities were found to be very useful by local authorities.

**Israel**

National tsunami exercises are taking place in the NEAM region. On 4 April 2016 Israel performed for the first time an end to end tsunami exercise named “BLUE WAVE” with the participation of the NEAMTWS TSPs of INGV (Italy), NOA (Greece) and KOERI (Turkey).

*Fig15* - End to end tsunami exercise in Israel –BLUE WAVE

The tsunami exercise presented Israel’s new approach for tsunami preparedness starting from the scenario of an earthquake and generated tsunami, all the way through the alert and evacuation to an assembly zone. The exercise involved the active participation of the local authorities and the public. The exercise was
concluded with a national tabletop exercise that dealt with the post-tsunami rehabilitation (infrastructure, of local authorities, affected population). The scenario for the exercise was the historical destructive 8.5 magnitude earthquake that occurred east of Crete on AD 1303 causing a basin wide tsunami in the eastern part of the Mediterranean that also affected the coast of Israel. The particular scenario allowed for about 45-60 minutes warning time, and the inland flooding height was determined to reach up to 5 meters above sea level. All the relevant governmental offices, first responders and local authorities of Israel participated in the “BLUE WAVE” exercise.

The National Emergency Management Authority (NEMA) concluded that the “BLUE WAVE” exercise was extremely successful. The exercise was covered by the Israeli media who for the first time raised awareness of the risk of tsunami.

**Fig16- Tsunami information and evacuation signs along the coast in the city of Ashkelon, Ashdod, Ashdod Sea Port**

As a preparation of the exercise Israel had developed tsunami information and evacuation signs. These signs are now put up along the Southern coast of Israel and the media also raised awareness about these signs. It will take another 18-24 months to place all the tsunami information and evacuation signs.
**Italy**

The Italian Department of Civil Protection has since 2013 undertaken a national communication campaign “Io non rischio Maremoto (I don’t take risks – Tsunami)” for the dissemination of risk knowledge and rules of behaviour to adopt before, during and after a tsunami event (Fig. 15). The basic idea behind the campaign is that a citizen who is more informed and aware can become an active ambassador in the field of risk prevention and reduction, especially when - as in the case of tsunami risk - one is dealing with natural phenomena that are not well known or of which there is a limited perception. Along with the Department, ANPAS (National Association of Public Assistance), INGV (National Institute of Geophysics and Volcanology), ReLUIS (Laboratories University Network of seismic engineering), ISPRA (National Institute for Environmental Protection and Research) and OGS (National Institute of Oceanography and Experimental Geophysics) are also among the promoters of the campaign.

“Io non rischio Maremoto” is part of the national communication campaign “Io non rischio” (I don’t take risks) aimed at making people more aware of the risks in Italy and disseminating rules of behaviour and best practices in civil protection. As of today, besides tsunami risk, the campaign has addressed earthquake and flood risks and, in the future, more risks will be included. Each year, “Io non rischio” days are organized within the initiative.

**Fig 17- Activities during the “I don’t take risks – Tsunami” campaign**
in which local volunteers in civil protection who have been appropriately trained meet their fellow citizens in town squares to make them more aware of the risks in their territory, including via the distribution of information.

In 2013, the first edition of the campaign “Io non rischio Maremoto” involved 28 coastal municipalities in the province of Salerno that are exposed to tsunami risk. The initiative belongs to the international project Twist - Tidal Wave In Southern Tyrrhenian Sea, co-funded by the European Commission. A drill was carried out in the closing phase. During the drill, there was a simulation of the effects of a tsunami wave, triggered by a landslide of the submarine volcano Palinuro. The communication campaign “Io non rischio Maremoto” was completely integrated within the project, as the objectives were common: increasing the awareness of citizens and institutions on tsunami risk, both through operational activities, and through training and dissemination activities and supporting civil protection planning at local level. The campaign went on tour: each weekend in the month of October the initiative was carried out simultaneously in 7/8 coastal municipalities. It was also held each weekend just in the municipality of Salerno. Campaign support was obtained from some 500 volunteers from local groups and regional associations of civil protection in the Campania region and local sections of 7 national organizations. For the occasion, to support the activities of volunteers, Campania Region also made available a camper-van, set up with the campaign logo and colours, that travelled around in the relevant ports and squares.

After the successful campaign carried out during the Twist project, the initiative was proposed again also in 2014 with “Io non rischio Maremoto”. Due to bad weather, the campaign was carried out in two phases, on 14 and 15 June and 11 and 12 October 2014. Based on the experience gained during the previous year, the communication campaign dedicated to tsunami risk was associated with earthquake risk as the knowledge of seismic risk proves fundamental in understanding tsunami risk. The initiative was carried out in 22 squares of 20 coastal municipalities exposed to tsunami risk and, this time, besides Campania region, it was extended also to Calabria, Puglia and Eastern Sicily. A total of over 300 volunteers from the local sections of 12 national organizations of civil protection and three local groups of Campania Region contributed to the campaign. In 2014 the initiative “Io non rischio” was carried out under the High Patronage of the President of the Italian Republic.

