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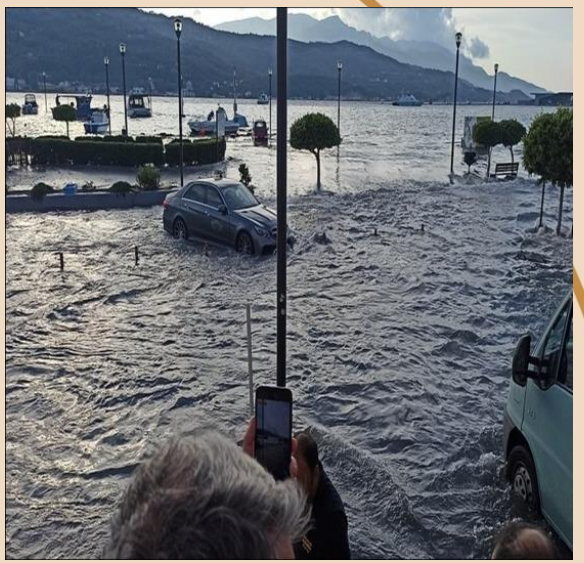
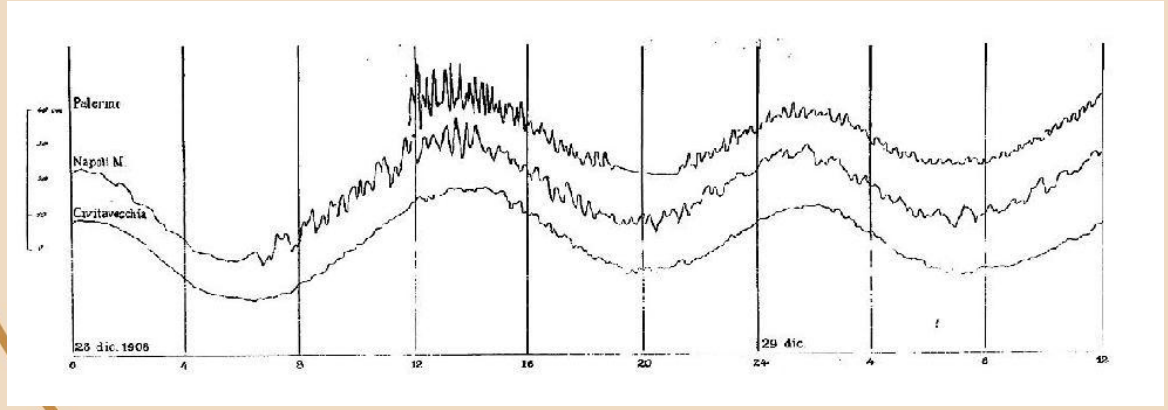
PIANO NAZIONALE DI RIPRESA E RESILIENZA
ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

WP 8
Coordinator
Stefano Lorito
INGV

TUO

TsUnami Observation





Assigned Budget: 3 M€

ICG/NEAMTWS

The Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and connected seas (ICG/NEAMTWS) was formed in response to the 26 December 2004 Indian Ocean Tsunami. The Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) received a mandate from the international community to coordinate the establishment of the System.

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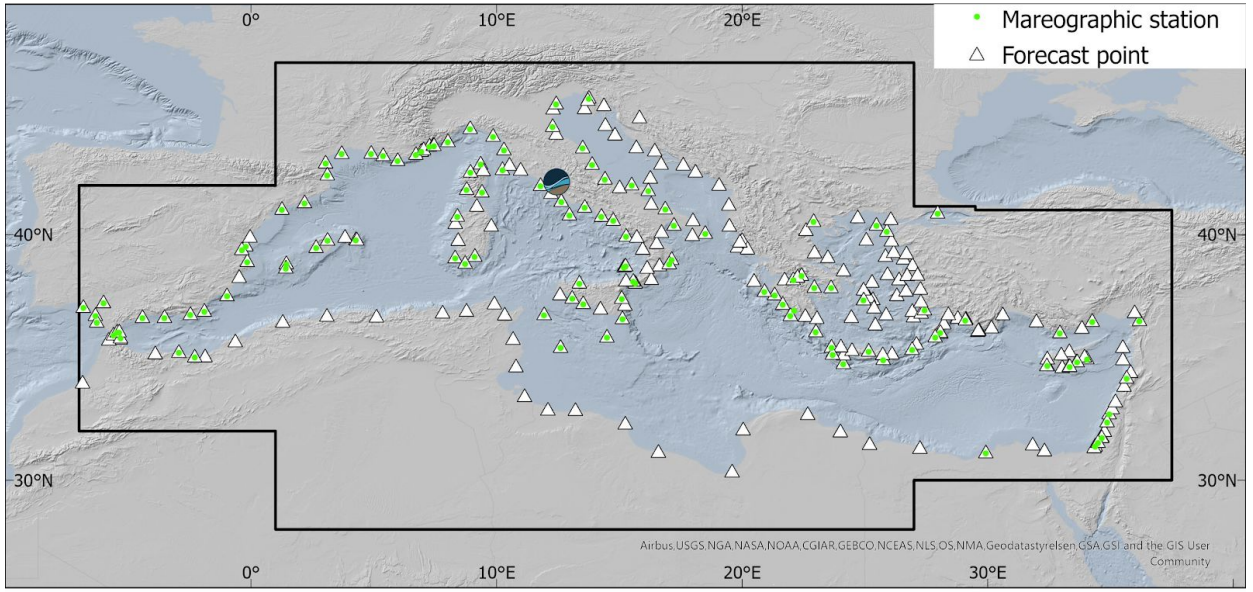
UNESCO United Nations Educational, Scientific and Cultural Organization · Intergovernmental Oceanographic Commission

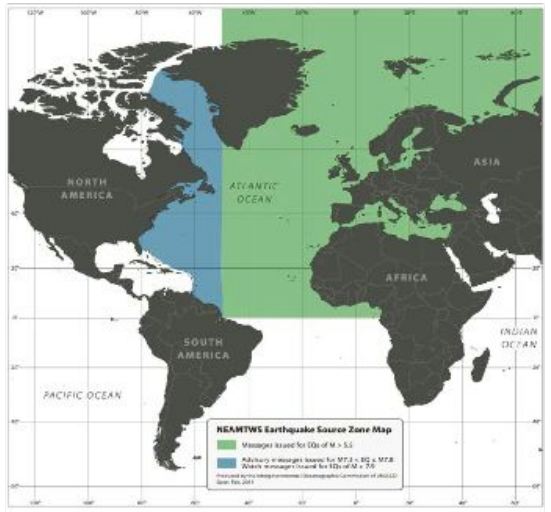
CAT-INGV Tsunami Service Provider

CAT-INGV monitors tsunami sources in the Mediterranean Sea



Earthquake Source Zone Monitored by the NEAMTWS-TSPs

The map below shows the Area of Responsibility (AoR) of Tsunami Service Providers (TSPs) operating within the ICG/NEAMTWS.



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UNESCO United Nations Educational, Scientific and Cultural Organization · Intergovernmental Oceanographic Commission

CAT-INGV Tsunami Service Provider

- **Nov 2013:** A Tsunami Warning Centre *(CAT - Centro Allerta Tsunami) is established at INGV*
- **October 2014:** *CAT-INGV begins to operate as Candidate Tsunami Service Provider for the NEAM region*
- **September 2016:** *CAT-INGV is accredited (together with CENALT, NOA and KOERI) as Tsunami Service Provider by the ICG/NEAMTWS*
- **February 2017:** *The Italian Prime Minister issues a Directive for establishing the «National Alert System for Tsunami generated by earthquakes in the Mediterranean Sea (SiAM)», composed of the Italian Civil Protection Department (DPC), CAT-INGV and the Italian Institute for Environmental Protection and Research (ISPRA)*

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PROTEZIONE CIVILE NAZIONALE
INGV
ISPRA

CAT-INGV Tsunami Service Provider

- The INGV Service for **Tsunami Alert** is fully integrated with the companion Service for **Earthquake Monitoring**
- The Monitoring Room in Rome hosts, on a 24/7 basis, 4 persons:
  - 2 Seismologists
  - 1 Tsunamist
  - 1 Tecnician/Engineer
- In addition to these, we have 5 persons available on call:
  - 1 expert Seismologist
  - 1 expert Tsunamist
  - 3 Technicians/Engineers

