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Istituto Superiore per la Protezione e la Ricerca Ambientale

Sistema Nazionale per la Protezione dell'Ambiente

New Frontiers of Marine Science and Technology
A Japan-Italy Perspective
Italian Research Day 2019 in Tokyo

Overview of the Italian Tsunami Alert System

and

innovative low-cost solutions for fast mitigation measures

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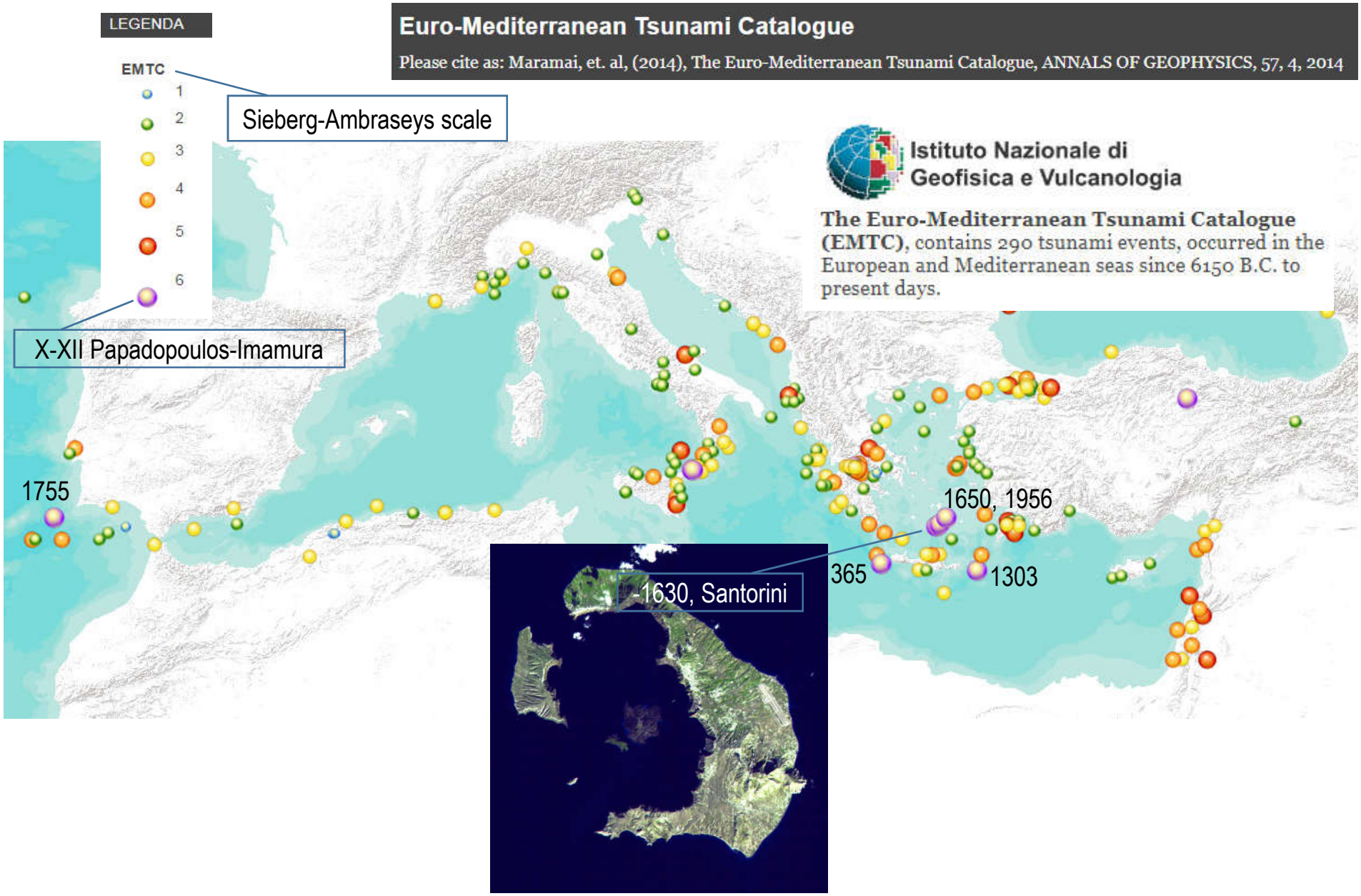
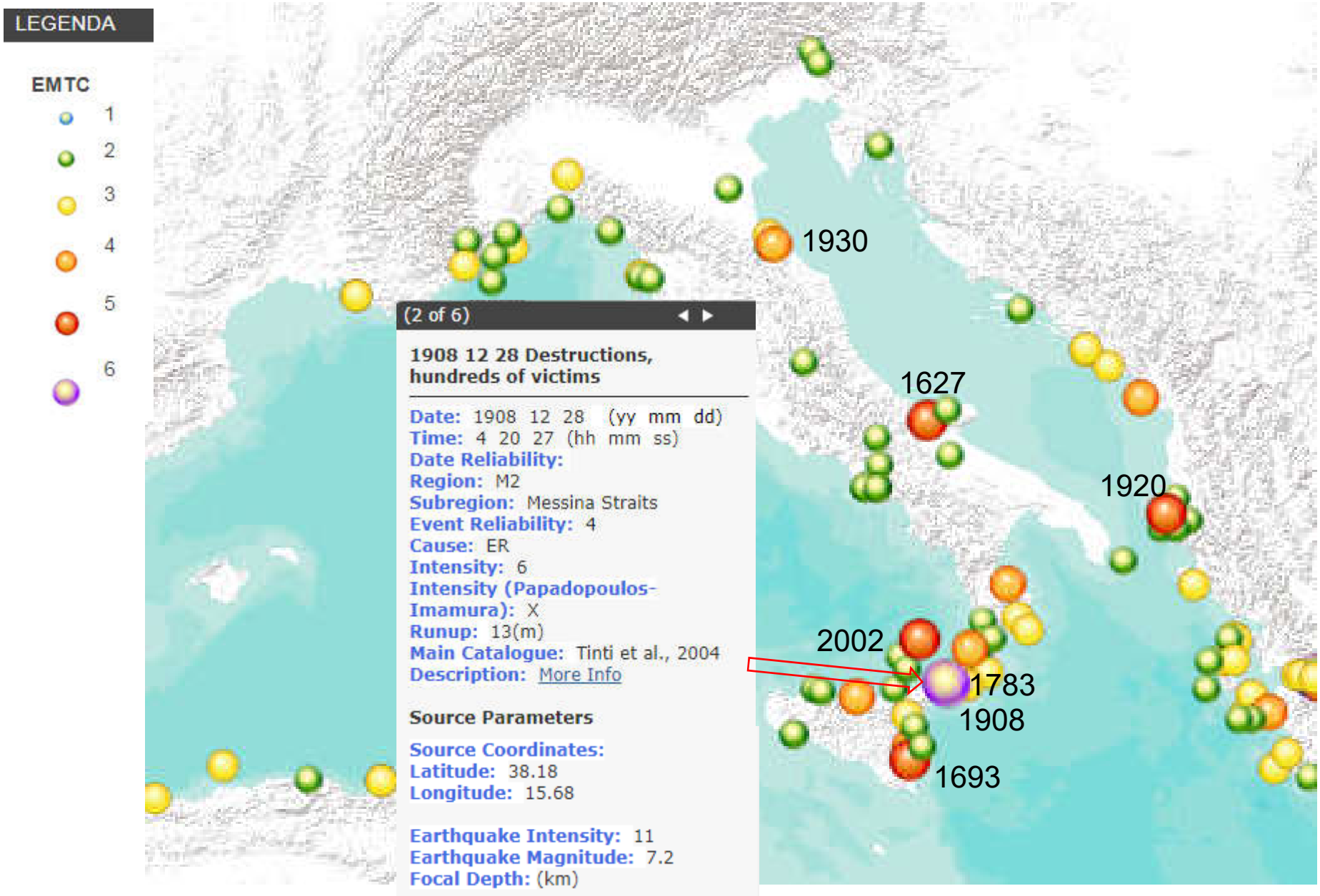
giornata della RICERCA ITALIANA

Tsunami catalogue



Tsunami catalogue



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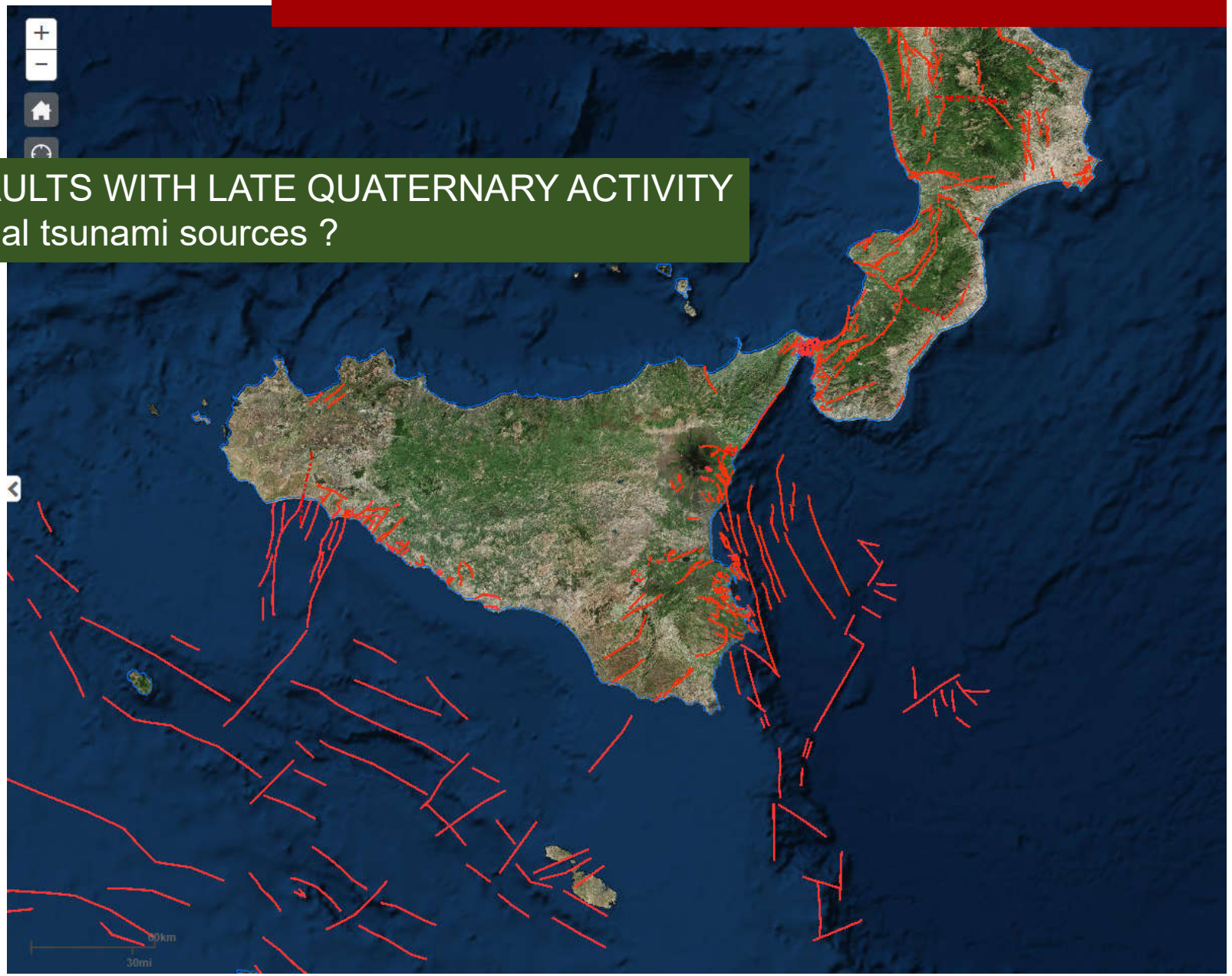
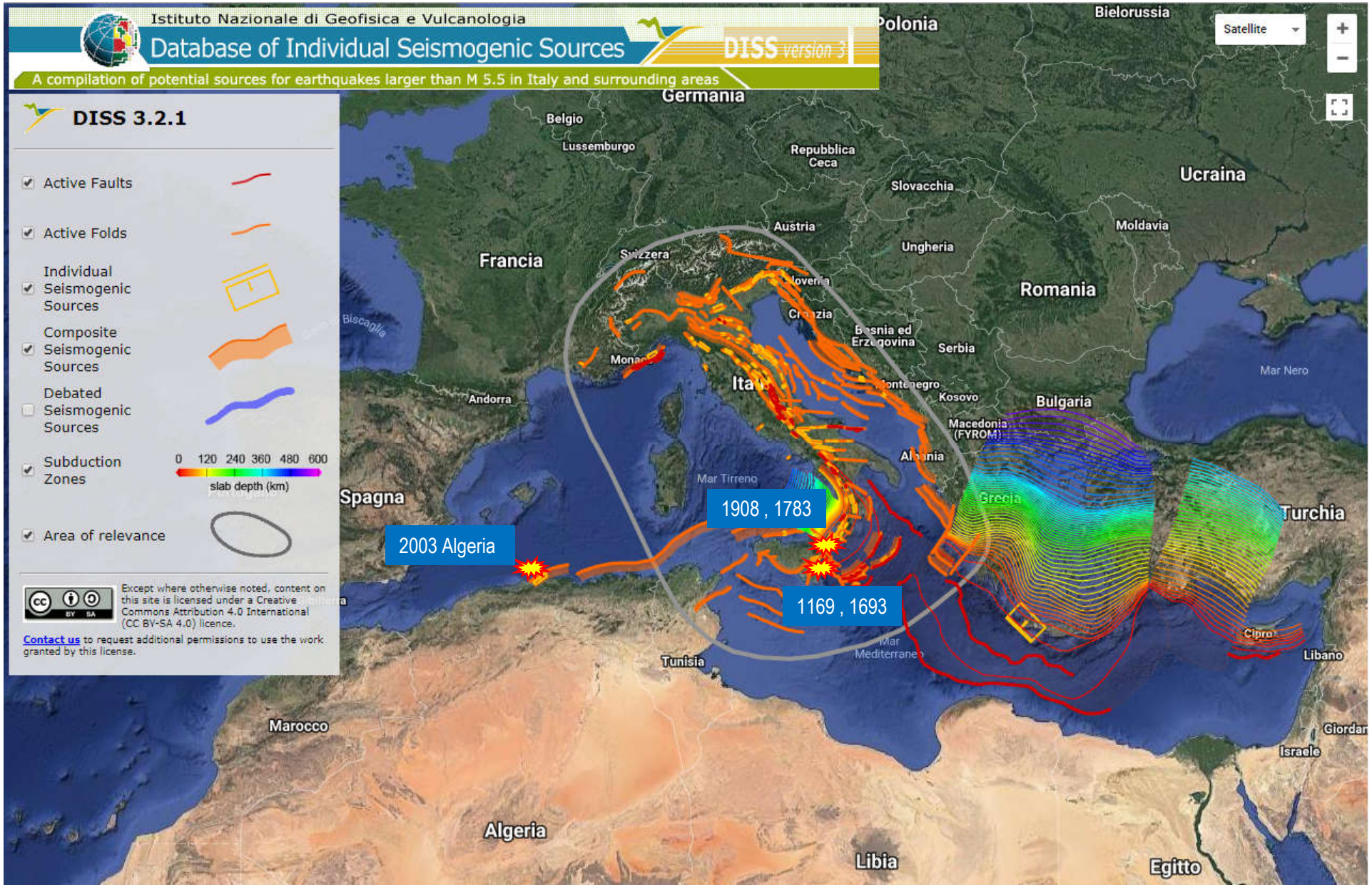
ITHACA - CATALOGO DELLE FAGLIE CAPACI

ISPRA - Dipartimento Difesa del Suolo

MANY FAULTS WITH LATE QUATERNARY ACTIVITY
→ Potential tsunami sources ?