For the 2015 edition of “Io non rischio”, as all the Italian coasts are exposed to tsunami risk, the campaign was further extended to all the squares where “Io non rischio terremoto” was already planned. The regions involved were Abruzzo, Basilicata, Calabria, Campania, Emilia Romagna, Friuli Venezia-Giulia, Lazio, Lombardy, Marche, Molise, Puglia, Sardinia, Sicily, Tuscany, Umbria and Veneto. In total, over 120 Italian municipalities
took part in the initiative, mobilising a total of more than 1,000 volunteers from 22 communal groups and regional associations and 22 national organizations associated with civil protection voluntary work.

**Greece**

In Greece the strong (M≥6) earthquake mean repeat time is one per year as an average. More than 50% of this activity takes place under the sea. However, the tsunami occurrence is much less frequent than the earthquake occurrence. Therefore, the development of actions about the education and awareness raising as regards tsunamis remained several years behind of such actions regarding earthquakes.

The first organized education and awareness raising programme regarding earthquakes was developed after 1983 when the Earthquake Planning and Protection Organization (EPPO, http://www.oasp.gr/) was established by the state. EPPO systematically produces educational and other material relevant to the antiseismic protection, such as posters, leaflets, brochures, audiovisual products and others. This material

![Image](image-url)

**Fig 18-** Tsunami education for school children organized by HL-NTWC during the Athens Festival for Science and Technology, Athens, 3-8 April 2016. The tsunami education tank attracted great interest and caused enthusiasm among the kids. The tsunami education tank produced by HL-NTWC within the frame of EU-FP7 ASTARTE Project with the aim to educate in a funny way school children as regards tsunami generation and impact.
contains, among others, background information about the earthquakes and associated phenomena, including tsunamis. This national programme includes also exercises and training meetings for schools, local authorities, fire brigades and other target groups. The aim is to disseminate knowhow and practical information on the best practices for protection against several types of hazards related to the seismic activity, including tsunami hazard. Similar activities are undertaken by the General Secretary for Civil Protection (GSCP) (e.g. http://civilprotection.gr/en/earthquakes) after its establishment in 1995. In this parallel programme, GSCP is collaborating with EPPO as regards the seismic risk mitigation. In general, one may say that the education and awareness raising programme for tsunamis in Greece is only a part of the overall national programme for the protection from earthquakes.

Apart from the EPPO’s and GSCP’s initiatives, other activities are undertaken by other organizations. A good example is the Earthquake and Tsunami section of the Museum of Natural History of the University of Crete, situated at Heraklion which is the capital city of Crete. In that section, not only printed educational material can be found but also earthquake and tsunami simulators. In fact, an educational shaking table (earthquake simulator) is operating at the Museum offering visitors the opportunity to learn about earthquakes and experience real earthquake shaking in a safe environment. In a nearby space, the visitors are able to mechanically produce a tsunami by themselves in a 2-m-long tank constructed to act as a tsunami simulator. In this way, the visitors understand how tsunamis are really generated by the sudden, massive displacement of water. Of special interest is also the collaboration between the Hellenic National Tsunami Warning Center (HL_NTWC, NOA, Greece) and the educational programme of NEAMTIC. For example, an educational illustrative poster was produced containing information about the tsunamis in general and the practical ways of self-protection against tsunami hazard. This poster was translated in several languages including Greek with the contribution of NOA.

Very recently, in the frame of the EU FP7 ASTARTE tsunami research project standardized questionnaire surveys were performed in several test-sites of the project. The aim of these surveys was to investigate the level of tsunami risk awareness by the general public. Some results have been obtained. For example, in the highly touristic test-site of Heraklion, Crete Isl., Greece, preliminary results showed that Greek and foreign visitors are better aware about the tsunami risk than local people (Papageorgiou et al., 2015).

Future plans of the HL-NTWC include the creation of a web-site specifically for the tsunami risk mitigation programme including educational and training material. The plan includes also the production of a booklet and leaflets on the same topics. The general public will be the main target group for these activities.
Key achievements and future challenges and opportunities

Since the establishment of the ICG/NEAMTWS 10 years ago, there has been steady progress towards the provision of tsunami watch services for the NEAM region. As of today, France, Greece, Italy and Turkey have established National Tsunami Warning Centres and act as Tsunami Service Providers in the region. Portugal is on the verge of similar capability. Various working groups and task teams support the work of the ICG/NEAMTWS. A Tsunami Information Centre for the NEAM region (NEAMTIC) has been set-up to provide tools and products to increase the awareness and the preparedness of the citizens, to educate youngsters, and to promote a better cooperation with the Civil Protection Authorities of the region. Regular Communication Tests are held and NEAMWave12 and NEAMWave14 were the first in a sequence of Tsunami Exercises. The performance of these tests and exercises and the suggested improvements that result are discussed and incorporated into planning for the future.