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CAT-INGV

35 alerts since 2017
- 4 Watch
- 6 Advisory
- 25 Information

9 alerts in 2022
- 1 Advisory
- 8 Information

Origin Time UTC	Region	Mag	Depth Km	Alert level	Initial message issued at:
09/11/22 06:07	Italy	6.0	12	Information	09/11/22 06:13
31/10/22 21:41	Italy	5.5	260	Information	31/10/22 21:51
02/10/22 04:04	Greece	5.6	20	Information	02/10/22 04:10
08/09/22 07:36	Greece	5.6	94	Information	08/09/22 07:44
31/08/22 10:10	Greece	5.5	10	Information	31/08/22 10:18
20/05/22 12:35	Morocco	5.5	11	Information	20/05/22 12:44
22/04/22 21:13	Bosnia and Herzegovina	5.9	10	Information	22/05/22 12:44
02/02/22 21:03	Cyprus	5.5	35	Information	02/02/22 21:14
11/01/22 01:07	**Cyprus**	**6.4**	**20**	**Advisory**	**12/10/21 01:17**
29/12/21 05:08	Greece	5.5	18	Information	29/12/21 05:15
26/12/21 18:59	Greece	5.5	10	Information	26/12/21 19:06
19/10/21 05:32	Greece	6.0	106	Information	19/10/21 05:40
12/10/21 09:24	**Greece**	**6.1**	**20**	**Advisory**	**12/10/21 09:31**
27/09/21 06:17	**Greece**	**6.2**	**20**	**Advisory**	**27/09/21 06:24**
27/03/21 13:47	Italy/Albania	5.6	5	Information	27/03/21 14:23
18/03/21 01:04	**Algeria**	**6.2**	**13**	**Advisory**	**18/03/21 01:14**
04/03/21 18:38	Greece	5.9	11	Information	04/03/21 18:47
03/03/21 11:16	Greece	6.3	20	Information	03/03/21 11:24
30/10/20 11:51	**Greece**	**7**	**10**	**Watch**	**30/10/20 11:59**
18/09/20 16:28	Greece	5.9	20	Information	18/09/20 16:35
20/05/20 23:43	Greece	5.5	10	Information	20/05/20 23:55
02/05/20 12:51	**Greece**	**6.7**	**10**	**Watch**	**02/05/20 12:59**
21/03/20 00:49	Greece	5.8	12	Information	21/03/20 00:57
30/01/20 11:21	Greece	5.9	11	Information	30/01/20 11:30
27/11/19 07:23	Greece	5.8	15	Information	27/11/19 07:30
26/11/19 02:54	**Albania**	**6.5**	**20**	**Advisory**	**26/11/19 03:01**
26/09/19 10:59	Turkey	5.9	10	Information	26/09/19 11:08
21/09/19 14:04	Albania	5.9	10	Information	21/09/19 14:13
20/03/19 06:34	Turkey	6.0	10	Information	20/03/19 06:41
30/10/18 15:12	Greece	5.9	10	Information	30/10/18 15:20
25/10/18 22:54	**Greece**	**6.8**	**19**	**Watch**	**25/10/18 23:02**
20/07/17 22:31	**Turkey**	**6.8**	**10**	**Watch**	**20/07/17 22:41**
12/06/17 12:28	**Greece**	**6.5**	**16**	**Advisory**	**12/06/17 12:38**

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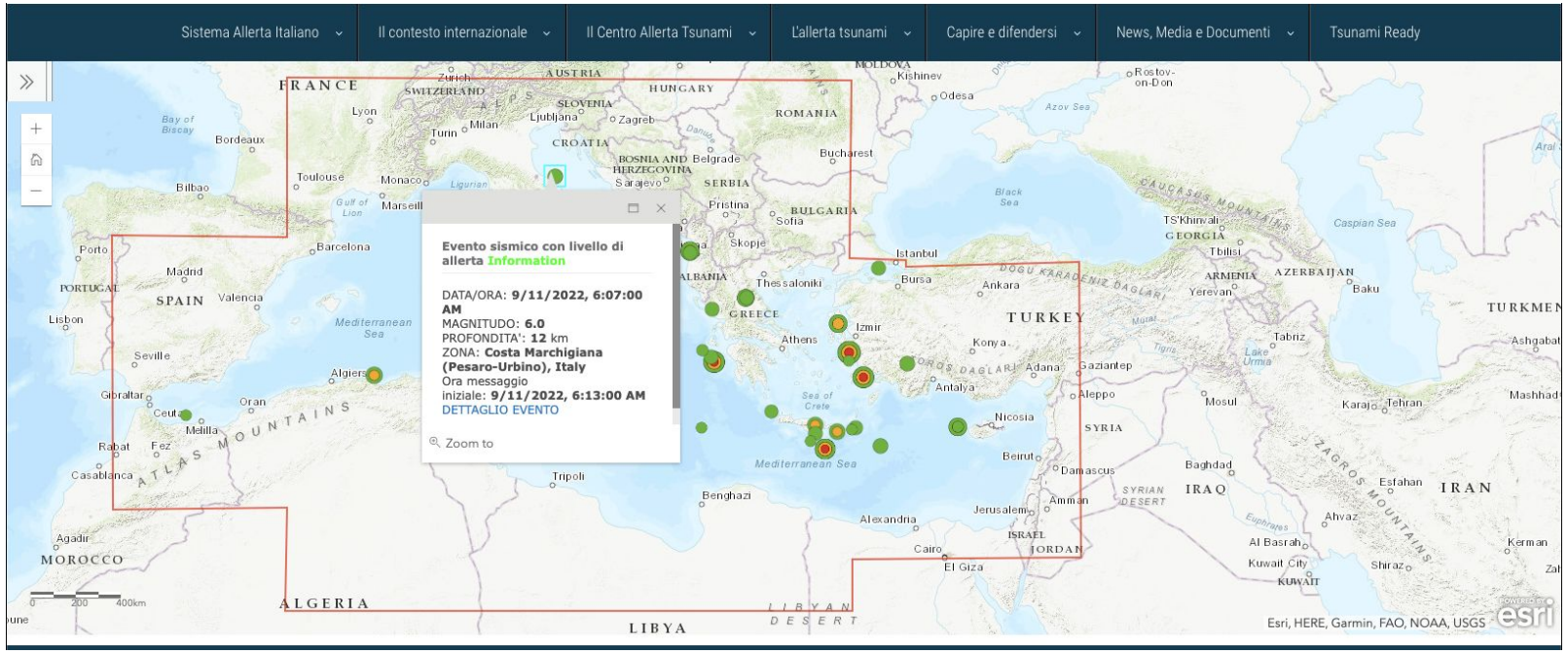
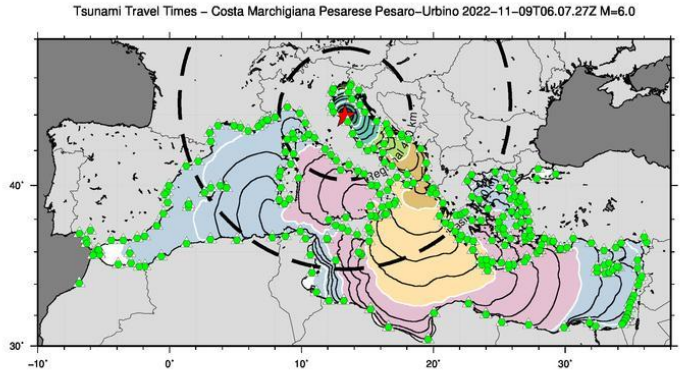
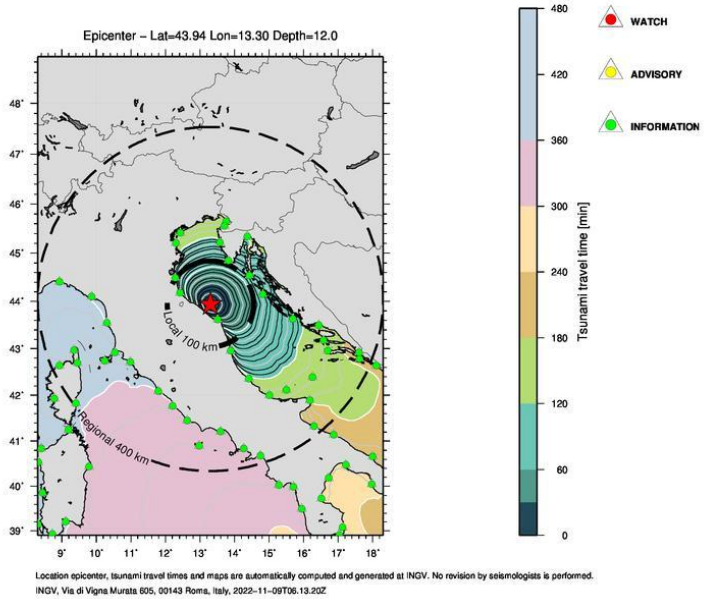
09.11.22 - messaggio INFORMATIVO per terremoto a largo della costa marchigiana (Pesaro-Urbino)