Seismic sources in the Mediterranean Sea



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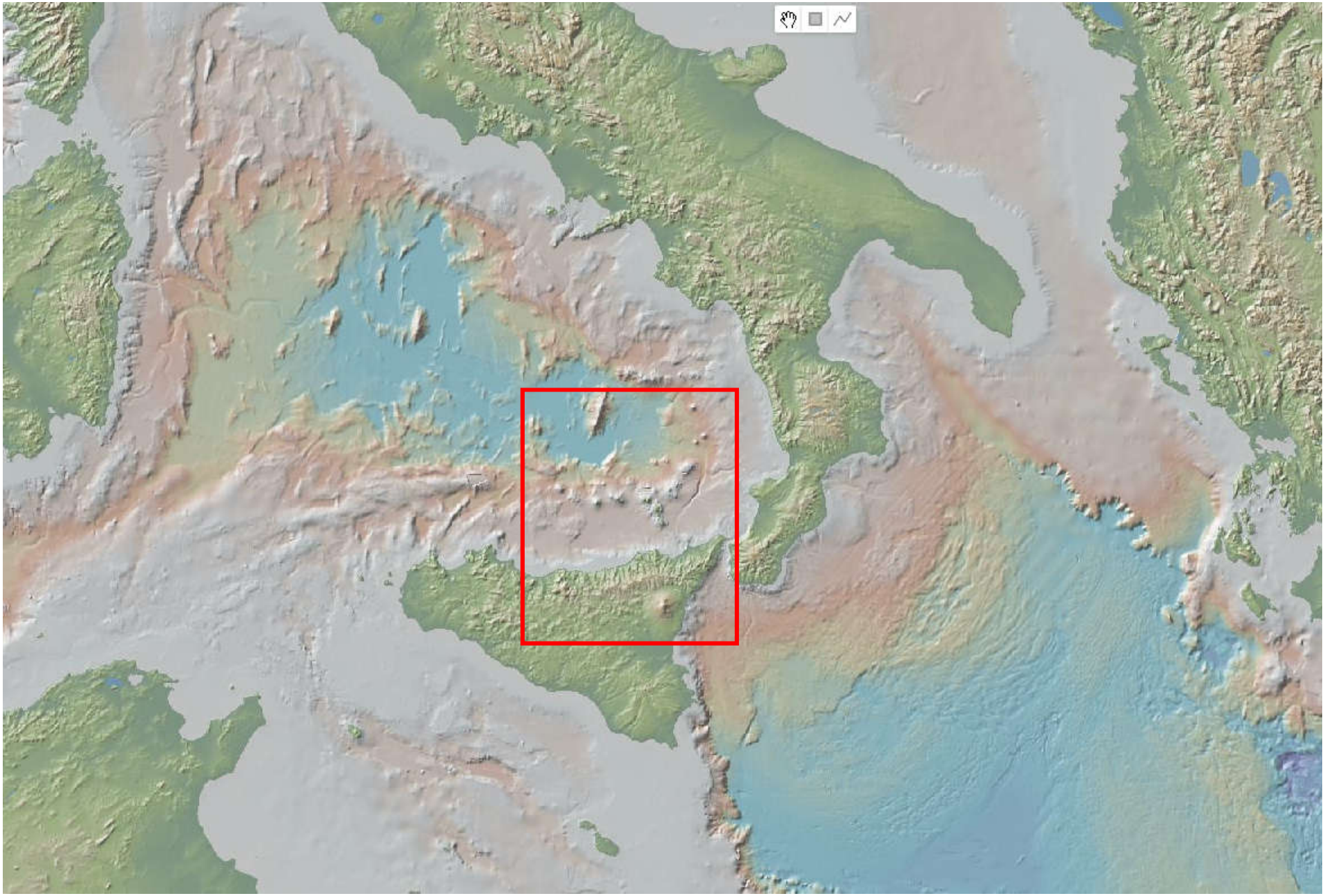
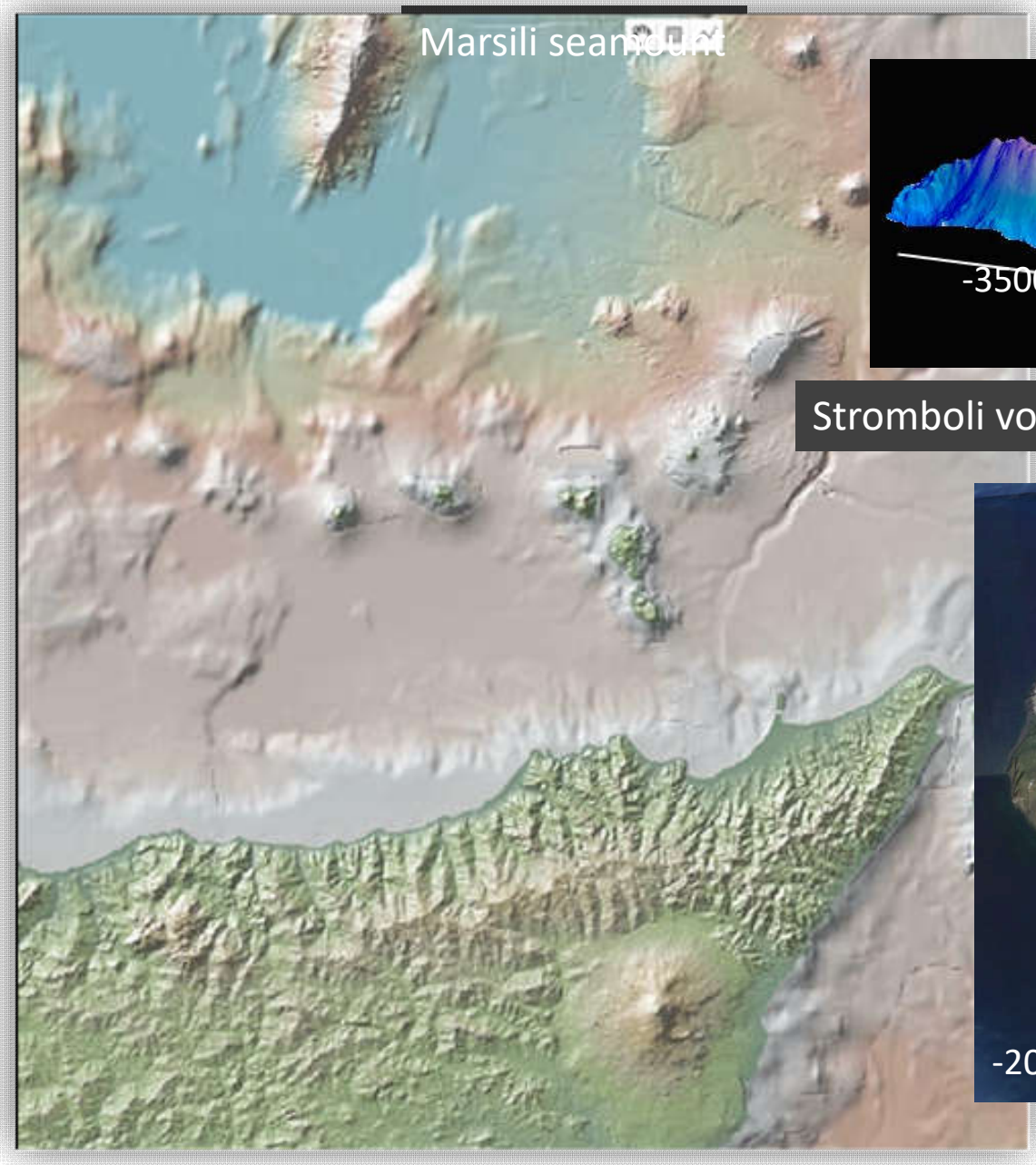
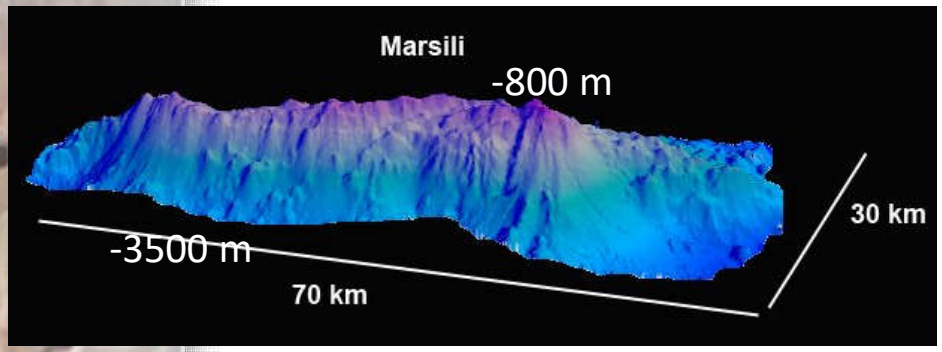
Volcanic and submarine slide sources in the Mediterranean Sea