However, despite these achievements there is much more to be done, including:

**Tsunami hazard and risk assessment**

- A holistic assessment of tsunami hazard and risk in the NEAM region, as a basis for long term risk mitigation planning, and as a tool for evacuation planning in case of a tsunami warning.

**Monitoring, warning and forecast**

Further development of the technical monitoring and warning elements of the Tsunami Early Warning System so as to improve the reliability of detection and accuracy of warnings and to reduce the rate of false alarms. Links with the research community need to be maintained and the warning system needs to have the flexibility to take advantage of new results without compromising operational integrity.
• Increased efforts to maintain and improve real time seismic and sea level observing networks ensuring a more uniform coverage around the NEAM region. The contribution of measurement systems such as HF radar and moored sensors for detecting tsunamis while still offshore should be explored and implemented as appropriate.

• Promoting research on novel methods on tsunami height forecast

**Dissimination and communication of risk and information**

• The NEAMWave exercise has shown that there is a need to further simplify the message distributed by TSPs. This will further improve information flow to the users.

• The use of graphical information such as maps need to be explored in NEAMTWS.

• Provide tsunami information to maritime communities

**Response capability**

• NEAMTWS activities need to focus on providing civil protection personnel in all member states with a basic understanding of the early warning elements and features of NEAMTWS. The procedures for evacuation planning and the need for Civil Protection organizations to demonstrate and maintain a capability to respond effectively to a rare, though possibly devastating event by carrying out regular drills and exercises.

• The public need to know what to do in presence of natural signs of a tsunami, with or without a warning. The effectiveness of any early-warning system ultimately depends upon an educated and trained population that are aware of the risks and likely impacts involved and must also be able to adopt the appropriate safety and risk reduction responses. Education and preparedness is a fundamental challenge to be addressed in the NEAM region.
NEAMTWS sustainability

• The sustainability of the NEAMTWS will be a challenge. Fortunately, tsunamis causing damage and loss of life although potentially devastating are rare. However, it is this combination that makes it both essential but difficult to maintain tsunami warning systems in a 24/7 operational mode. Incorporating a tsunami warning capability into broader multi-hazard warning systems, some of which may already exist in mature form, may help to ensure sustainability. Initial exploration of this multi-hazard approach within NEAMTWS shows considerable interest in taking this forward although the way this can be implemented is likely to vary considerably between member states.

• The sustainability of the NEAMTWS strongly depends how it is successfully rooted within the communities at risk, and the level of participation of all Member States, relevant actors and stakeholders in the region.

• Considerable effort and financial support for NEAMTWS has been provided by several member states, particularly those hosting TSPs, as well as UNESCO and the EC. Given the high mobility of citizens as tourists and for employment, tsunami risk has to be taken seriously by all member states with implications for cost sharing.

In the light of the above, the present governance and structure of NEAMTWS is under review and possible reorganisation to meet the challenges of the next 10 years is being explored by a task team.
# Main acronyms used

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<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AFAD</td>
<td>Turkey’s Disaster and Emergency Management Authority</td>
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<tr>
<td>ASTARTE</td>
<td>Assessment, STrategy And Risk Reduction for Tsunamis in Europe - an EC project</td>
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<tr>
<td>CEA</td>
<td>Commissariat à l’énergie atomique et aux énergies alternatives (France)</td>
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<td>CENALT</td>
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<td>TSP</td>
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<td>EC</td>
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<td>EMTC</td>
<td>Euro-Mediterranean Tsunami Catalogue</td>
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<td>ESEAS</td>
<td>European Sea Level Service</td>
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<td>GAR 2015</td>
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<td>GTS</td>
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<td>ICG</td>
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<td>INGV</td>
<td>National Institute of Geophysics and Volcanology (Italy)</td>
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<td>IOC</td>
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<td>JRC</td>
<td>Joint Research Centre (of the EC)</td>
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<td>KOERI</td>
<td>Kandilli Observatory and Earthquake Research Institute (Turkey)</td>
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<td>MedGLOSS</td>
<td>Monitoring Network System of Systematic Sea Level Measurements in the Mediterranean and Black Seas</td>
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<td>NEAMTIC</td>
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<td>UNESCO</td>
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10 Years of the North-Eastern Atlantic, the Mediterranean and Connected Seas Tsunami Warning and Mitigation System (NEAMTWS)

Accomplishments and Challenges in Preparing for the Next Tsunami

Intergovernmental Oceanographic Commission

United Nations Educational, Scientific and Cultural Organization

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