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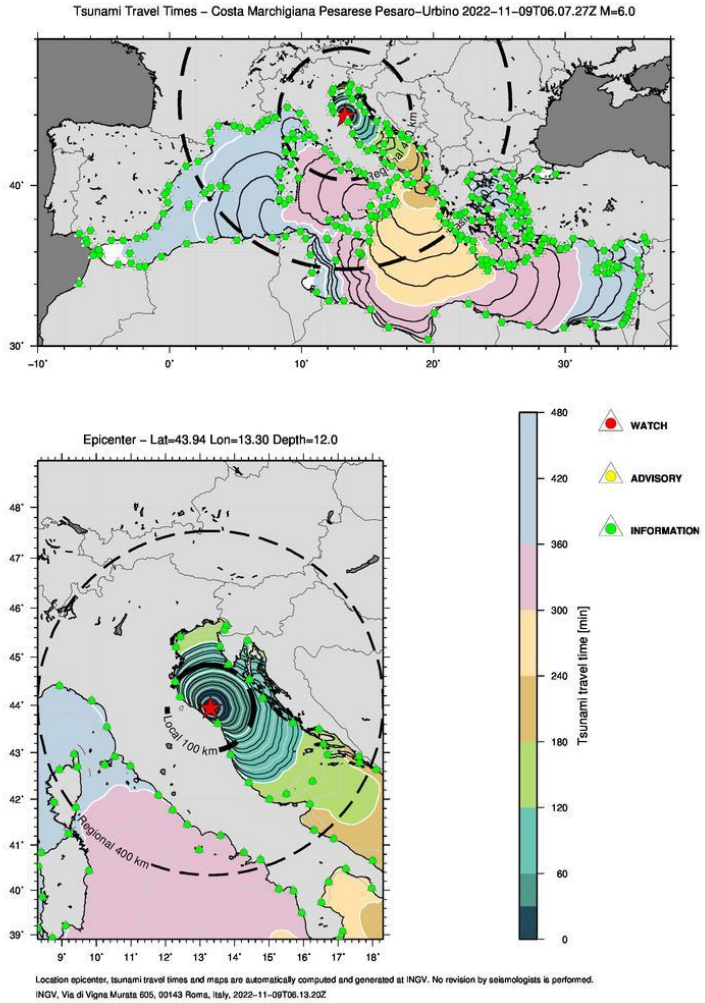
https://cat.ingv.it/it/

09.11.22 - messaggio INFORMATIVO per terremoto a largo della costa marchigiana (Pesaro-Urbino)

SISTEMA D'ALLERTAMENTO NAZIONALE PER I MAREMOTI GENERATI DA SISMA MESSAGGIO DI INFORMAZIONE ==========
MESSAGGIO ITALIA: INFORMAZIONE (INFORMATION) MESSAGGIO MEDITERRANEO: INFORMATION
E' IMPROBABILE CHE IL MAREMOTO, EVENTUALMENTE GENERATO DALL'EVENTO SISMICO, PRODUCA UN IMPATTO SIGNIFICATIVO SUL TERRITORIO DI RIFERIMENTO DEL MESSAGGIO.
PERTANTO IL MESSAGGIO NON SI CONFIGURA COME UN'ALLERTA.
========== MESSAGGIO N.: 001
NTWC: INGV-CAT IT-NTWC TIPO: INITIAL INVIATO: 07:13 LT 09 NOV 2022 (Local Time) 06:13 UTC 09 NOV 2022 (Coordinated Universal Time) Parametri automatici del terremoto
****

Tempo origine 07:07 LT 09 NOV 2022 06:07 UTC 09 NOV 2022 Area Costa_Marchigiana_Pesarese_Pesaro-Urbino Magnitudo 6.0 Coordinate 43.94 NORTH 13.30 EAST Profondita' 12 Km
****



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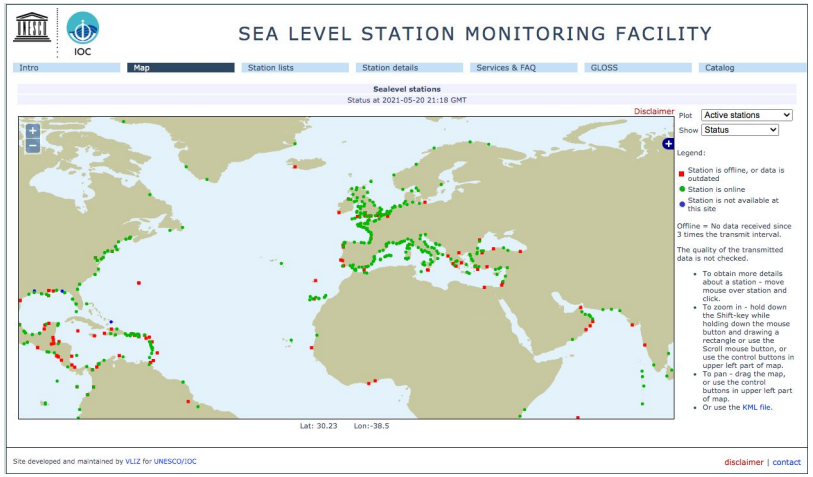
Seismic-based warning – Observational Gaps

The warning is based on Seismic detection and characterization; sea level data used for confirmation/cancellation

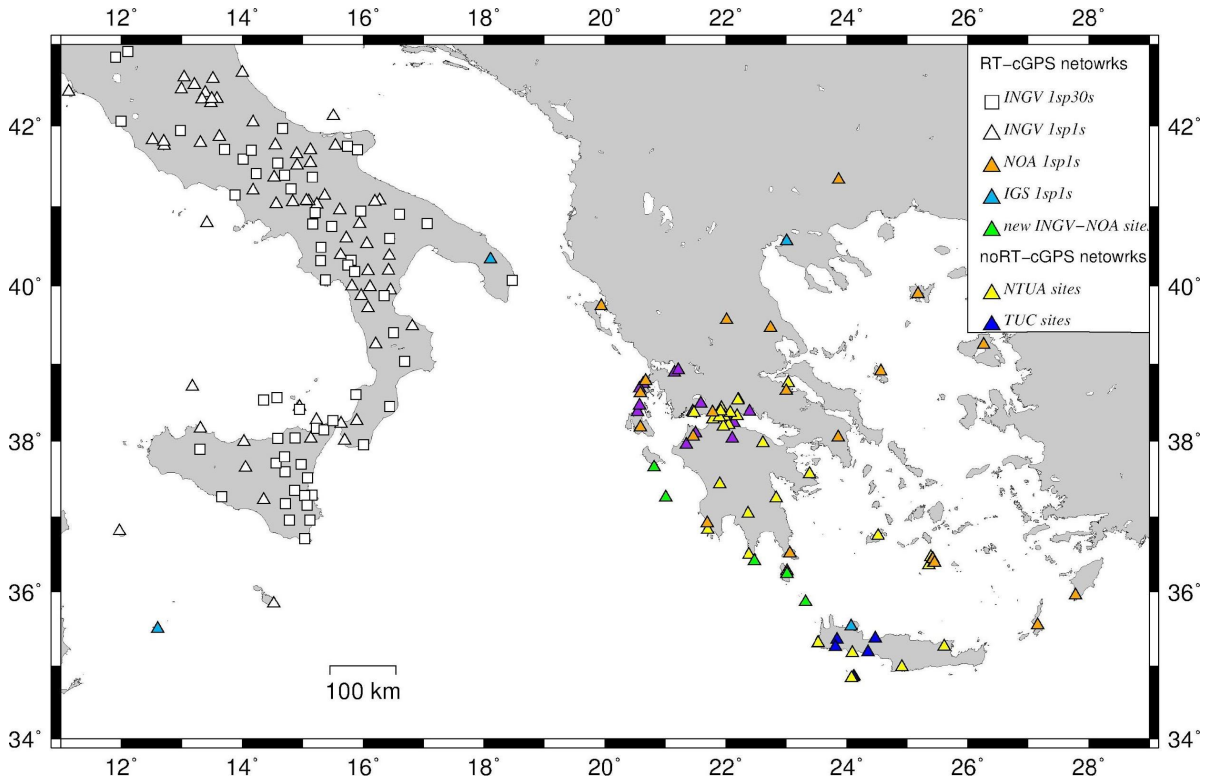


- There's a gap in (seismic and sea level) instrumental coverage to the South
- Seismometers only: Real time GNSS data are not yet in the system (NOA-INGV network is being integrated)
- Coastal gauges only: offshore cabled and deep sea pressure sensors not yet existing or integrated in the system (cabled sensors and DARTs planned offshore eastern Sicily)
- Earthquakes only!!!