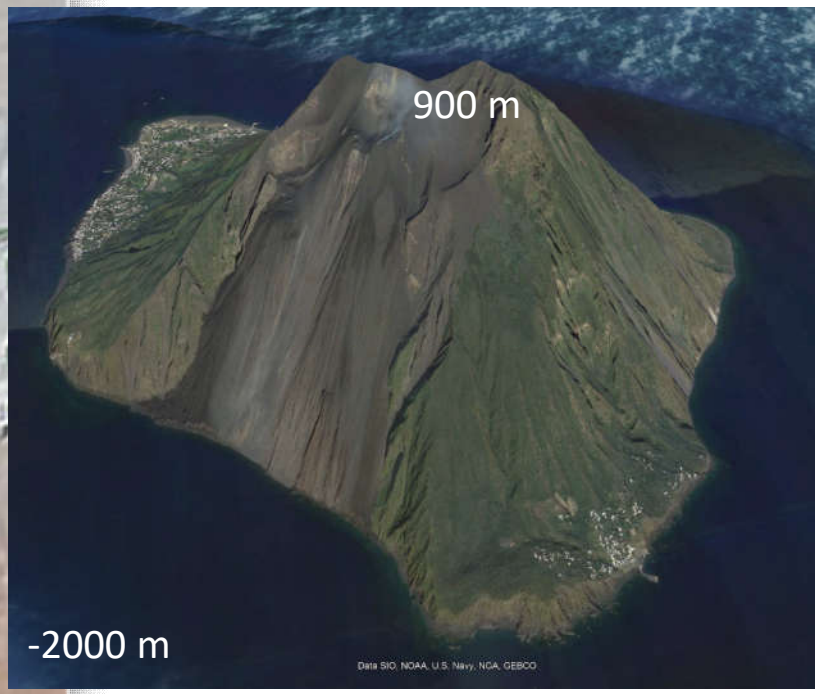


Volcanic and submarine slide sources in the Mediterranean Sea





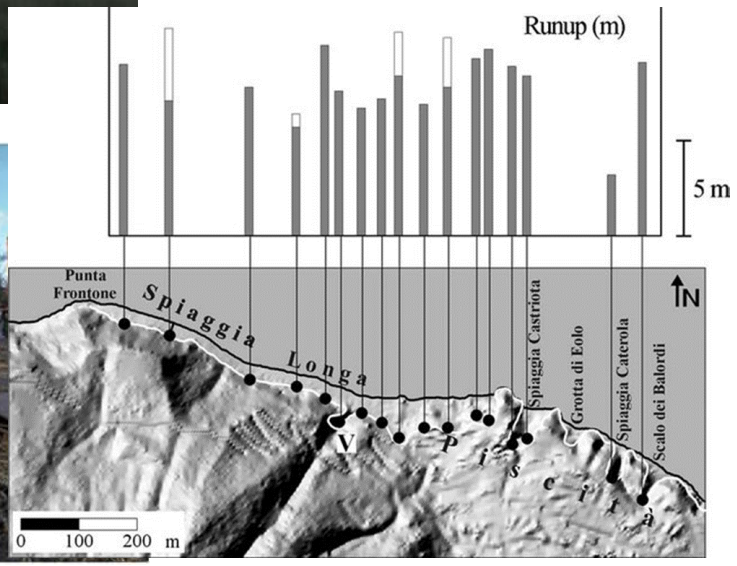
Stromboli volcano



Volcanic and submarine slide source

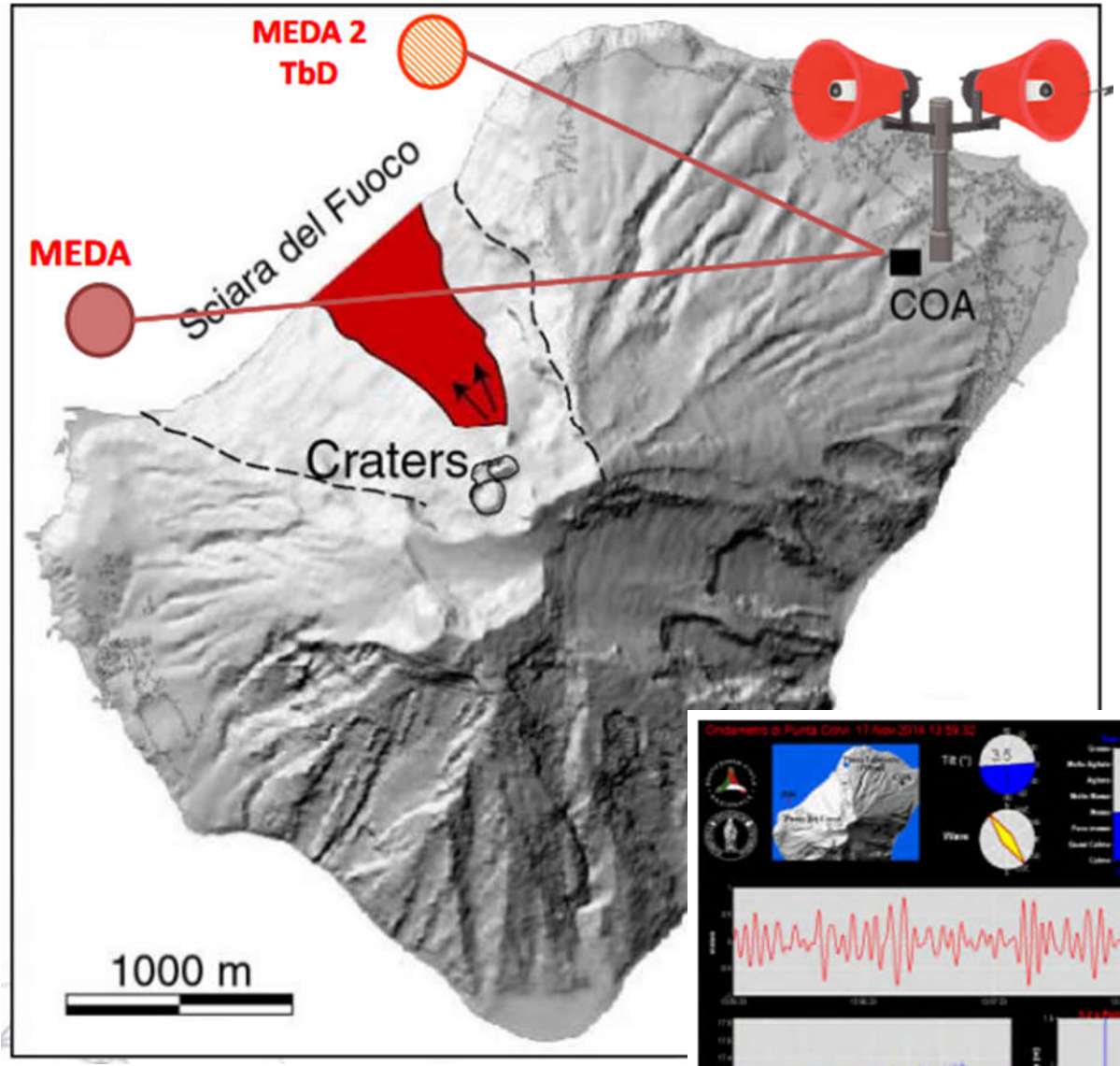
Stromboli volcano

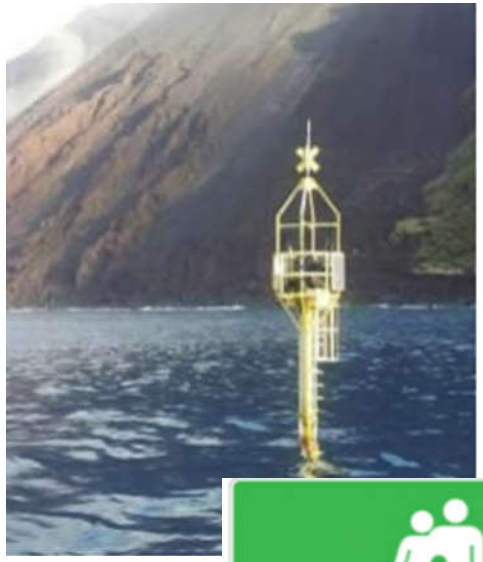
Runup > 10 m



Volcanic and submarine slide source

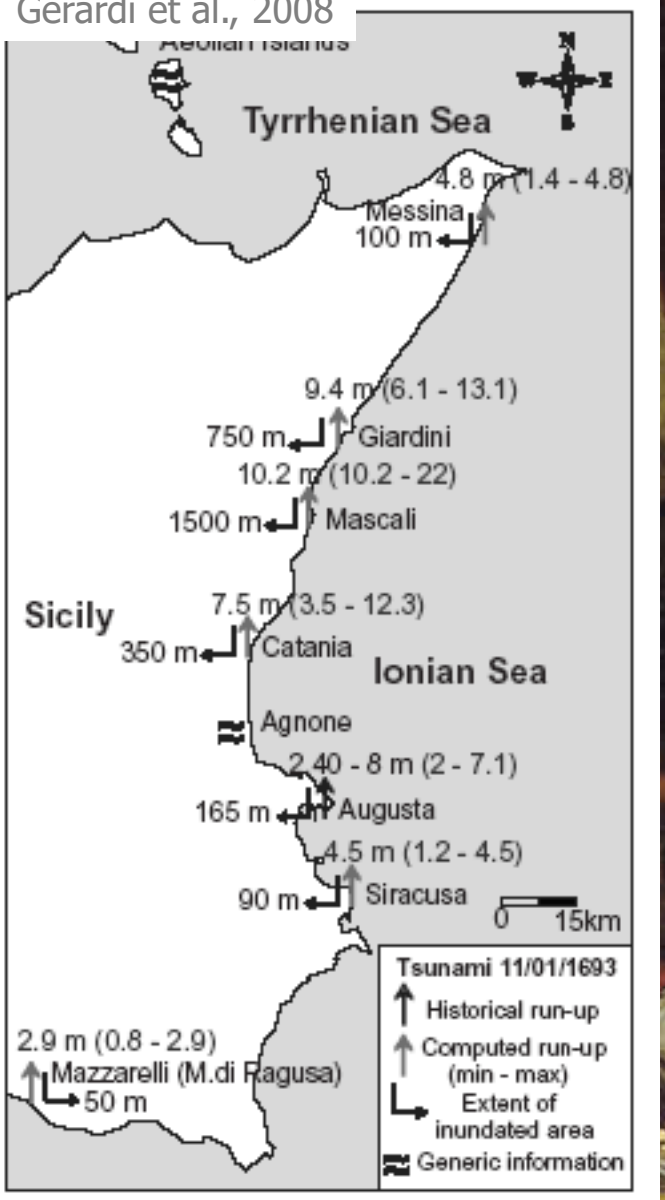
Stromboli volcano



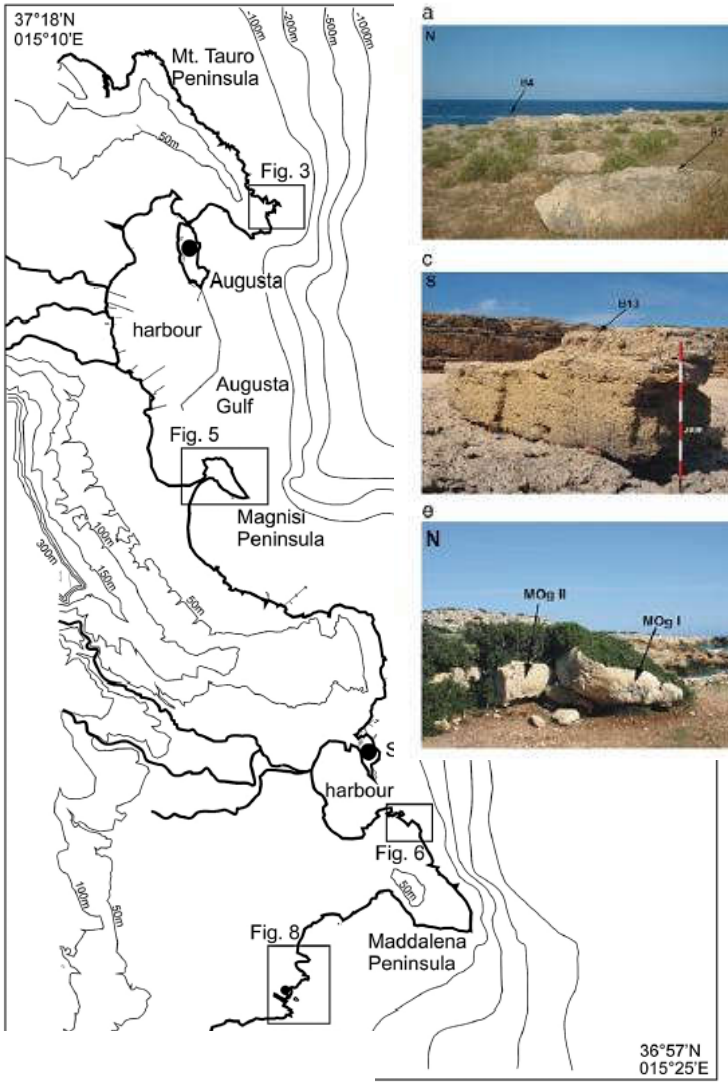


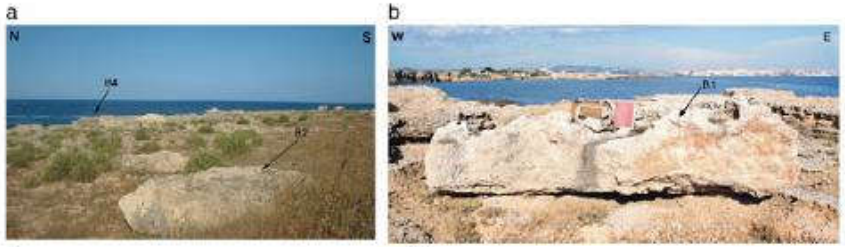
1693 event

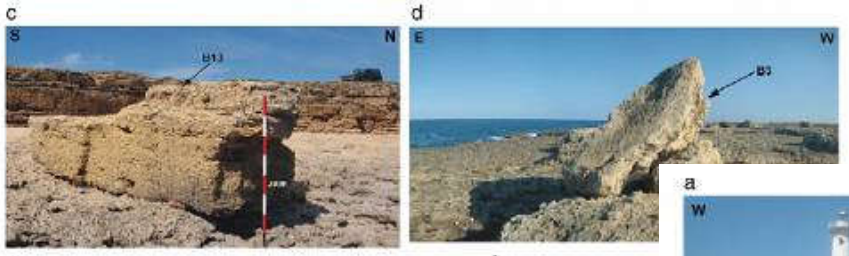
Gerardi et al., 2008



Tsunami evidence in Eastern Sicily





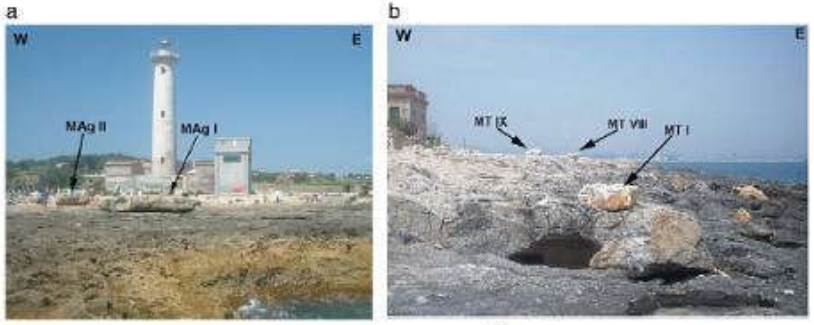


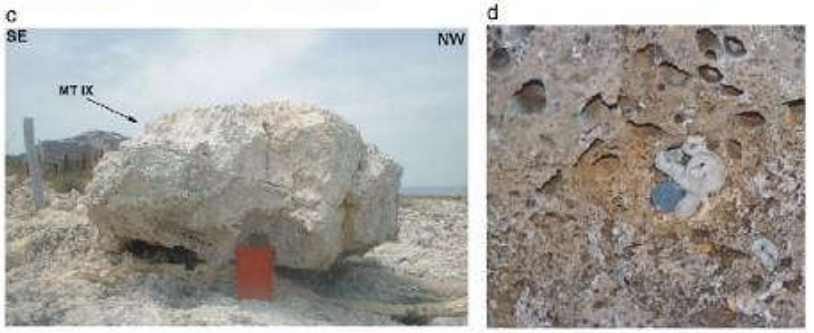
Events: 1693, 1169

Estimated run-up (Nott formula)

5,10 - 9.37 – 10,63 m

Observed run-up 12 m at Augusta (Boccone 1697)





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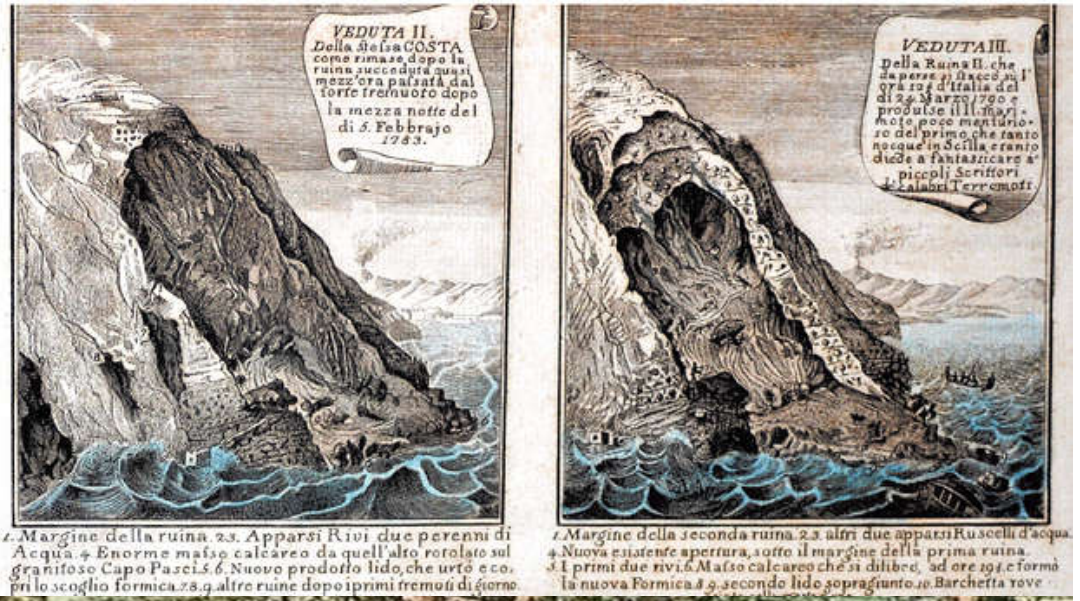
1783 event

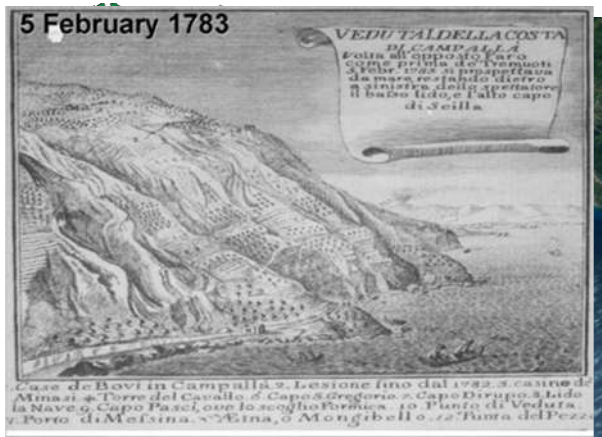
Mw 7.2 max

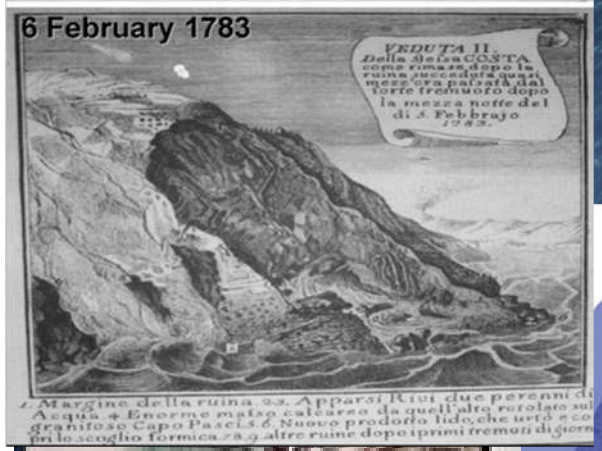
Runup 6-8 meters



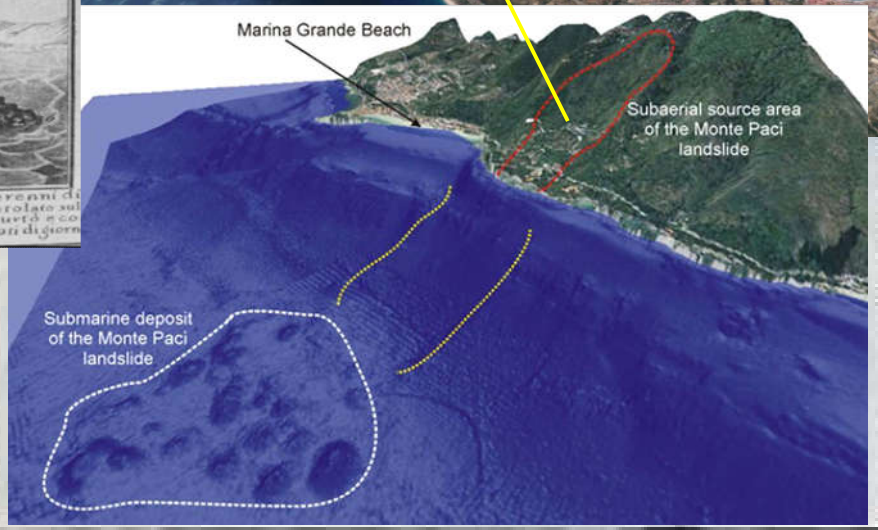
1. Margine della ruina 2.3. Apparsi Rivi due perenni di Acqua 4 Enorme masso calcareo da quell'alto rotolato sul granitoso Capo Pasci 5.6. Nuovo prodotto lido, che urtò e coprì lo scoglio formica 7.8.9 altre ruine dopo i primi tremoti di giorno

1. Margine della seconda ruina 2.3 altri due apparsi Ruscelli d'acqua 4. Nuova esistente apertura, sotto il margine della prima ruina. 5. I primi due rivi 6. Masso calcareo che si dilibrò, ad ore 19 e formò la nuova Formica 8 9. secondo lido sopraggiunto 10. Barchetta rove


5 February 1783
VEDUTA DELLA COSTA


6 February 1783
VEDUTA II.


1783 event


Marina Grande Beach
Subaerial source area of the Monte Paci landslide
Submarine deposit of the Monte Paci landslide

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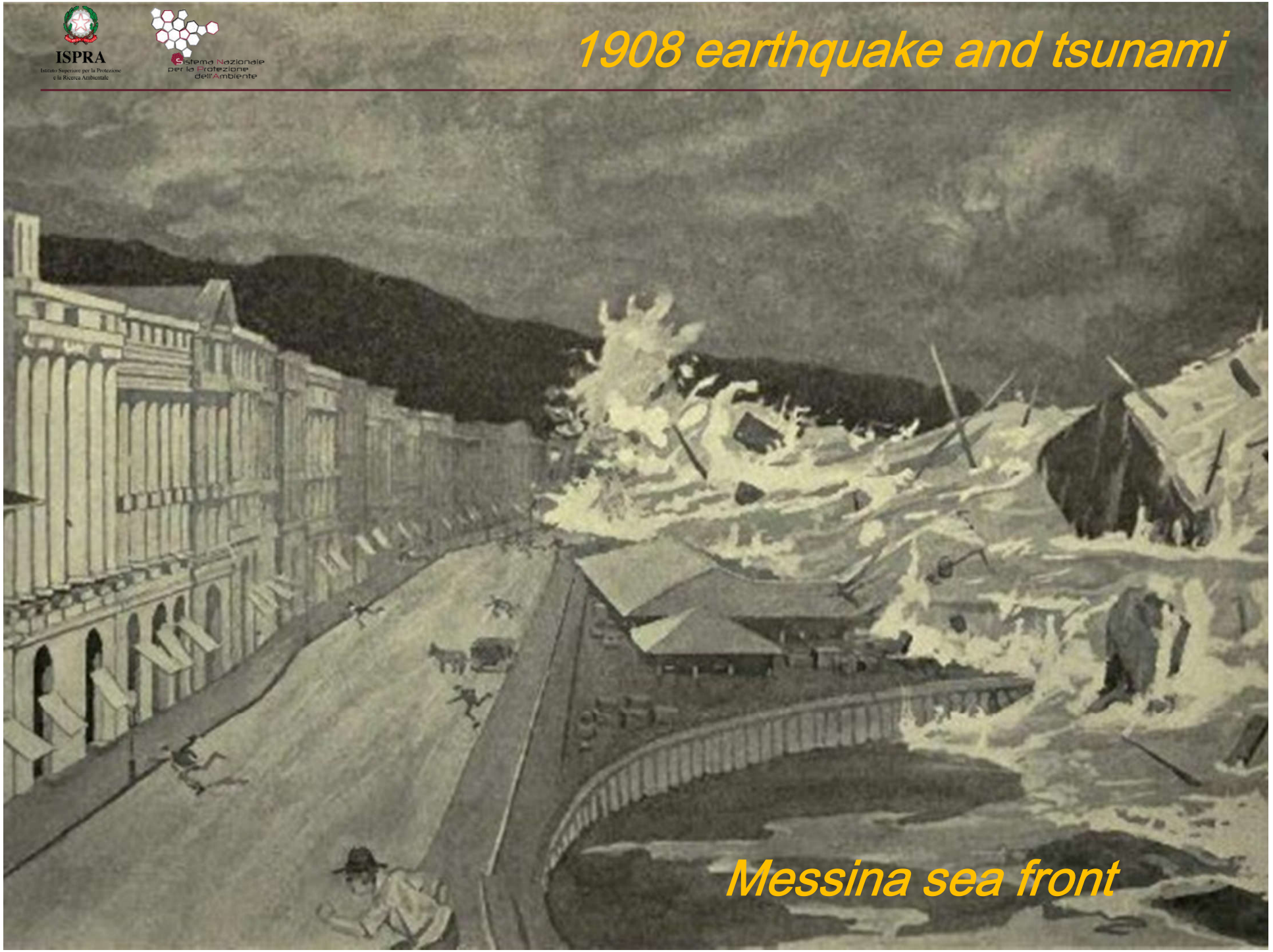
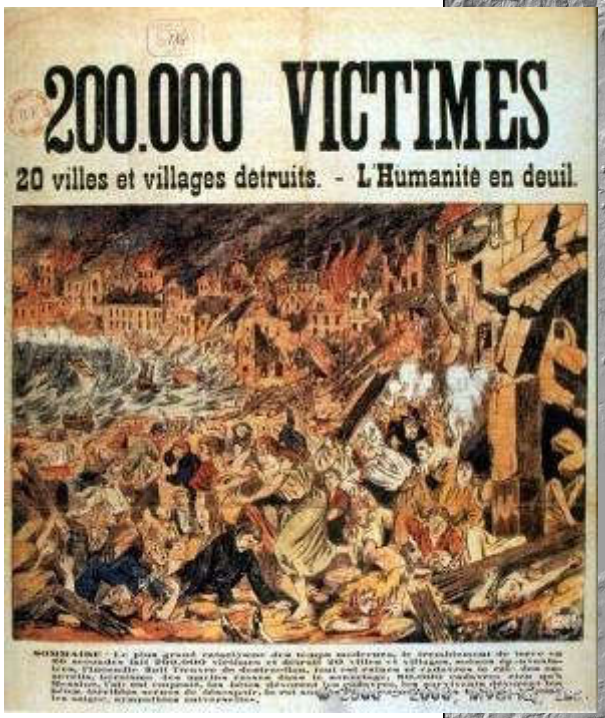
1908 earthquake and tsunami