Filling the Gaps

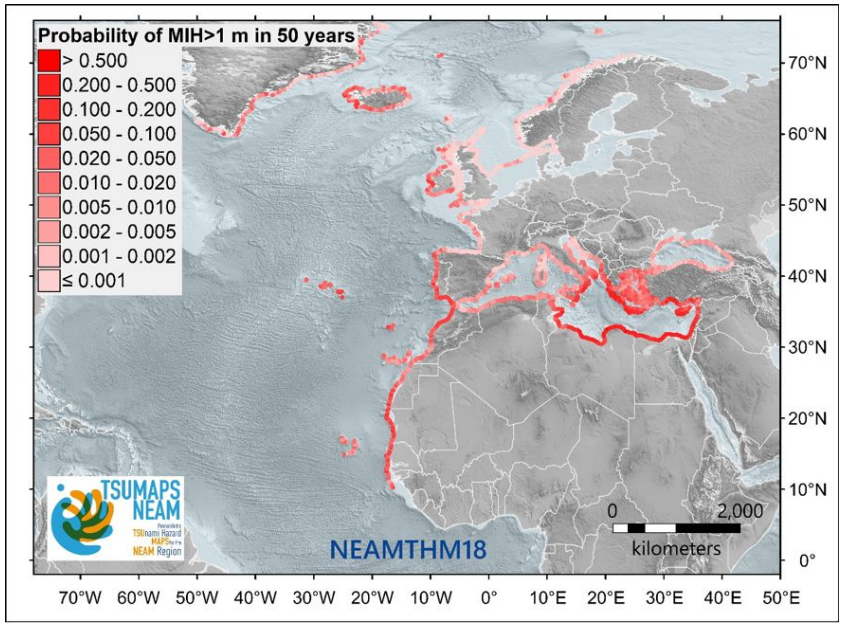
- **Towards Real-time cross-border GNSS network - real-time acquisition and positioning (NOA, Greece; INGV Italy)**

- **Joint exploitation of seismic + GNSS data + rapid finite fault inversion (EWRICA project, GFZ, Germany)**

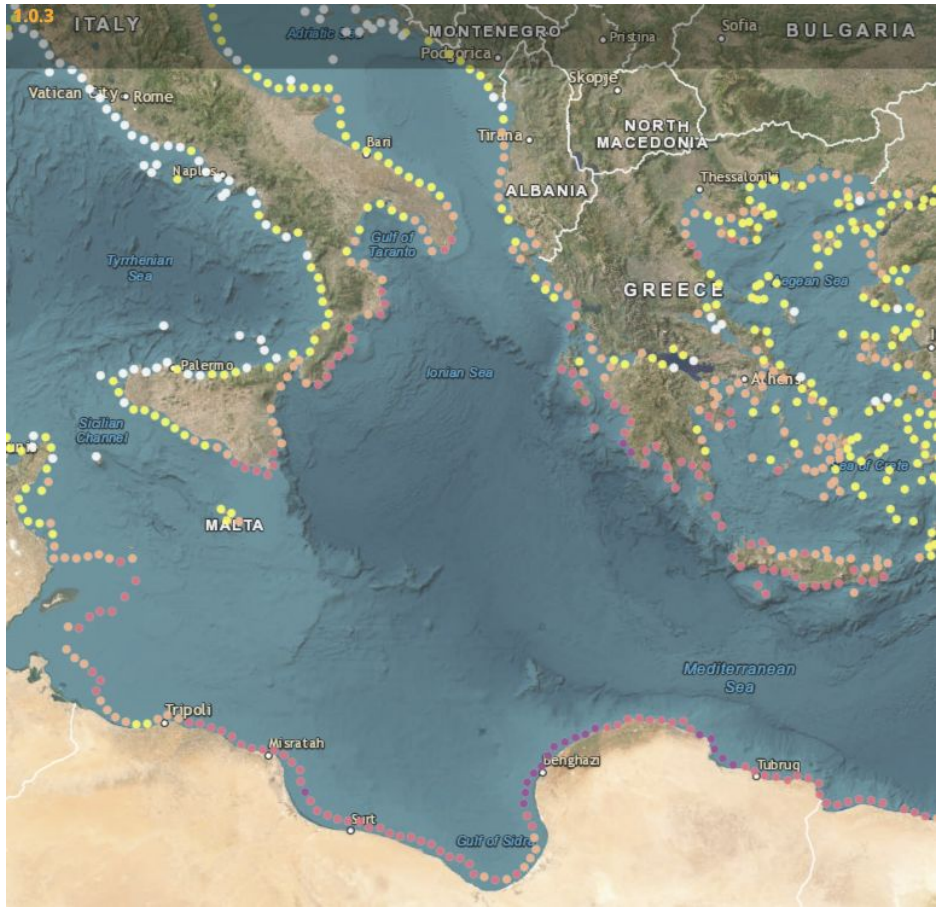


Filling the Gaps: WP8 TUO – TsUnami Observation

The highest earthquake-generated tsunami hazard in the region *is in the Ionian Sea / Eastern Mediterranean Sea*

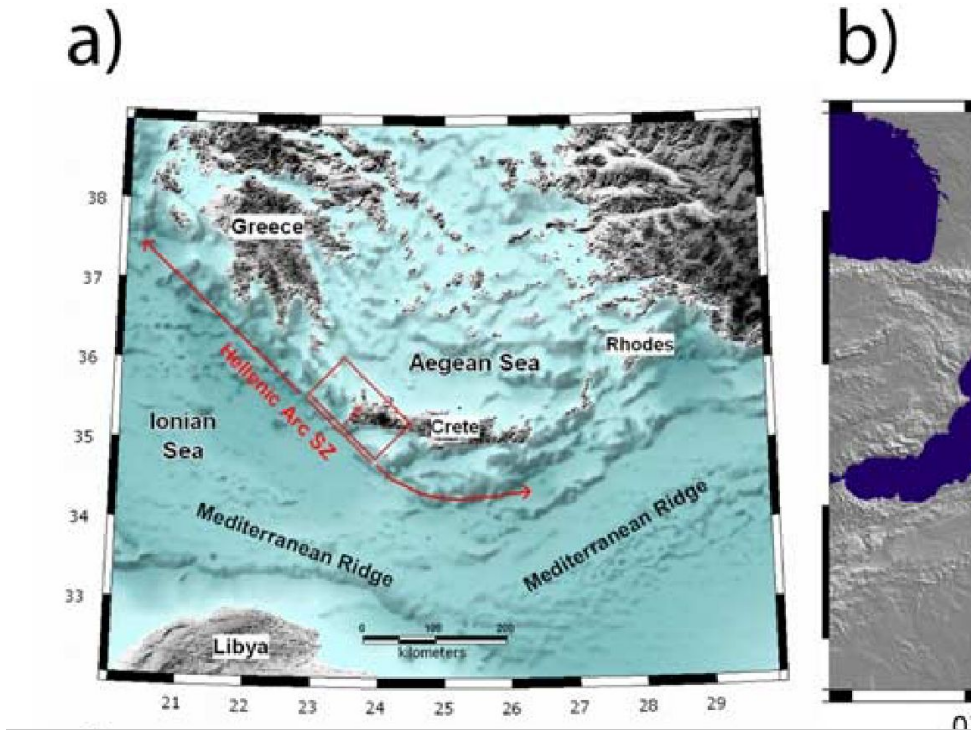


TSUMAPS NEAM
Probabilistic TSUnami Hazard MAPS for the NEAM Region



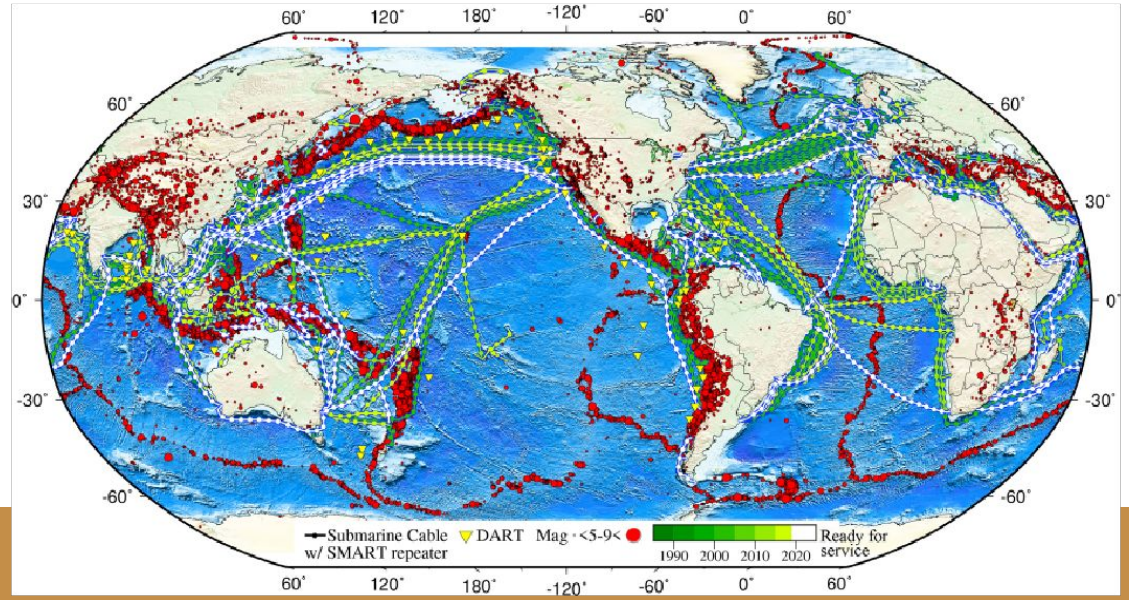
Filling the Gaps: WP8 TUO – TsUnami Observation

Travel times from minutes to hours – scarce tsunami detection capability



Improvements

- Early detection
- Uncertainty Reduction of the forecasting with Direct tsunami observation / measurement



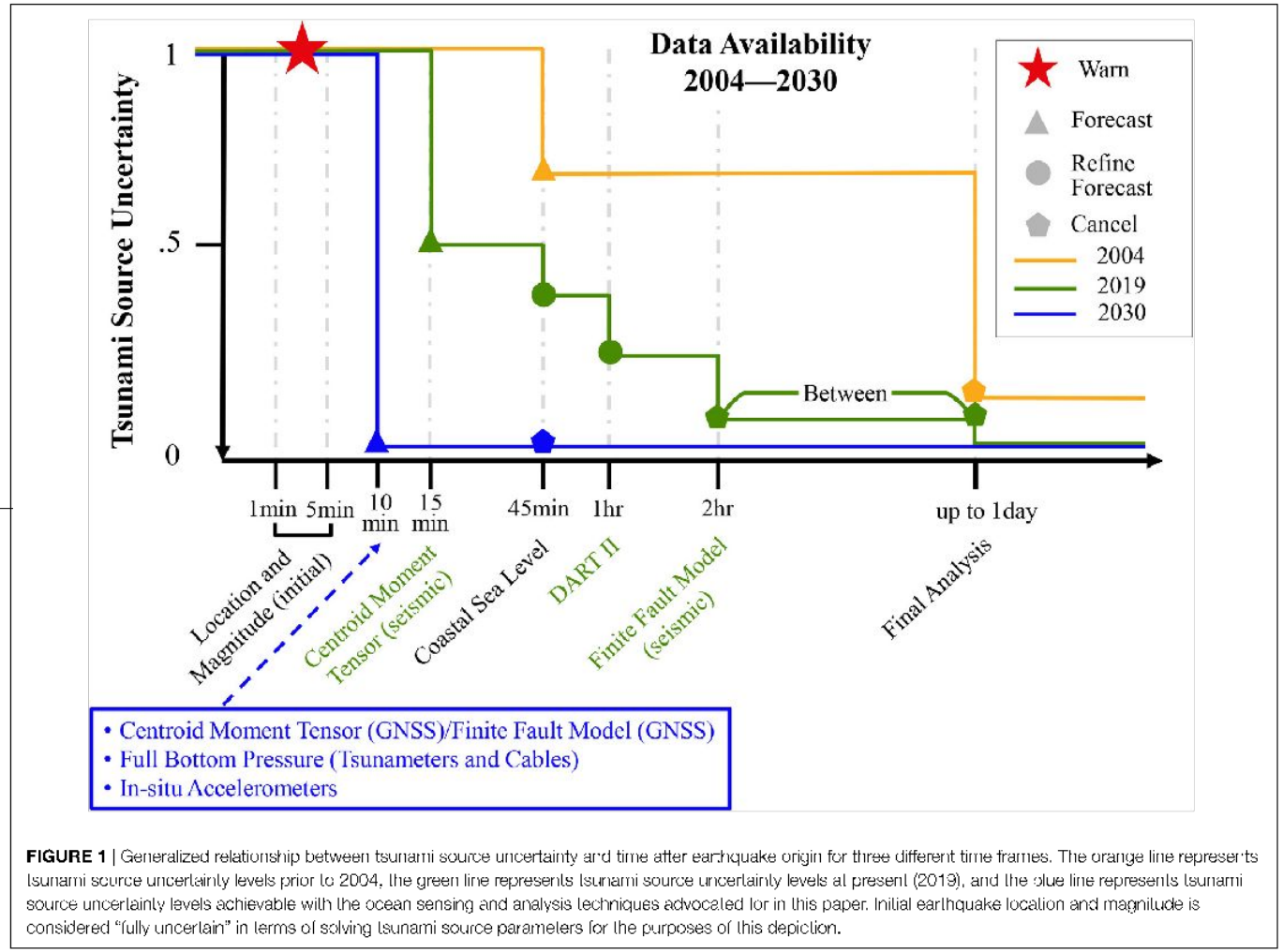
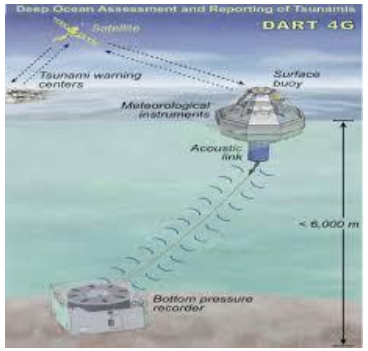
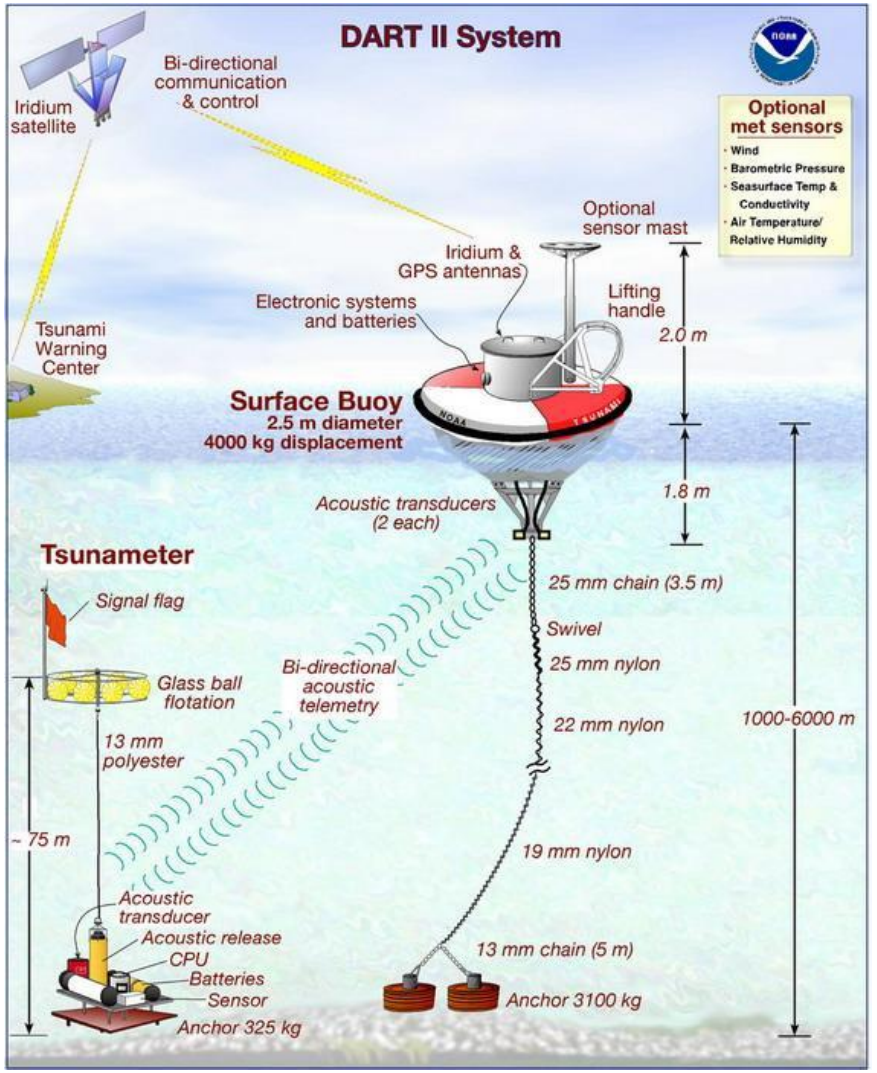