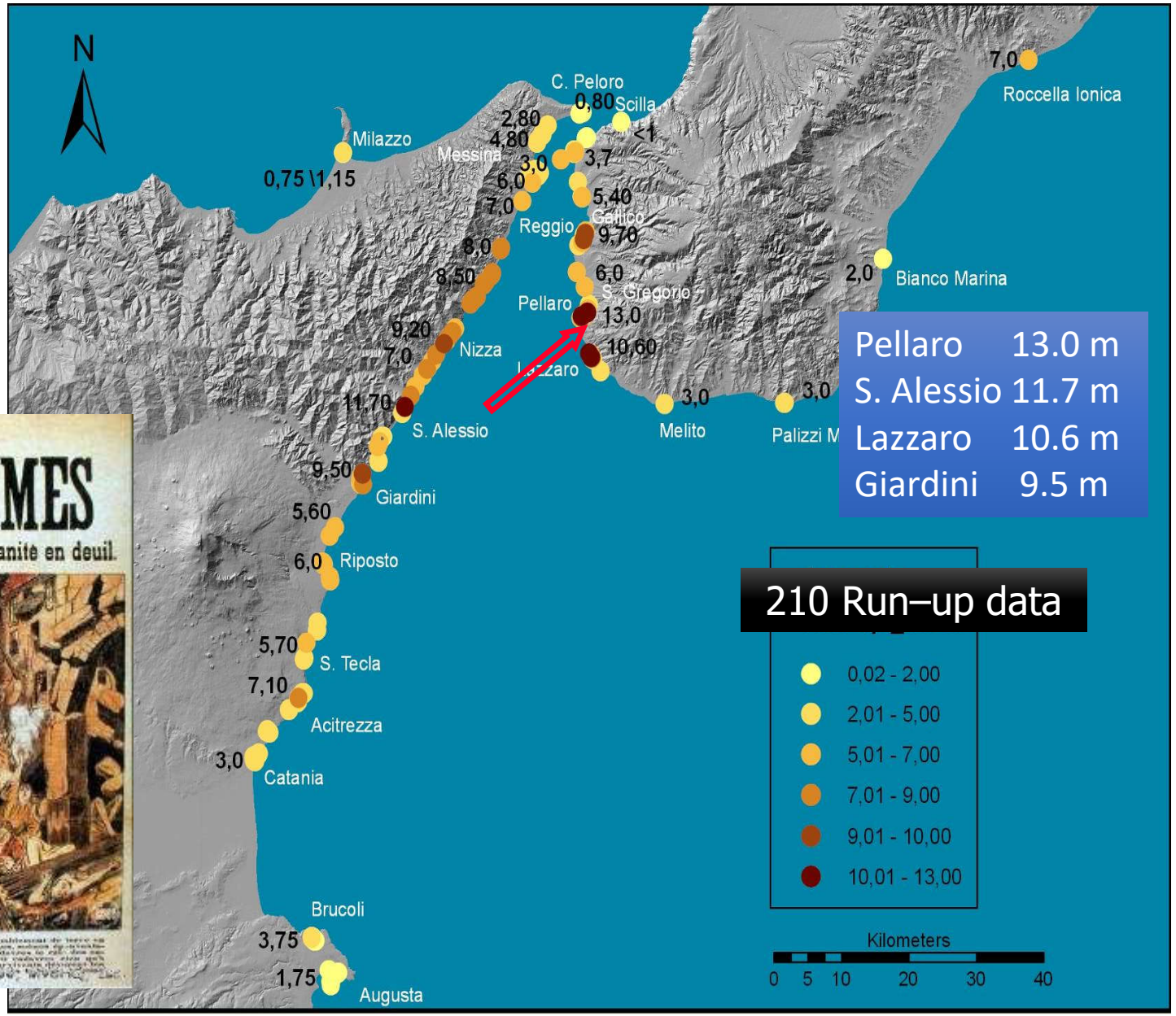


Messina sea front

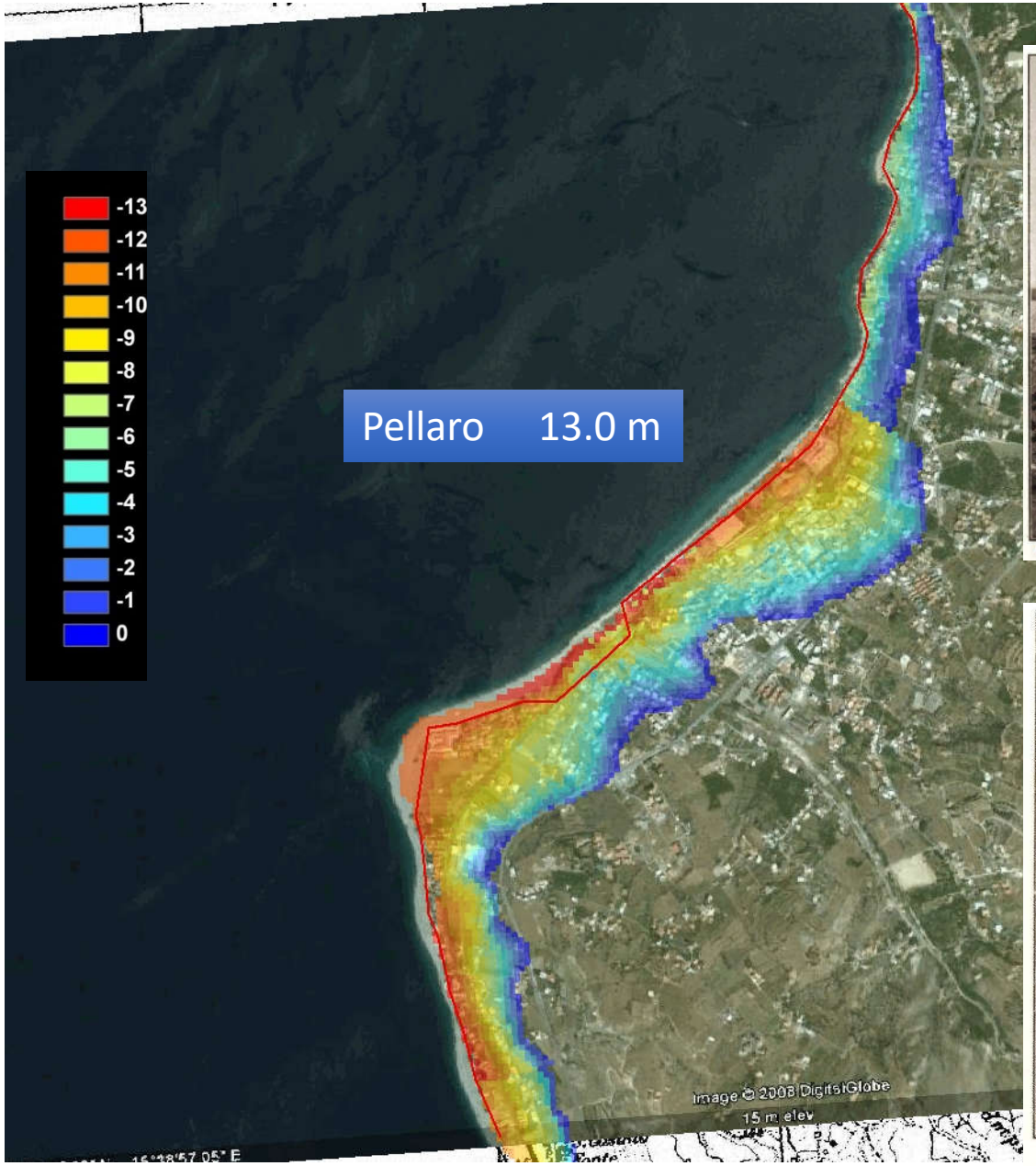
1908 event

Debated source: earthquake fault or submarine landslides?

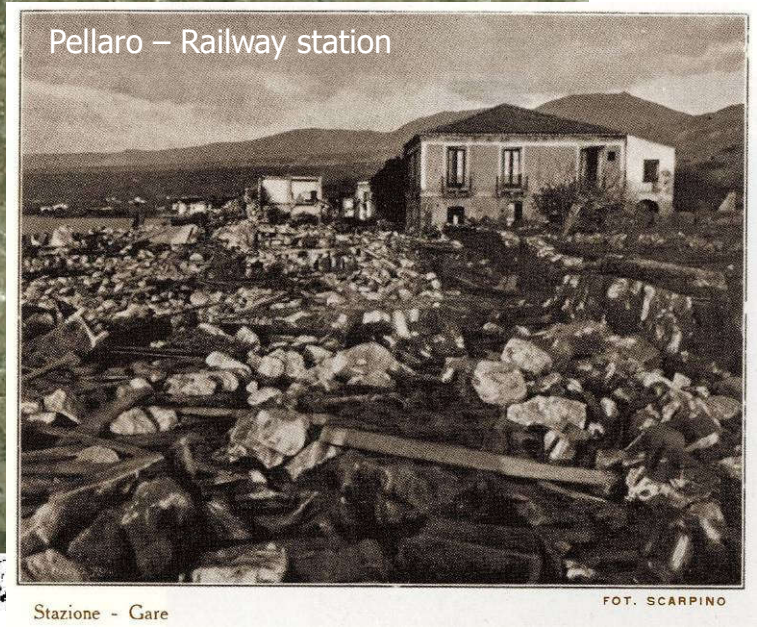




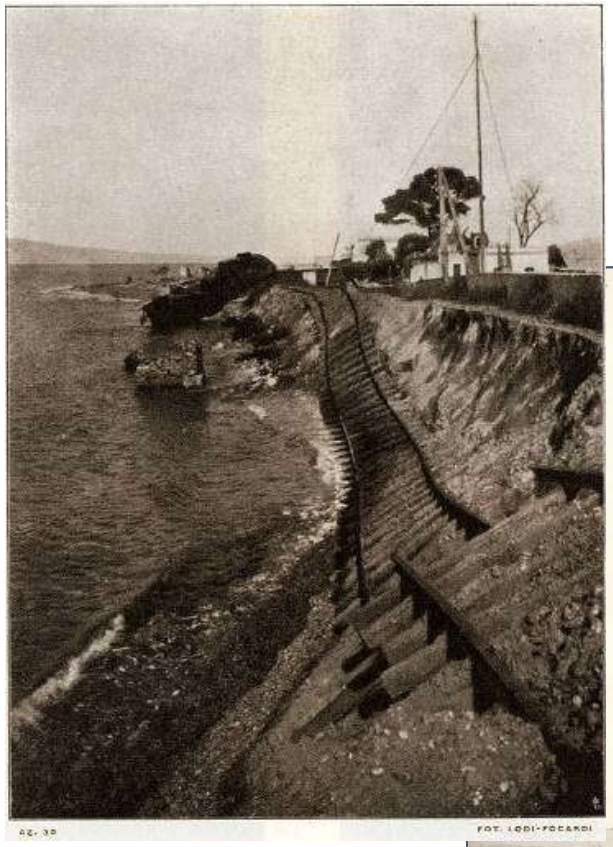
1908 event


-13
-12
-11
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
Pellaro 13.0 m
Image © 2008 DigitalGlobe
15 m elev


Pellaro – destroyed village
AZ. 6
FOT. LODI-FOCARDI


Pellaro – Railway station
Stazione - Gare
FOT. SCARPINO

1908 event



A. — MESSINA - Rovine della banchina

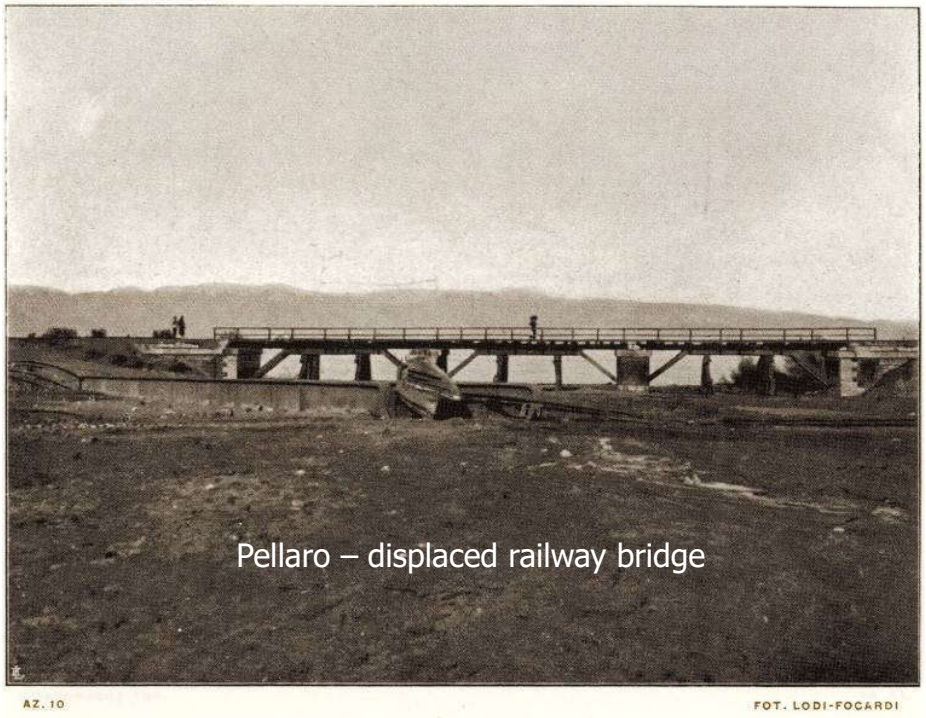
B. — MESSINA - Rovine della banchina (altro particolare)

1908 event


Pellaro – destroyed village
AZ. 6
FOT. LODI-FOCARDI


Messina dopo il terremoto del 28 Dicembre 1908
Via del Torrente Portalegni – Rovine