FIGURE 1 | Generalized relationship between tsunami source uncertainty and time after earthquake origin for three different time frames. The orange line represents tsunami source uncertainty levels prior to 2004, the green line represents tsunami source uncertainty levels at present (2019), and the blue line represents tsunami source uncertainty levels achievable with the ocean sensing and analysis techniques advocated for in this paper. Initial earthquake location and magnitude is considered "fully uncertain" in terms of solving tsunami source parameters for the purposes of this depiction.

Filling the Gaps: WP8 TUO – TsUnami Observation

DART® (Deep-ocean Assessment and Reporting of Tsunamis)





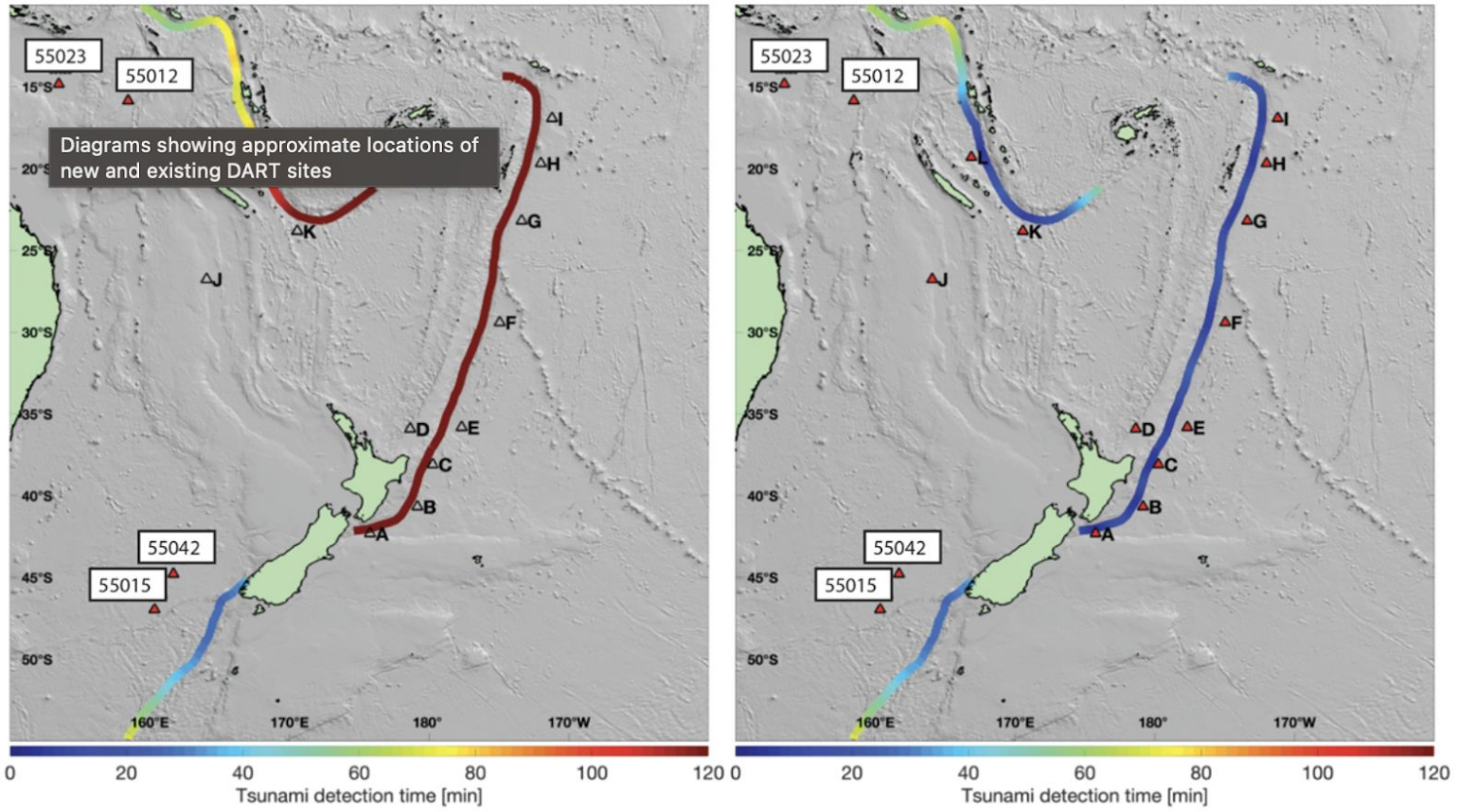
Filling the Gaps: WP8 TUO – TsUnami Observation

Fry et al., EOS, 2020

DARTs in New Zealand

Tsunami detection time improvement

12 new DARTs

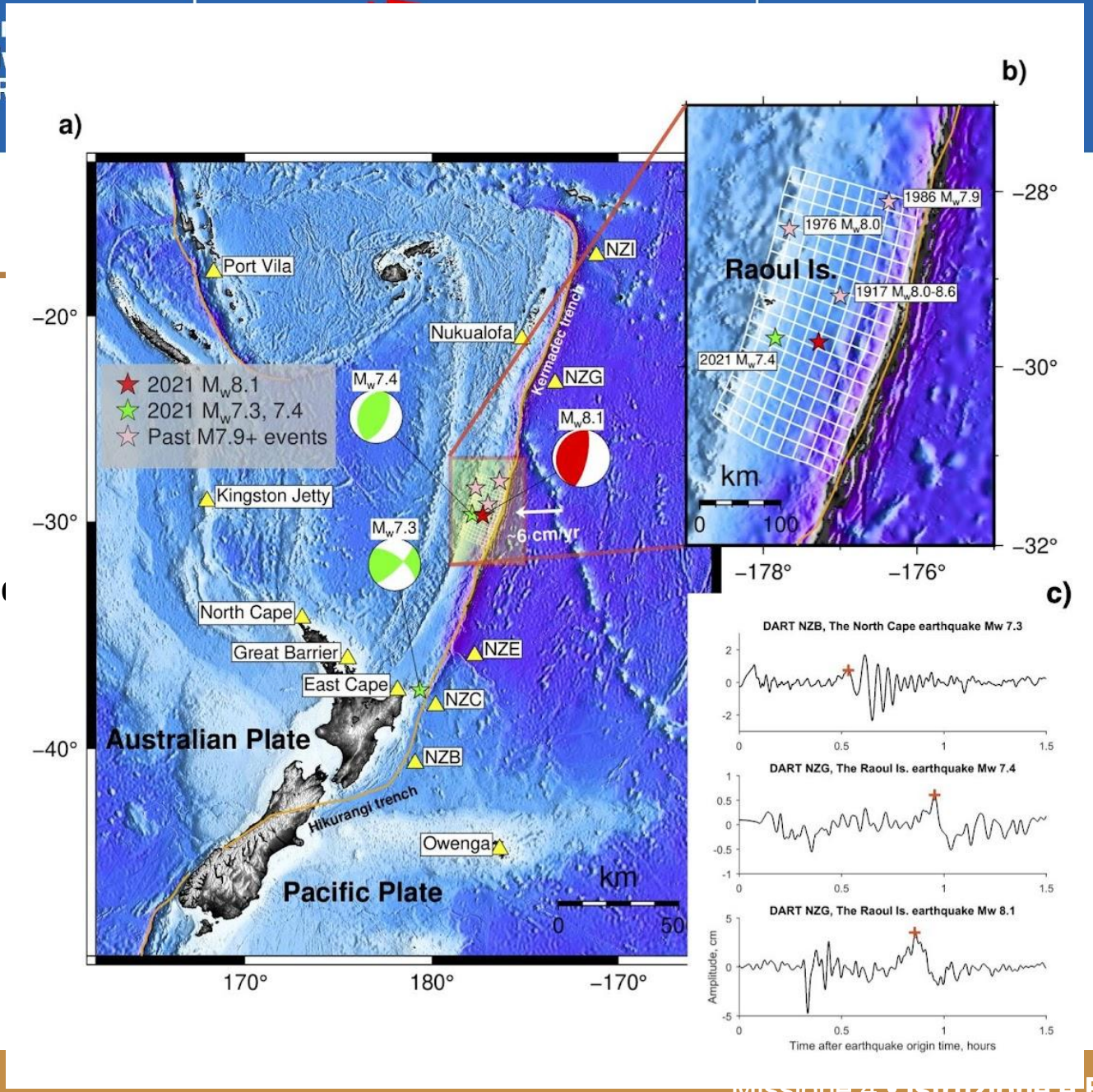


Filling the Gaps: WP8 TUO - TsUnami Observation

DARTs in New Zealand

Tsunami detection time improvement and uncertainty reduction

Romano et al., GRL, 2021



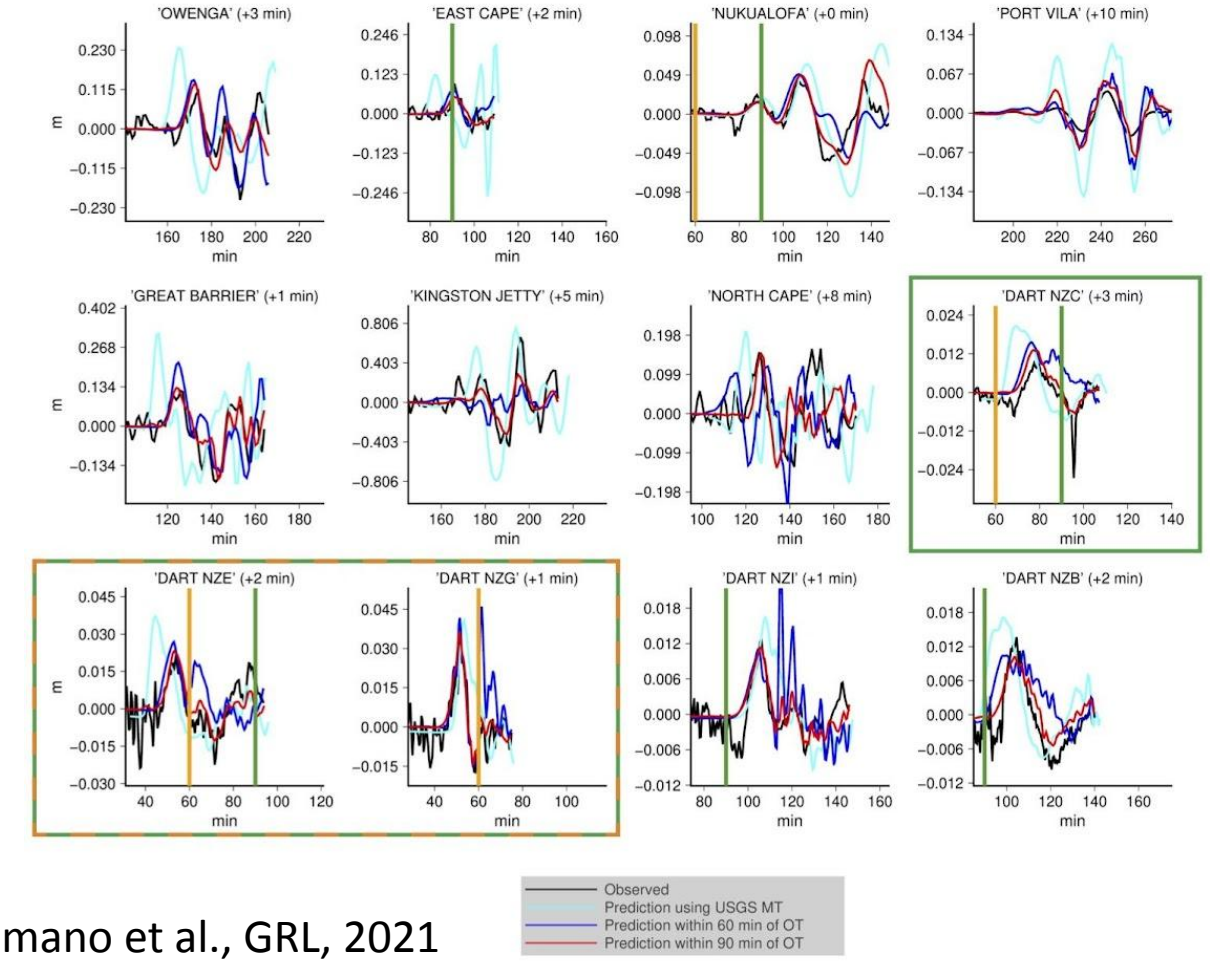
Filling the Gaps: WP8 TUO – TsUnami Observation

First max amplitude at Tide-gauge ~90 min after the OT

Inversion w/ DARTs whose max amp occur well before 90 min (NZE, NZG)

2 DARTs provide a satisfactory prediction for TW purposes

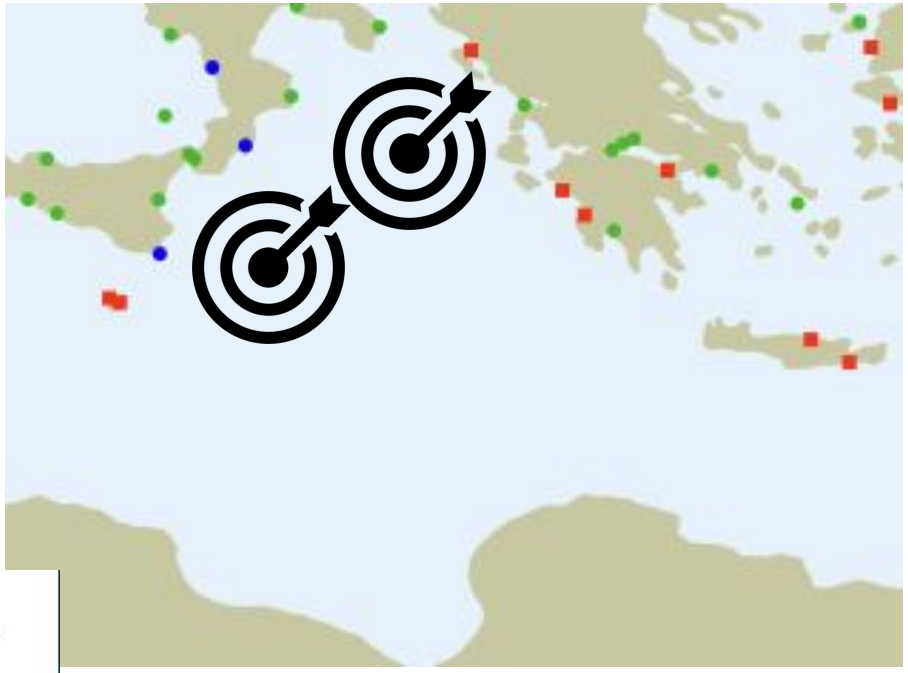
Prediction w/ Moment Tensor solution (the fastest available) overestimates the amplitudes