Eroded rail track
FOT. LODI-FOCARDI


Pellaro – displaced railway bridge
AZ. 10
FOT. LODI-FOCARDI

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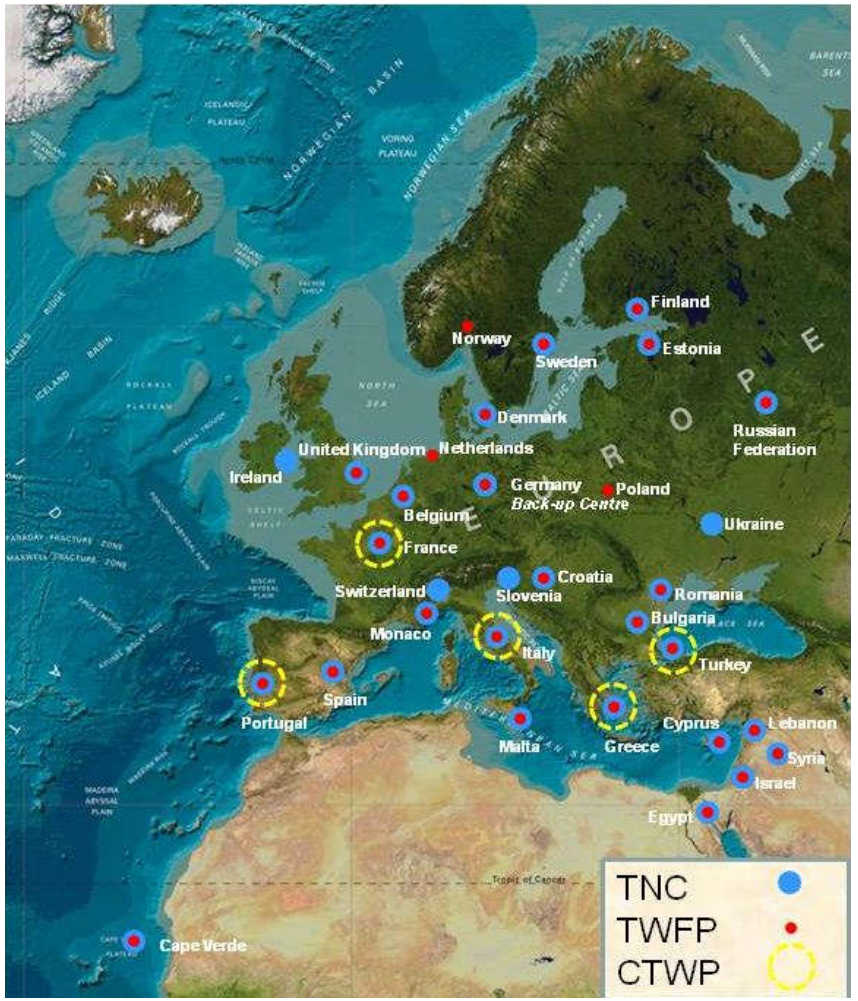
NEAMTWS

Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the Northeast Atlantic area, Mediterranean and connected seas (ICG / NEAMTWS)

Promotes

- Collaboration among partners
- Guidelines for interoperability
- Regional monitoring networks



SiAM - National Alert System for Earthquake-triggered tsunamis

The Act foresees that DPC provides local authorities /operational bodies **guidelines** for

- inclusion of tsunami hazard in emergency plans
- Definition of potential coastal inundation areas

SERIE GENERALE

Spediz. abb. post. - art. 1, comma 1
Legge 27-02-2004, n. 46 - Filiale di Roma

Anno 158° - Numero 128

GAZZETTA UFFICIALE

DELLA REPUBBLICA ITALIANA

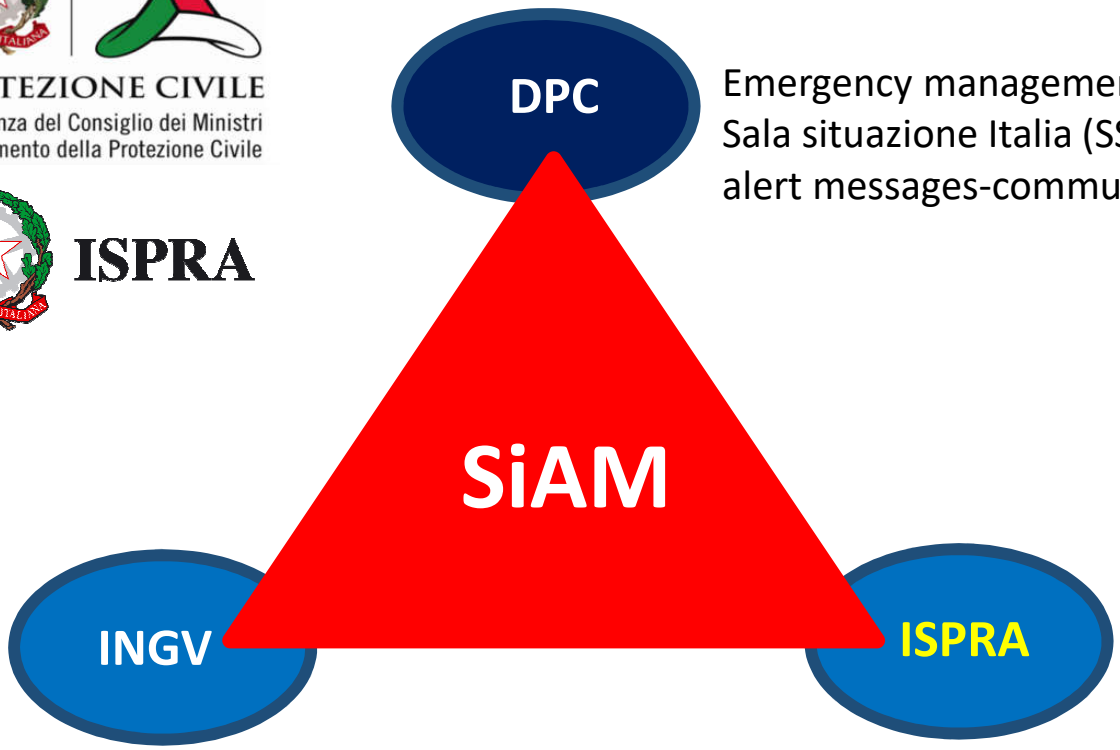
PARTE PRIMA — Roma - Lunedì, 5 giugno 2017 — SI PUBBLICA TUTTI I GIORNI NON FESTIVI

DIREZIONE E REDAZIONE PRESSO IL MINISTERO DELLA GIUSTIZIA - UFFICIO PUBBLICAZIONE LEGGI E DECRETI - VIA ARENULA, 70 - 00186 ROMA
AMMINISTRAZIONE PRESSO L'ISTITUTO POLIGRAFICO E ZECCA DELLO STATO - VIA SALARIA, 691 - 00138 ROMA - CENTRALINO 06-85081 - LIBRERIA DELLO STATO

DIRETTIVA DEL PRESIDENTE DEL CONSIGLIO DEI MINISTRI 17 febbraio 2017.

Istituzione del Sistema d'Allertamento nazionale per i Maremoti generati da sisma - SiAM.

SiAM structure



Emergency management through the Sala situazione Italia (SSI)
alert messages-communication

Tsunami Alert Center (CAT) – Earthquake and Tsunami monitoring in real time.
Probabilistic Hazard calculation

Real time data of the sea level monitoring network to CAT.
Inundation/evacuation maps

Alert levels

The SiAM Directive defines at the national level the same alert procedures of those internationally used for the NEAMTWS program.

2 alert levels
(ICG/NEAMTWS)
+Information

Orange level
(*Advisory)*

Red level
(*Watch*)

Delimitation of coastal alert / evacuation zones

Main requirements:

1. alert / evacuation zones → reliable envelope of all areas potentially subject to flooding due to tsunamigenic seismic sources
2. Maps → available quickly and for the entire national territory, so that the alert system can be fully operational and effective.
3. Methodology → verified and homogeneous, easily replicable

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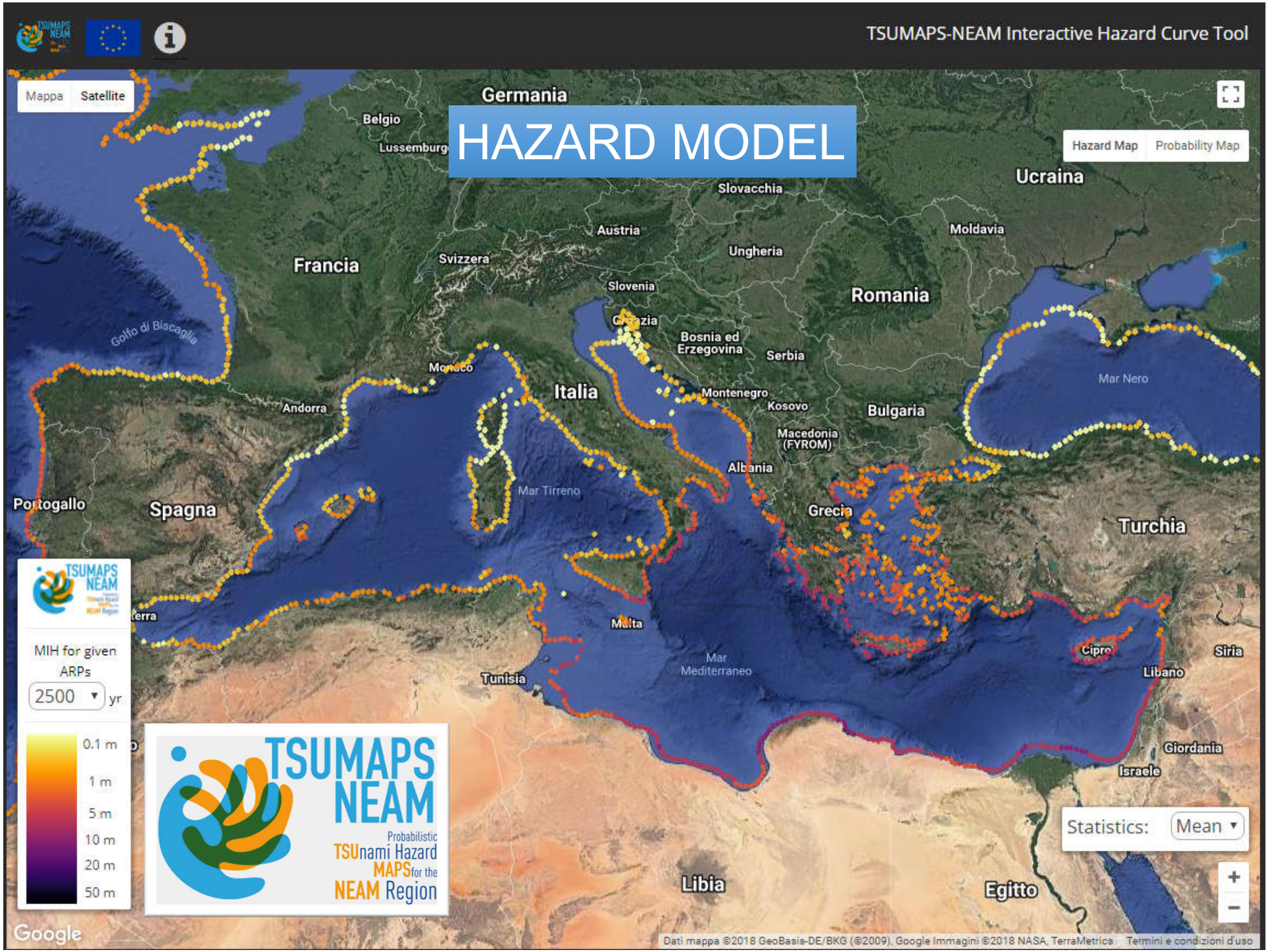
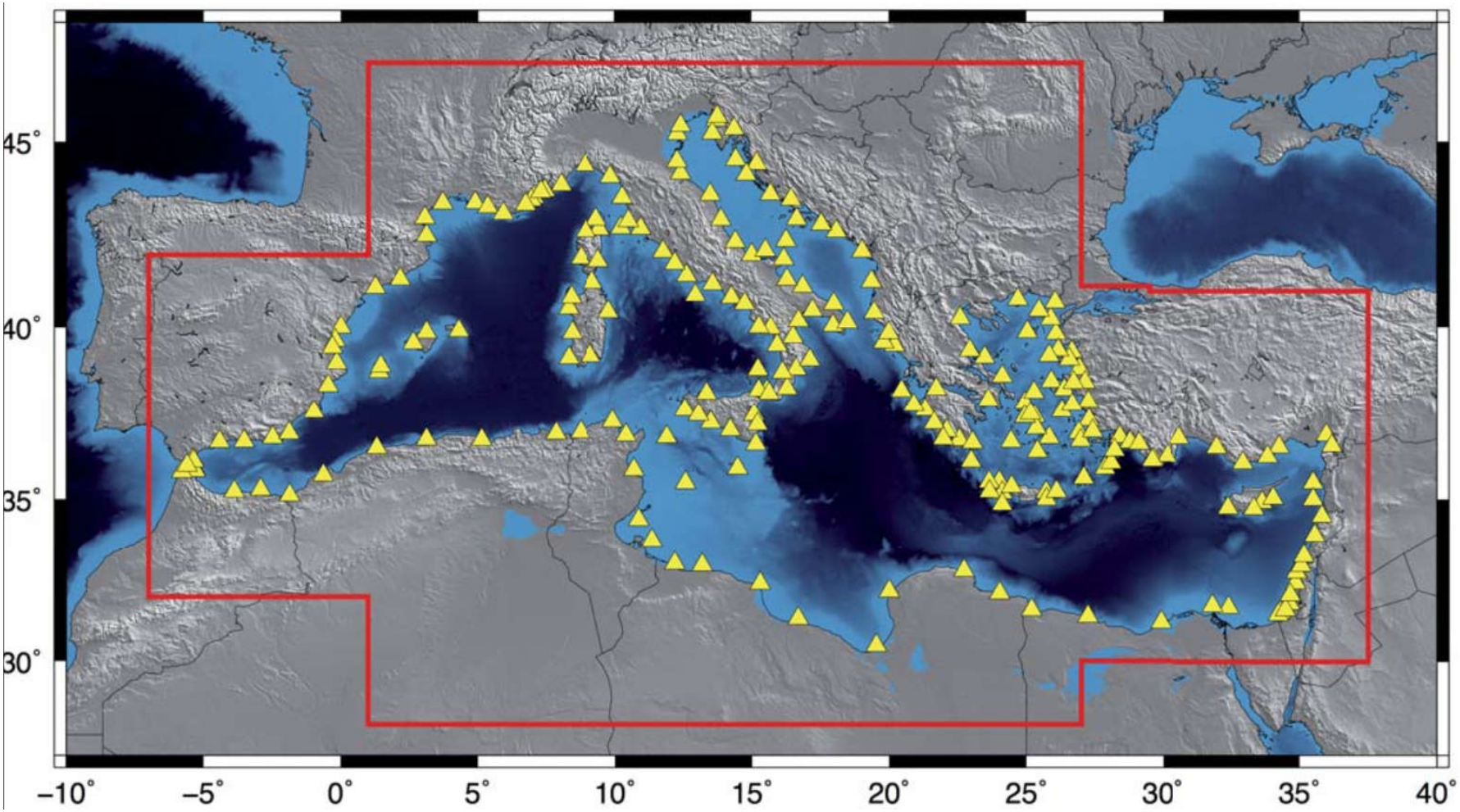
Decision Matrix

Depth	M	Epicenter Location	Tsunami Potential	ALERT LEVEL *VS* DISTANCE		
				Δeq ≤ 100 km	100 km < Δeq ≤ 400 km	Δeq > 400 km
< 100 km	5.5 ≤ M ≤ 6.0	Offshore or Inland ≤ 100 km	Nil	Information Bulletin		
	6.0 < M ≤ 6.5	Inland (40 km < Inland ≤ 100 km)	Nil	Information Bulletin		
		Offshore or near the coast (Inland ≤ 40 km)	Potential of weak local tsunami Δeq < 100 km	Local Tsunami Advisory	Information Bulletin	
	6.5 < M ≤ 7.0	Offshore or Inland ≤ 100 km	Potential of destructive local tsunami Δeq < 100 km | 400 km	Local Tsunami Watch	Regional Tsunami Advisory	Infonmation Bulletin
	7.0 < M ≤ 7.5		Potential of destructive regional tsunami Δeq < 400 km | basin	Regional Tsunami Watch		Basin-wide Tsunami Advisory
	M > 7.5		Potential of destructive tsunami in the whole basin any Δeq	Basin-wide Tsunami Watch		
≥ 100 km	*M ≥ 5.5*	*Offshore or Inland ≤100 km*	*Nil*	*Information Bulletin*	*Information Bulletin*	*Information Bulletin*
				LOCAL	REGIONAL	BASIN-WIDE


TSUMAPS-NEAM Interactive Hazard Curve Tool
HAZARD MODEL
Mappa
Satellite
Hazard Map
Probability Map
Germania
Belgio
Lussemburgo
Francia
Svizzera
Austria
Slovacchia
Ucraina
Moldavia
Ungheria
Romania
Slovenia
Croazia
Bosnia ed Erzegovina
Serbia
Montenegro
Kosovo
Bulgaria
Macedonia (FYROM)
Albania
Grecia
Turchia
Mar Nero
Golfo di Biscaglia
Monaco
Andorra
Italia
Mar Tirreno
Portogallo
Spagna
Malta
Tunisia
Mar Mediterraneo
Cipro
Siria
Libano
Giordania
Israele
Libia
Egitto
MIH for given ARPs
2500
yr
0.1 m
1 m
5 m
10 m
20 m
50 m
TSUMAPS NEAM
Probabilistic TSUnami Hazard MAPS for the NEAM Region
Statistics:
Mean
Google
Dati mappa ©2018 GeoBasis-DE/BKG (©2009), Google Immagini ©2018 NASA, TerraMetrics
Termini e condizioni d'uso

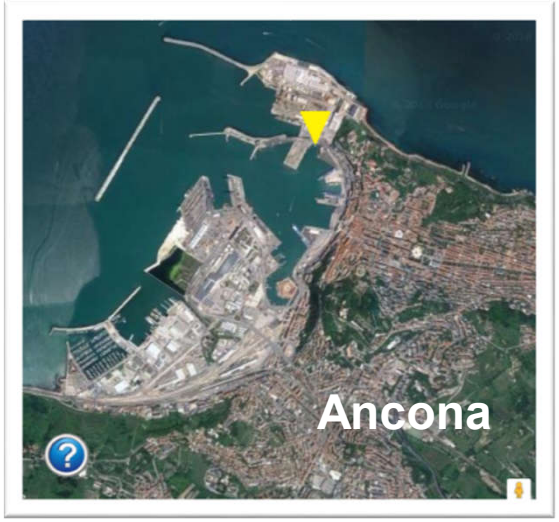
Area of competence and focal points for which **Alert level** and **arrival times** are computed in the Mediterranean Sea by **CAT**



SiAM - Activities performed by ISPRA

Monitoring-warning system (National Tide Gauge Network, RMN)

- Maintenance and optimization of the existing network
- Transfer of sea level data through several channels to IOC, INGV, JRC, DPC, other users
- Technological upgrade enabling quick transport of data by FAST and IRIDIUM systems
- Implementation of an off-shore/islands sea level monitoring network

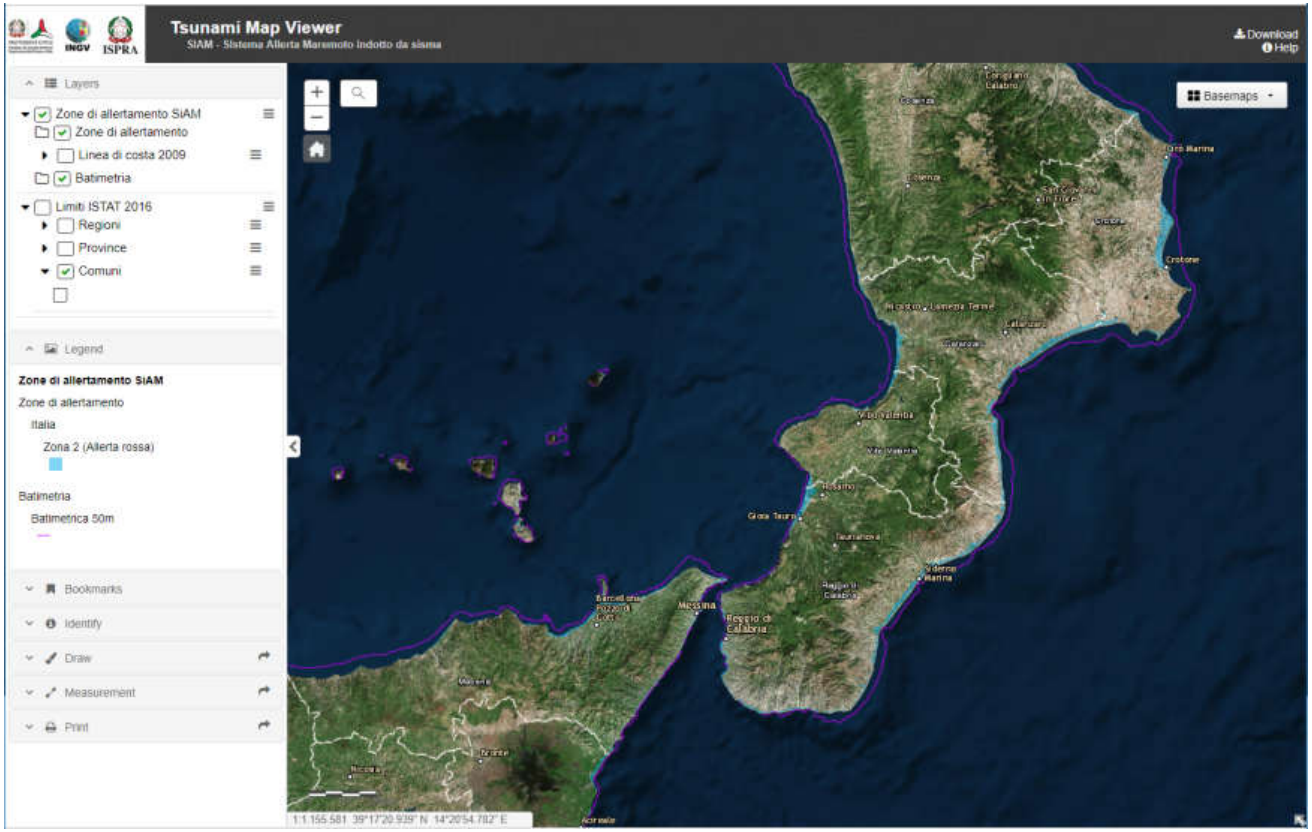


Modeling in selected critical coastal tracts of coastal inundation and vulnerability

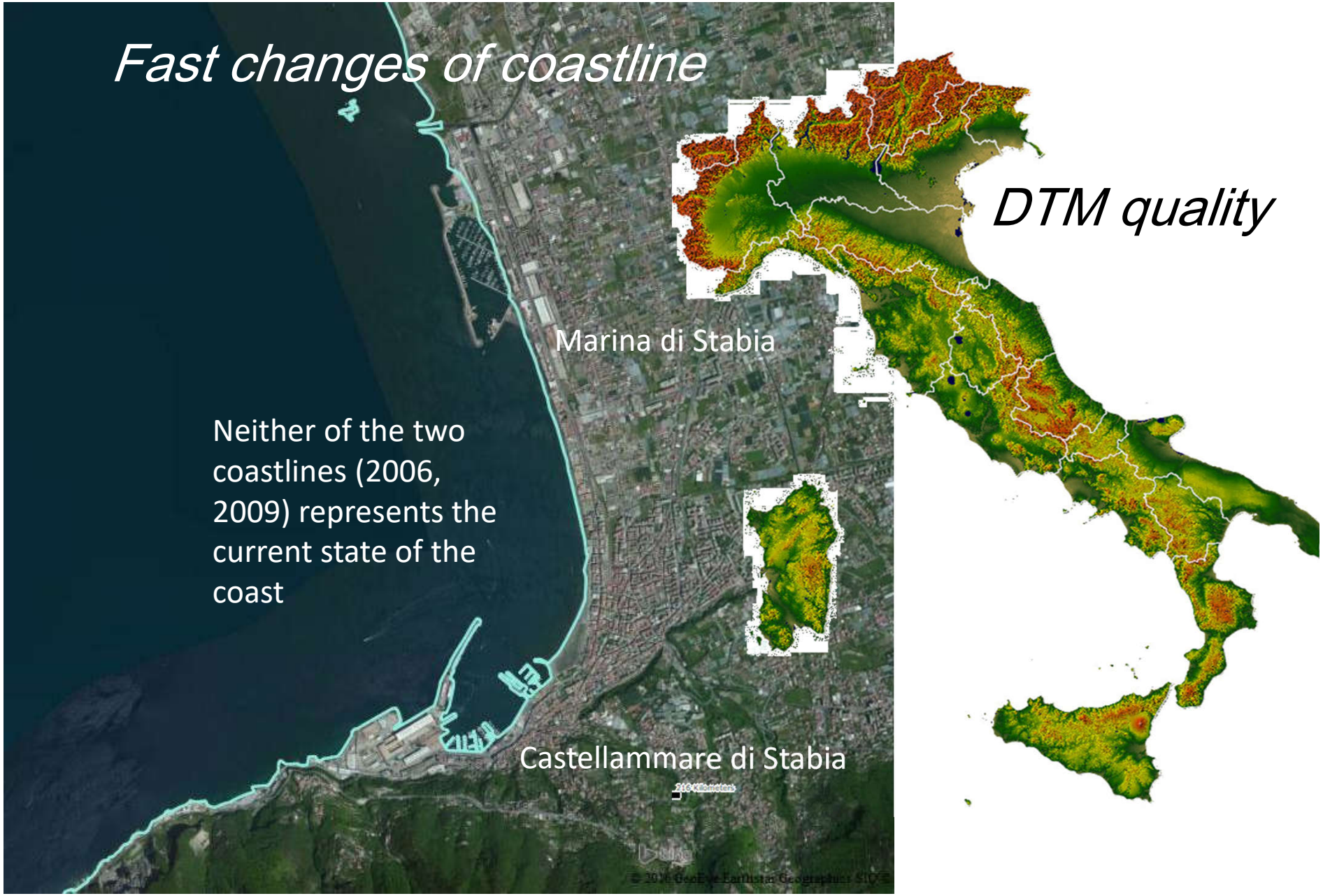
SiAM - Activities performed by ISPRA

Inundation (Geological Survey)

- Compilation and updating of inundation maps for scenario run-up values, freely accessible via web portal
- Support to local administrations for the definition of the alert zones and to Civil Protection for public awareness
- Modelling and historical studies



Problems


Fast changes of coastline
Marina di Stabia
Neither of the two coastlines (2006, 2009) represents the current state of the coast
Castellammare di Stabia
DTM quality

Inundation mapping

Numerical modeling

Valid approach, but generally quite complex, not able to provide reliable results for wide regions.

Empirical models of propagation and flooding

based on the application of an empirical relationship between run-up and inland wave penetration, obtained through observations following recent and historic tsunami events, especially in the Pacific area, in particular that of Tohoku (Japan) in 2011. In this way, the energy dissipation of the wave, mainly due to the resistance to flow due to the unevenness of the ground ("friction") is empirically taken into account.

Levels of uncertainty rather high but conservative and, at the same time, realistic.

Applied model

Empirical model of wave penetration against run-up, following in particular the example of the New Zealand guidelines (Leonard et al., 2009; MCDEM, 2008, 2016). Calculation of dry/wet pixels by GIS tools

Empirical relation between inundation and run-up

Scenario run-ups

Assessment nodes: Focal Points at -50 m b.s.l., distributed every ca. 200 km of coastline),

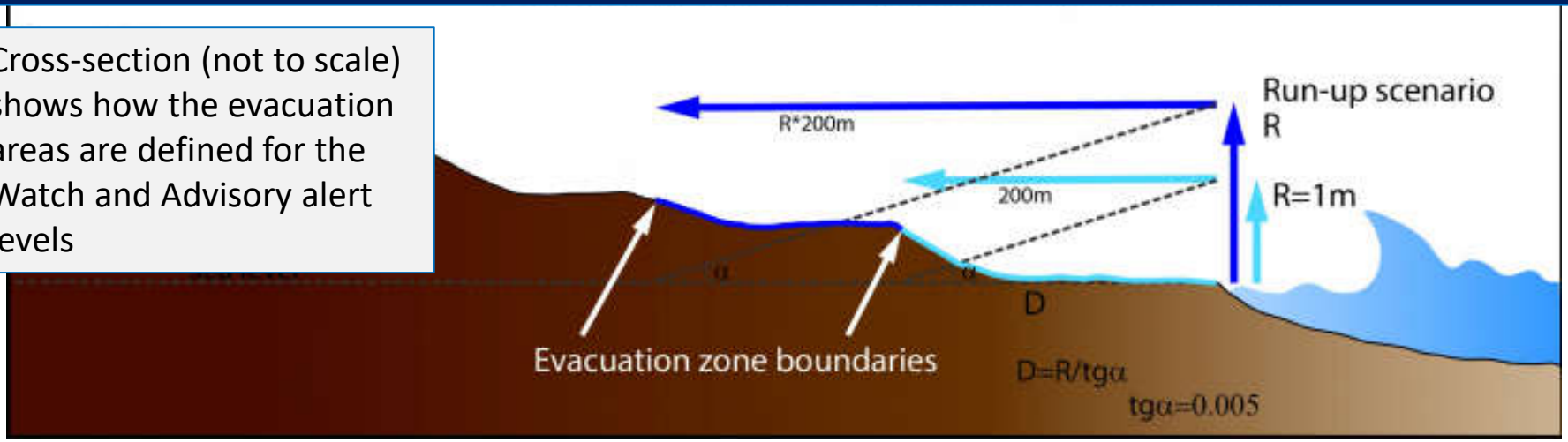
At each FP, wave height estimated based on a probabilistic hazard assessment → return period 2,500 years, 84th percentile

Maximum run-up (scenario run-up) established by numerical modelling for each coast sector facing a Focal Point

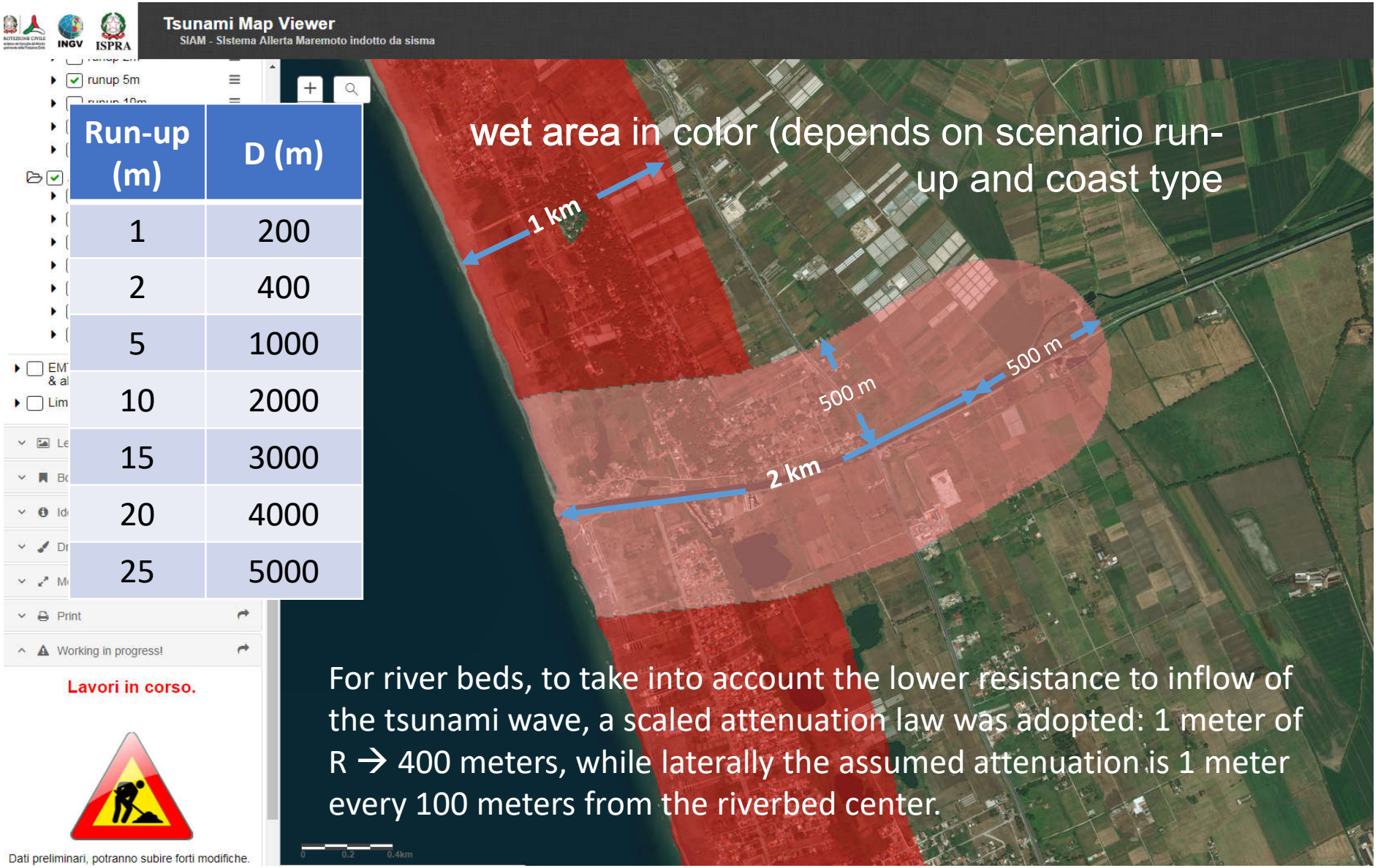
For each coastal sector, same Advisory level: 1 m (+1 m to account for uncertainties in the DTM)

Watch level varies depending on the scenario run-up

Cross-section (not to scale) shows how the evacuation areas are defined for the Watch and Advisory alert levels