Romano et al., GRL, 2021

Filling the Gaps: WP8 TUO – TsUnami Observation

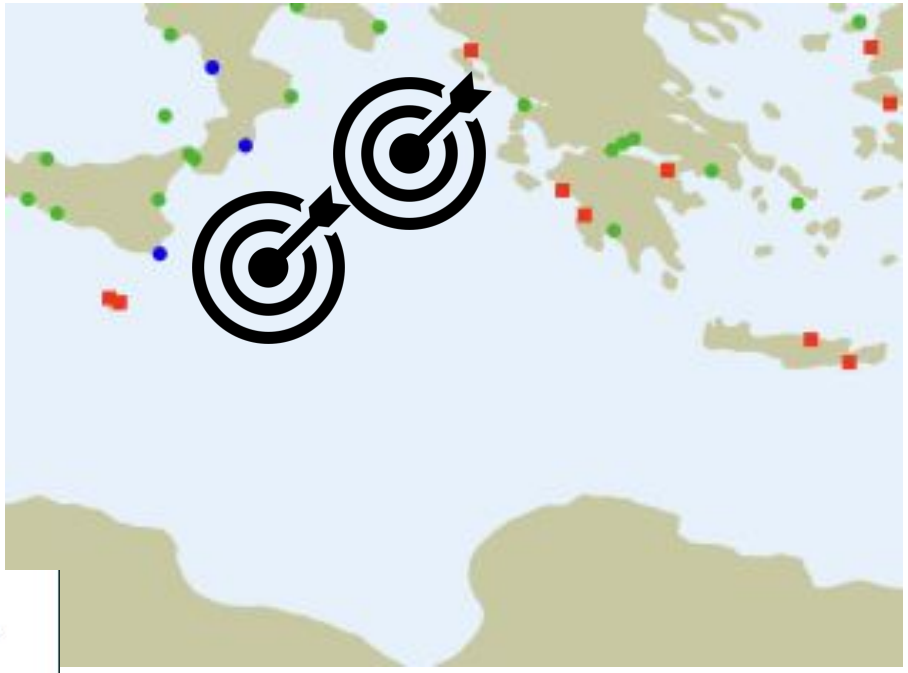
2 DARTs in the Ionian Sea – exact positions to be determined



Title	Bimester	Deliverables
IO8.1	8	D8.1 - D8.2 Assignment of the contract for the acquisition of 2 to 4 DARTs (bottom pressure gauges, acoustic communication link, sea surface buoy, anchor, mooring and satellite communication module to the control room), of the servers for data acquisition and analysis, and all the related services, incl. shipment, later refurbishment, vendor's specialist in-person assistance during the installation, software, training, etc.
IO8.2	12	D8.3 Installation of DARTs in two sites in the Ionian Sea; this includes the ship charter for the deployment cruise. Installation of servers and software for data acquisition and analysis
IO8.3	15	D8.4 Training for using the software for data acquisition, analysis and stations remote operations. Final report on data production, analysis and distribution

Filling the Gaps: WP8 TUO – TsUnami Observation

2 DARTs in the Ionian Sea – exact positions to be determined



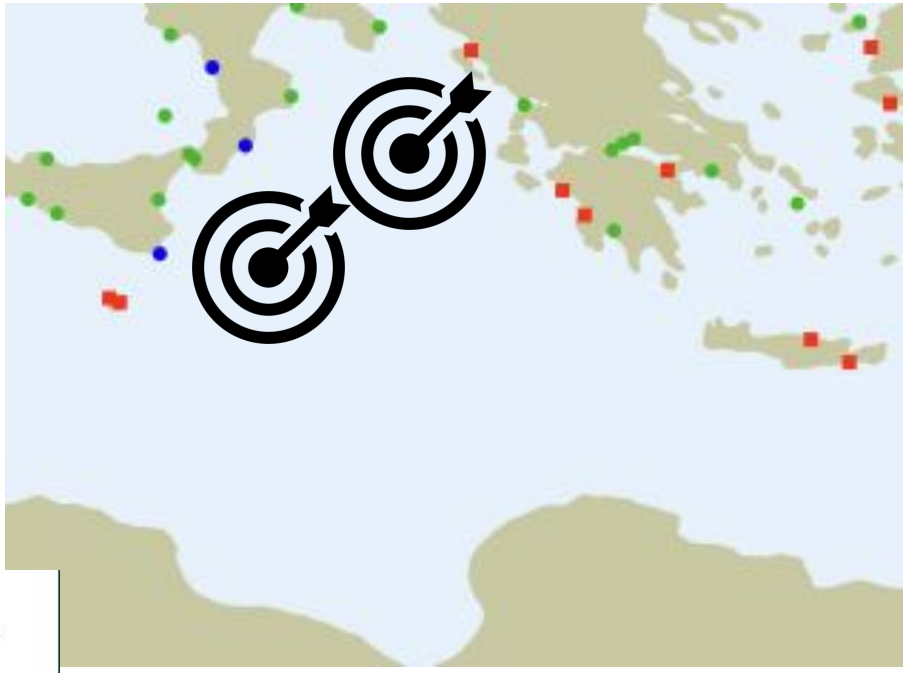
Legend:
- Station is offline, or data is outdated
- Station is online
- Station is not available at this site

43 Most relevant outcome:

●DART Infrastructure: 2 to 4 deep sea pressure systems of the DART type (https://nctr.pmel.noaa.gov/Dart/).
Depending on the market fluctuations, this will allow installing 1 or 2 of them in the Ionian Sea, which will be sending sea-level signals in real-time with a sampling rate that can be increased based on distant and autonomous triggers in case of seismic event or sea level anomaly; the 1 or 2 spare systems will replace the original ones after 24 months, and the original ones will be refurbished, ready to be deployed in the next cycle. The new instruments will allow, depending on the source-site path, the early detection and direct measurement of tsunamis in the Ionian Sea to forecast their impact before they reach the coastal sites; presently, tsunami forecasting is achieved only indirectly, that is using seismic observations; being capable of measuring millimetric anomalies in the deep sea, these sensors will be useful for the monitoring of other phenomena than earthquake-generated tsunamis (e.g. meteo-tsunamis, landslide effects), and for the calibration and benchmarking of other experimental and potentially lower-cost instruments which could be envisaged to replace DARTs in the future (e.g. prototypal instruments being developed by INGV, such as SMART cables and deep-sea observatories deployed by EMSO; seafloor fibre optics cables). The data from the DART stations will need standardisation and transformation to respect the FAIR principles. They will be provided to the CAT-INGV tsunami warning system and also conveyed into the cTCS Tsunami delivery framework, for the sake of preservation and long-term sustainability of the data provision.

Filling the Gaps: WP8 TUO – TsUnami Observation

2 DARTs in the Ionian Sea – exact positions to be determined



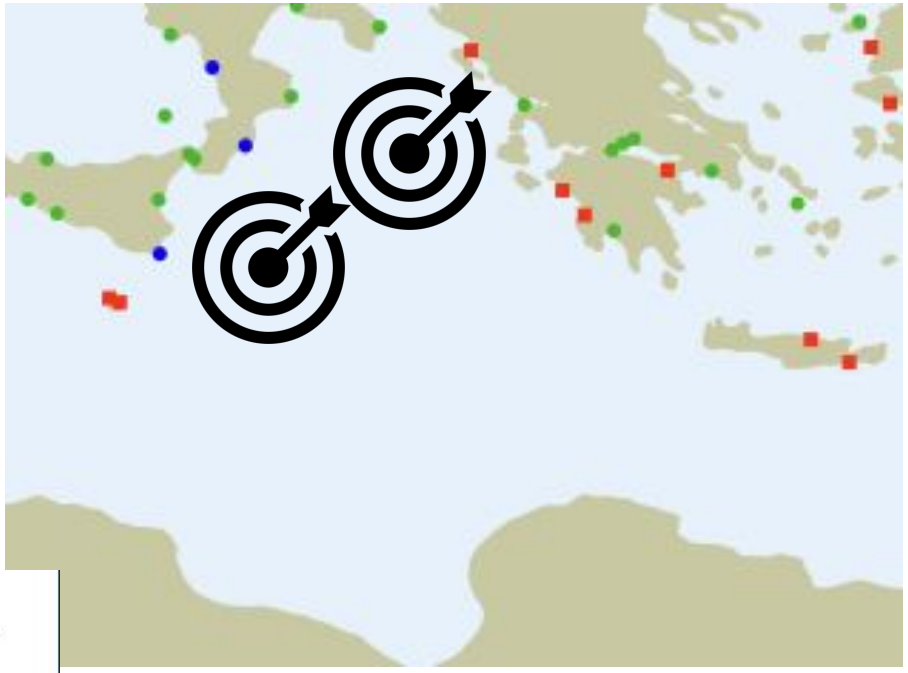
WP8, Tsunami Observations, aims to improve the understanding, modelling, and forecasting of tsunamis in the Central Mediterranean. WP8 contributes primarily to the Specific Objective 2 - Implementing Services for Science and Society. Nonetheless, WP8 will also contribute to Specific Objectives 1 and 3, since it will strengthen tsunami-related data provision and distribute them via the EPOS candidate Thematic Core Service (cTCS) Tsunami delivery framework.

42 WP inter-relation with other WWPP

WP10, WP11

Filling the Gaps: WP8 TUO – TsUnami Observation

2 DARTs in the Ionian Sea – exact positions to be determined



GRAZIE PER L'ATTENZIONE!