Example of inundation map calculation



Run-up (m)	D (m)
1	200
2	400
5	1000
10	2000
15	3000
20	4000
25	5000

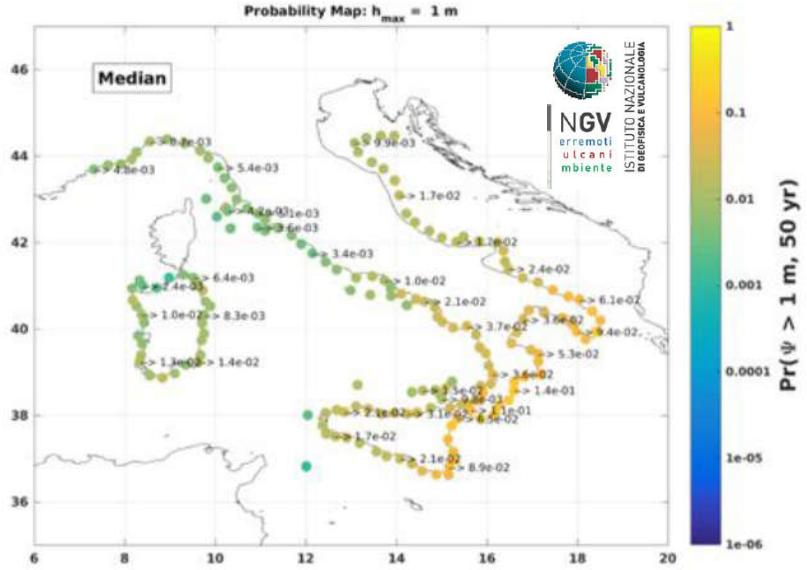
Emergency planning

national level for the local emergency planning

Definition of alert/evacuation zones

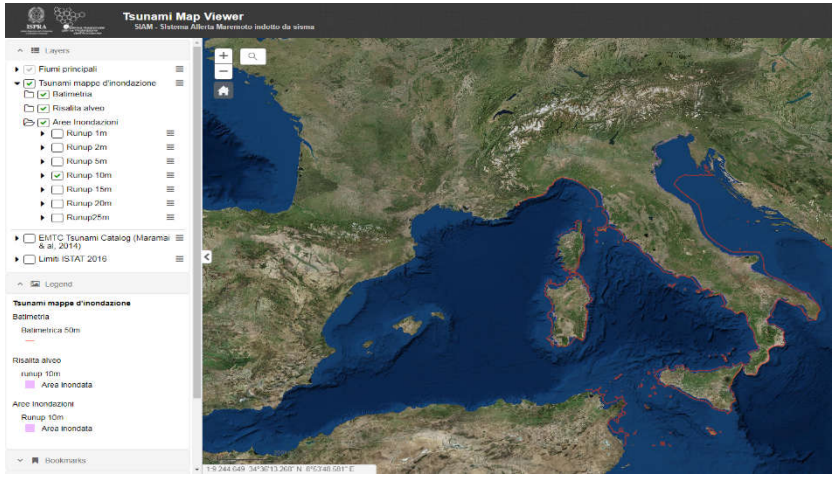
based on

hazard maps of INGV



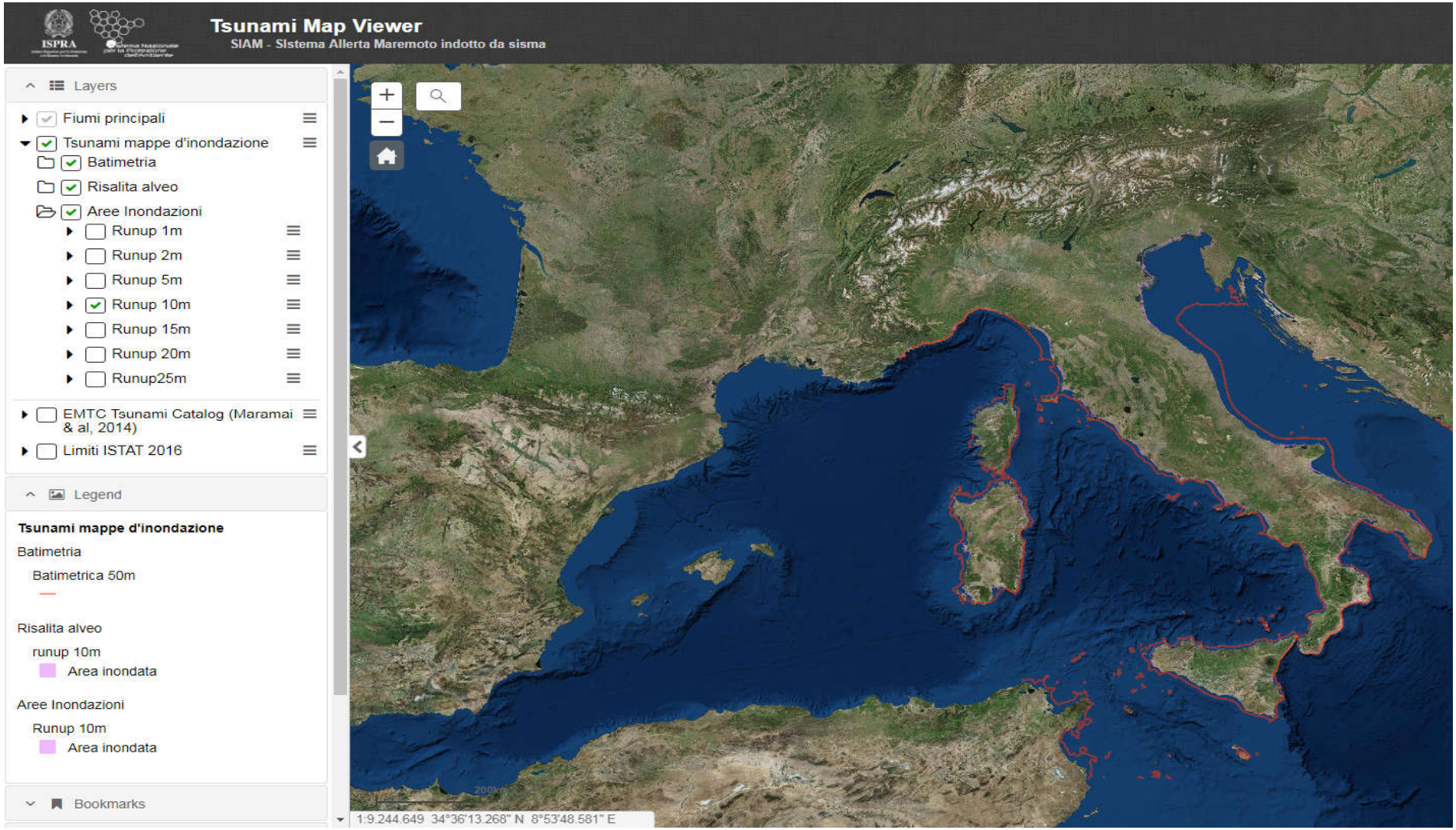
+

inundation maps of ISPRA



Emergency planning

national level for the local emergency planning



Inundation maps and alert zones accessible at http://sgi2.isprambiente.it/tsunamimap/

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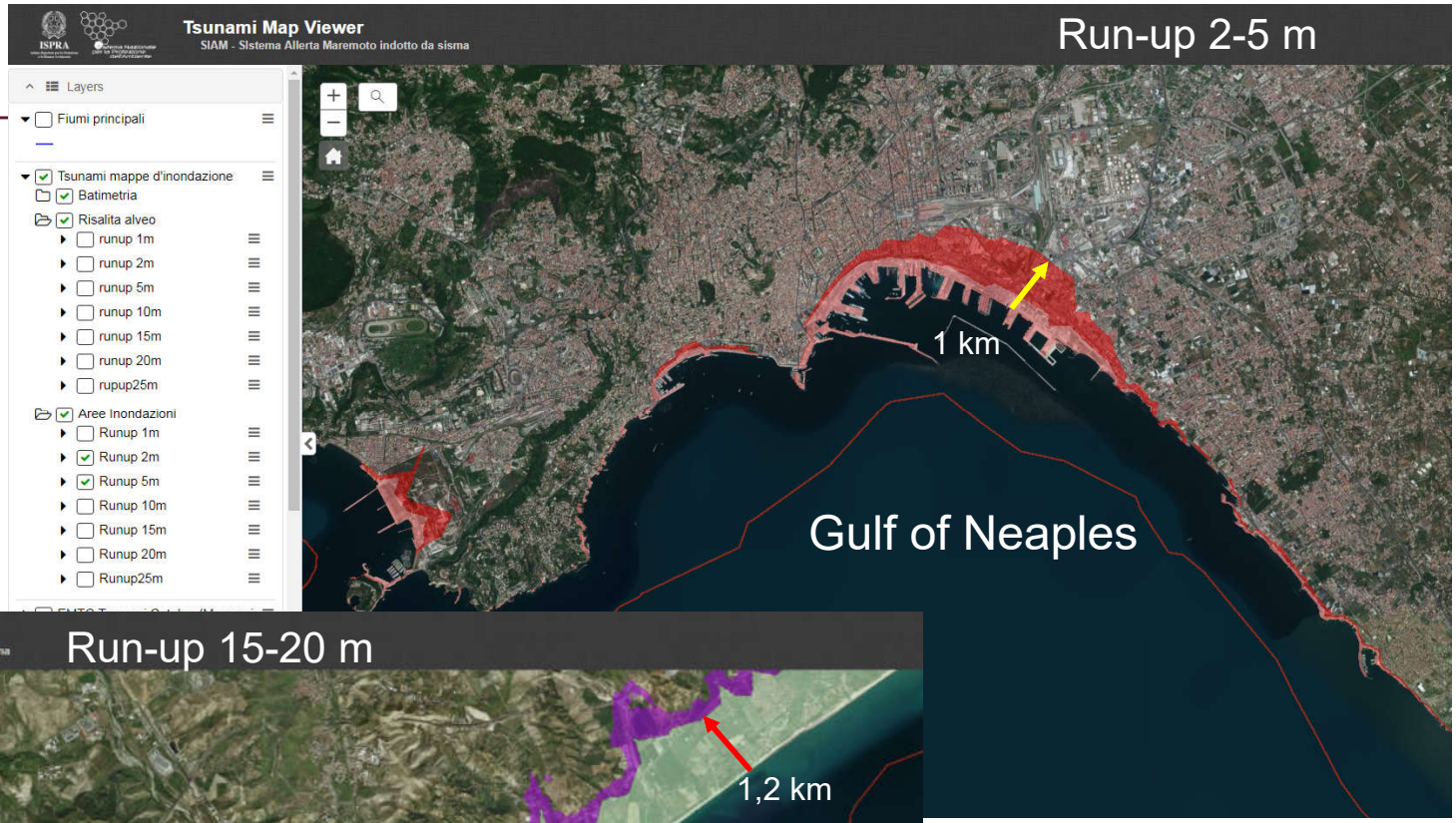
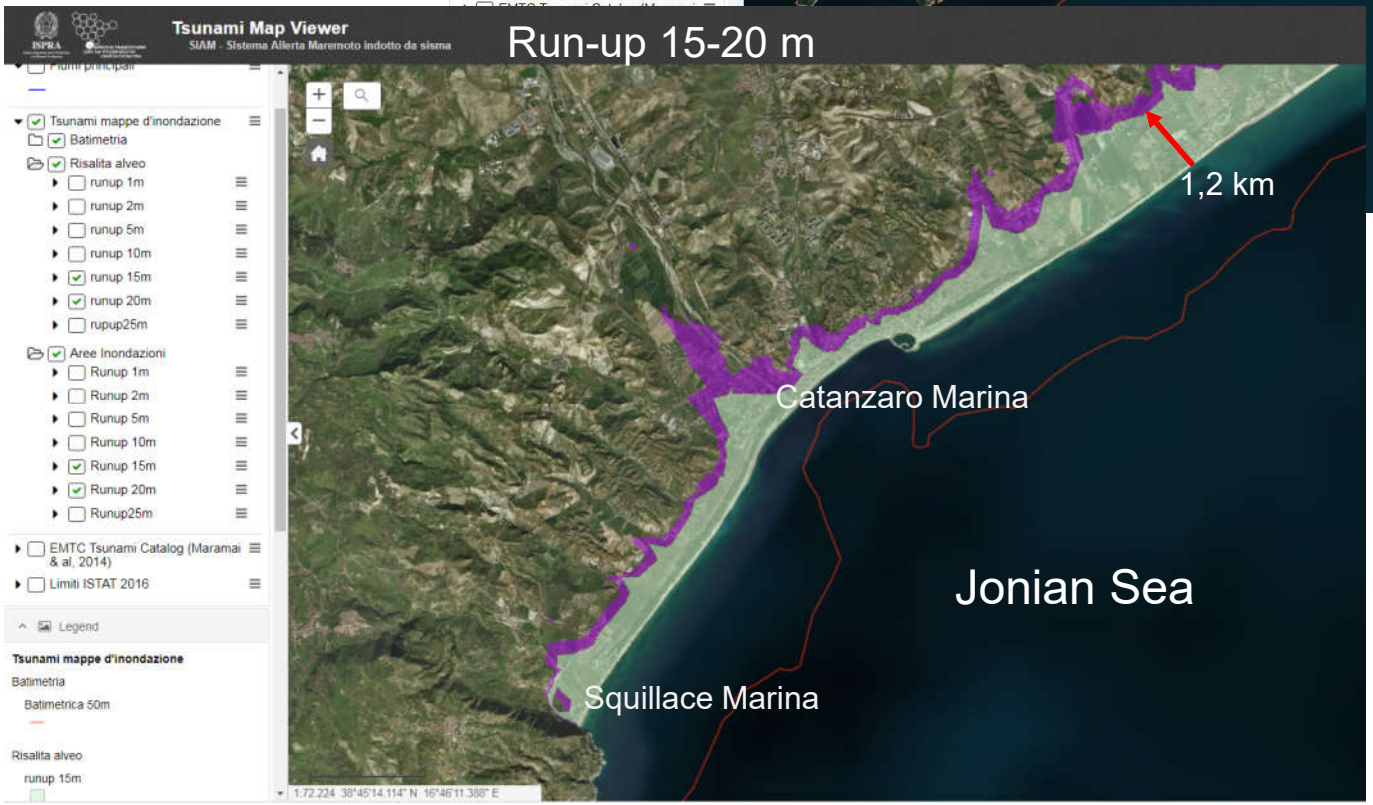
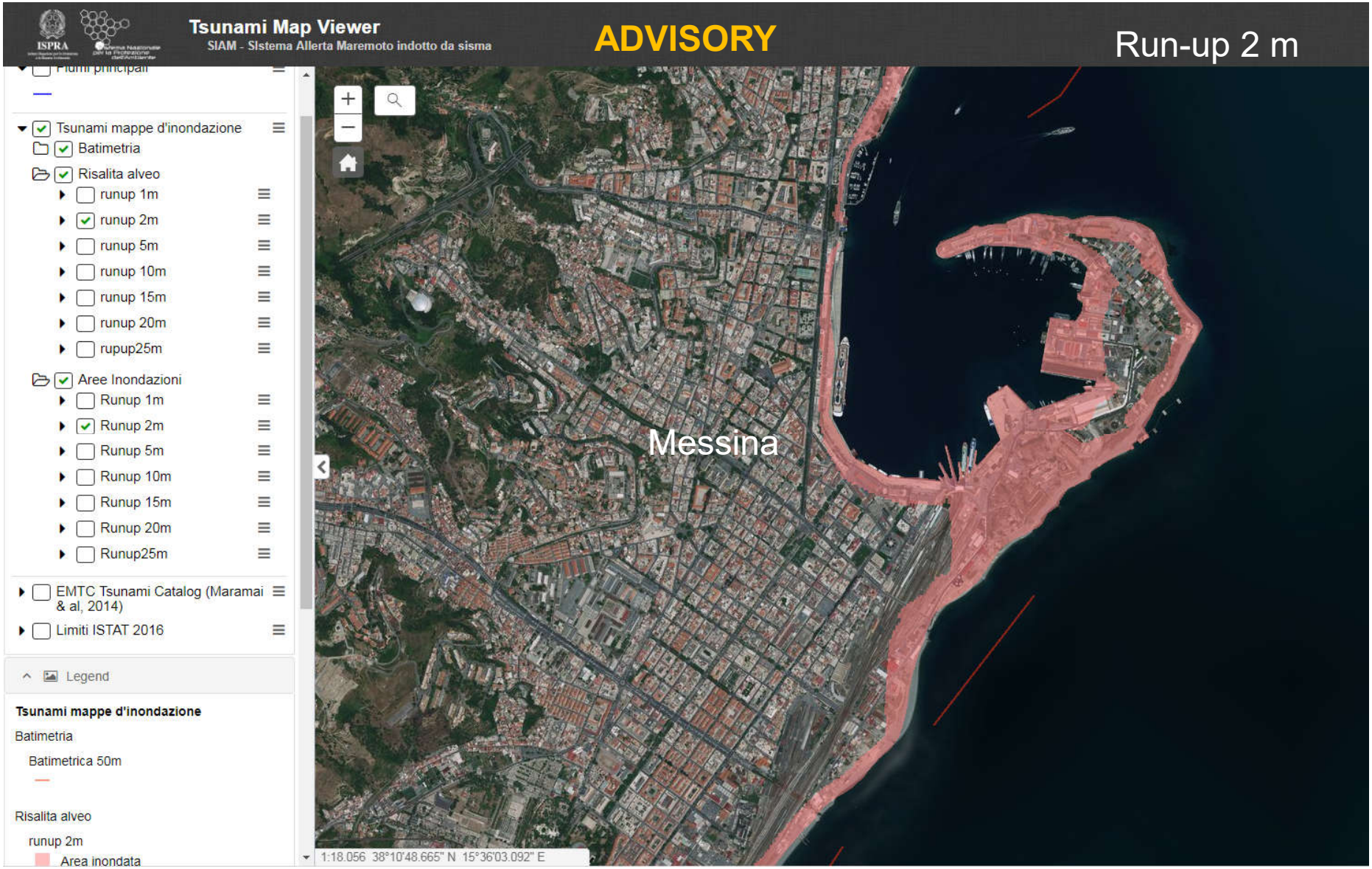
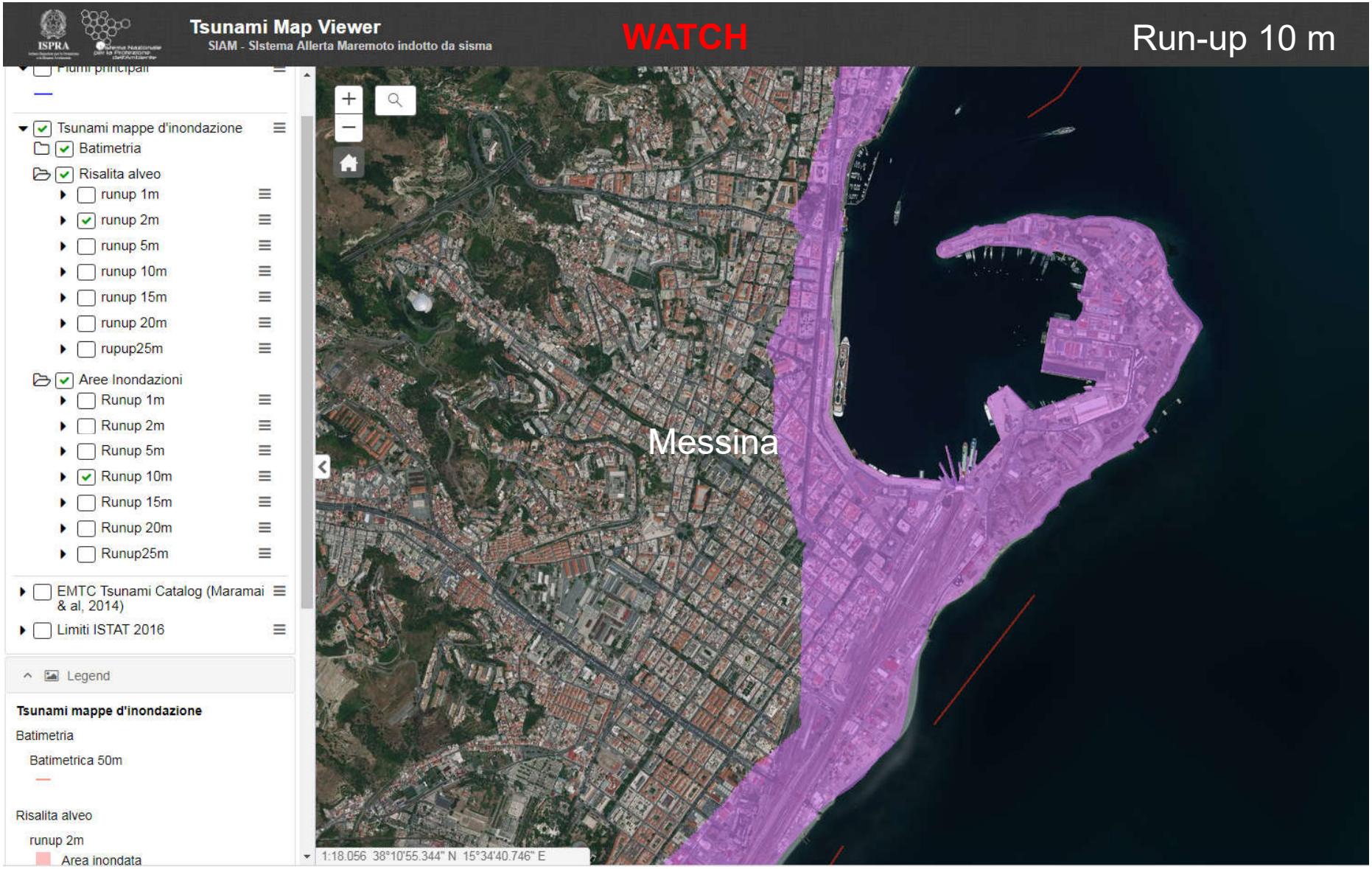




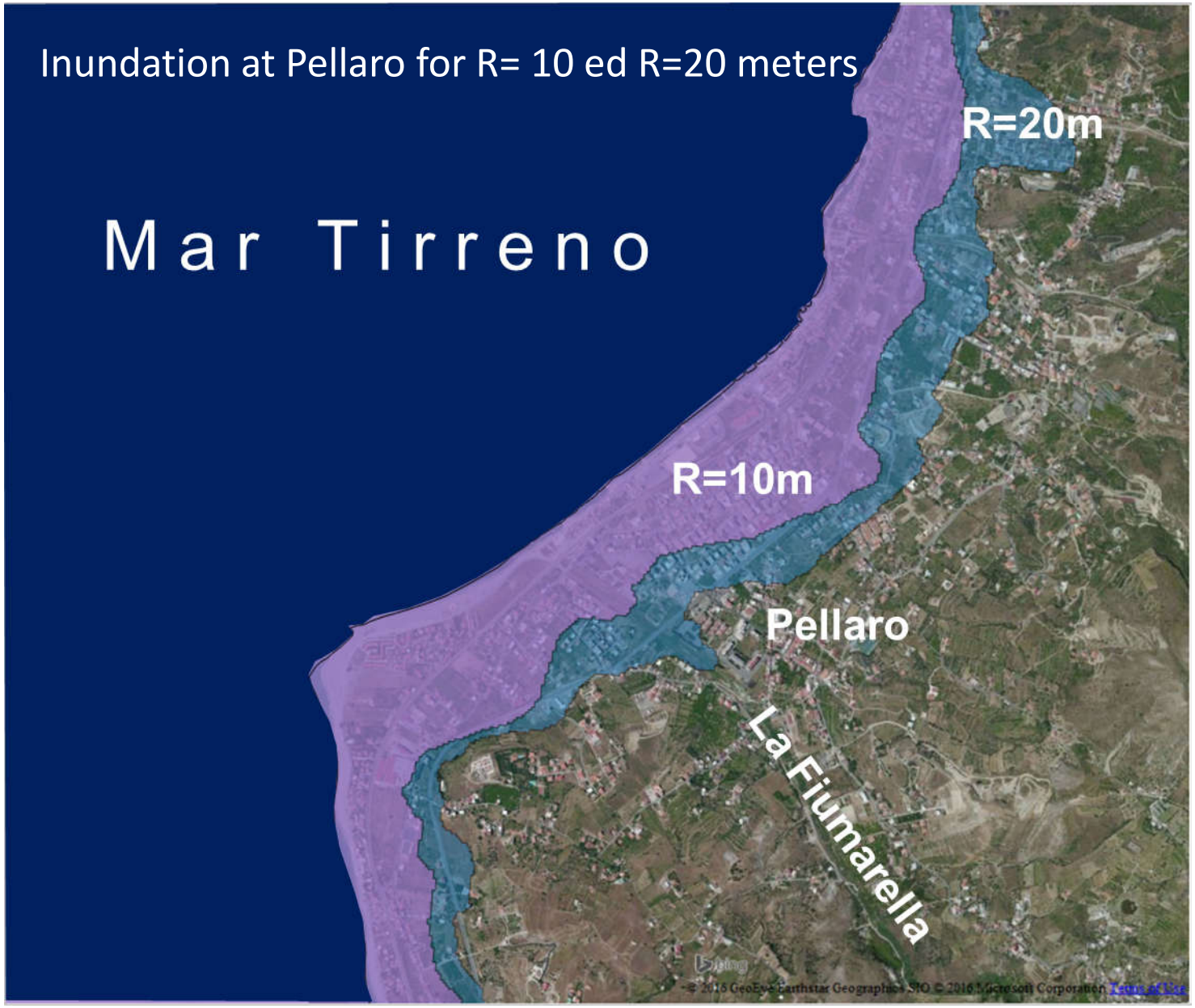
Flooded area with scenario run-up 2 m



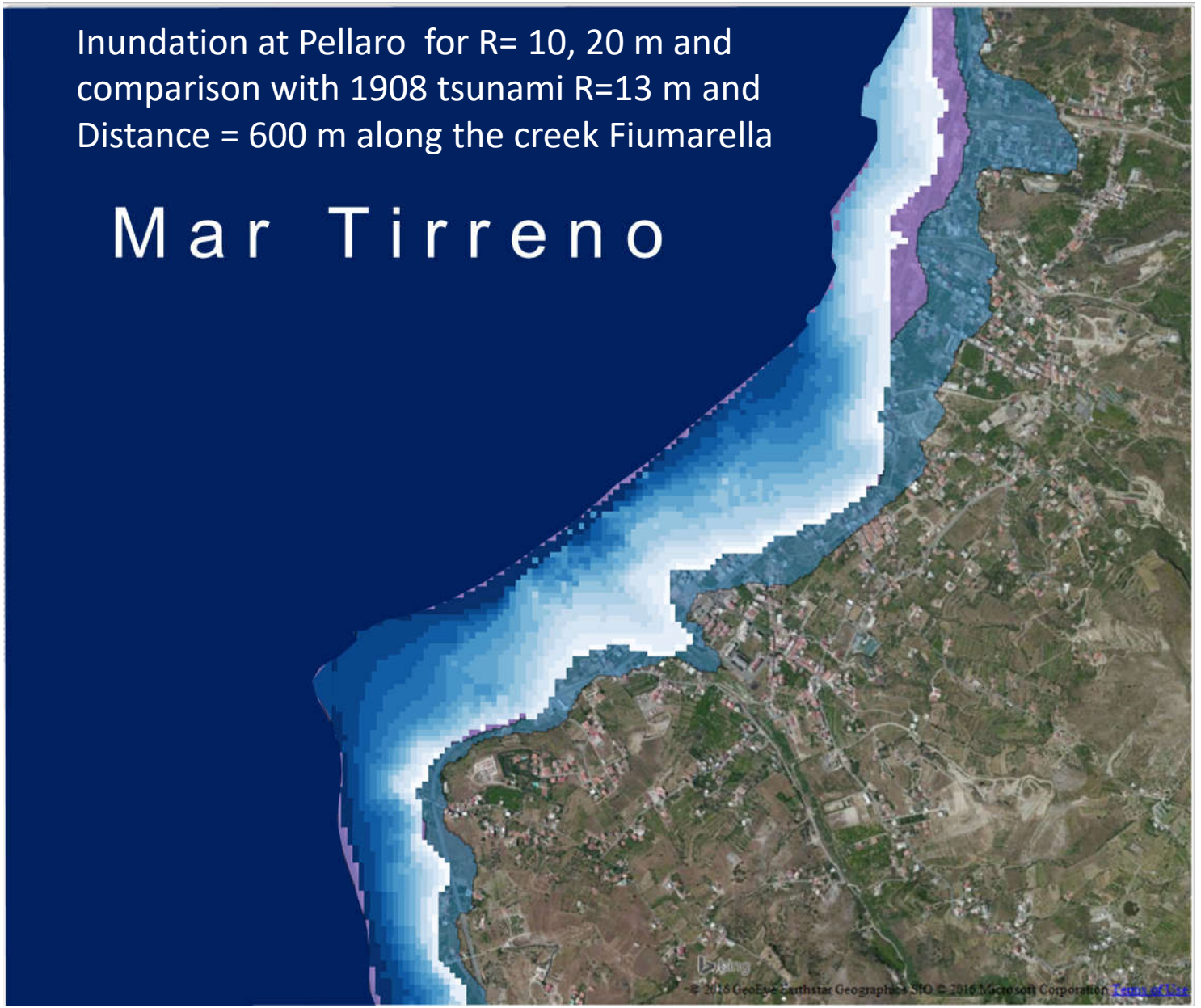
Flooded area with scenario run-up 10 m



Comparison with historical data



Comparison with historical data



Comparison with modelling

Testing performances of decision matrix and inundation zones defined in the frame of the Italian tsunami early warning system

R. Tonini[1], P. Di Manna[2], S. Lorito[1], B. Brizuela[1], F. Løvholt[4], A. Garcia-Aristizabal[3], Sylfest Glimsdal[4], A. Piatanesi[3], F. Romano[1], J. Selva[3], E. Vittori[3], M. Volpe[1]
[1]Istituto Nazionale Di Geofisica e Vulcanologia, Sezione di Roma 1, Roma, Italy | [2]Istituto Superiore per la Protezione e la Ricerca Ambientale, Roma, Italy
[3]Istituto Nazionale Di Geofisica e Vulcanologia, Sezione di Bologna, Bologna, Italy | [4]Norwegian Geotechnical Institute, Oslo, Norway

Acknowledgments
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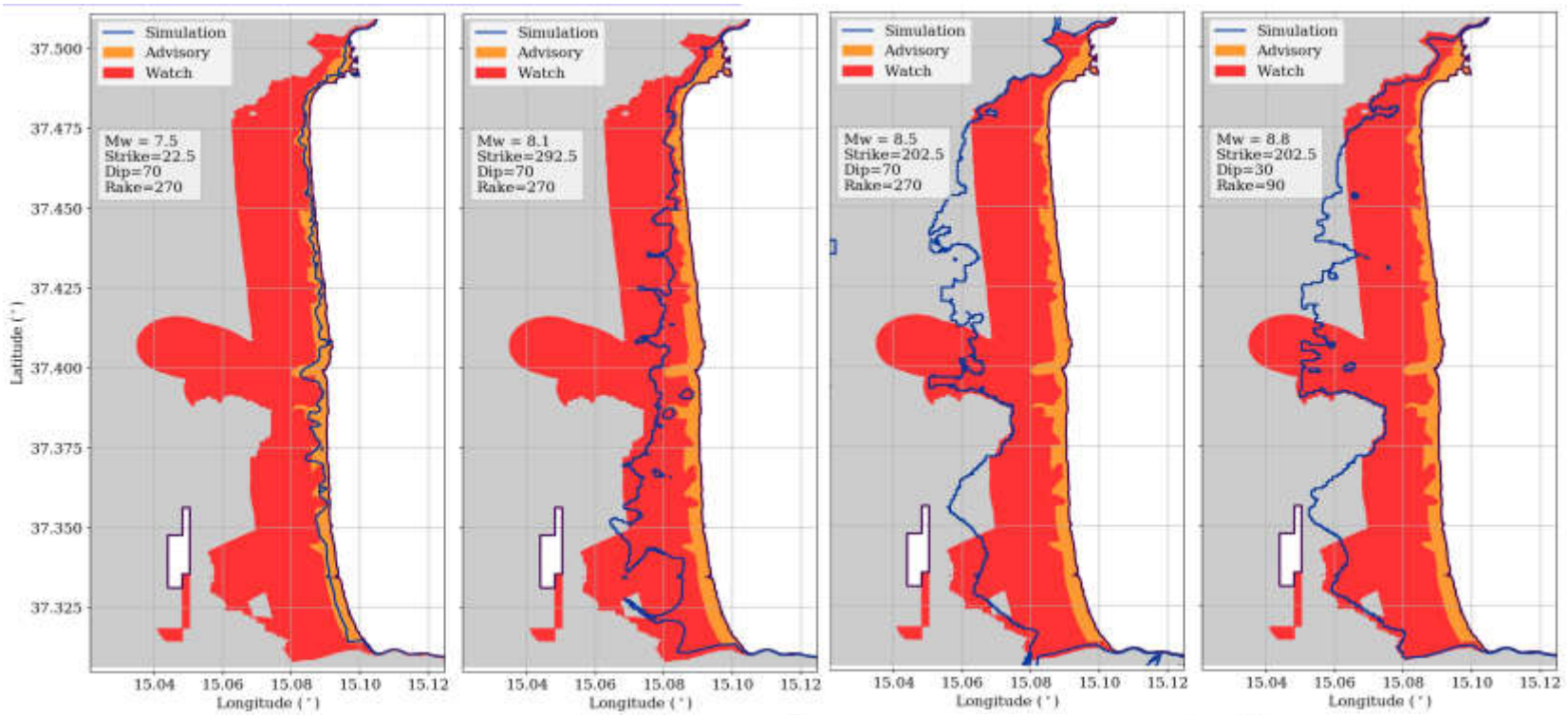
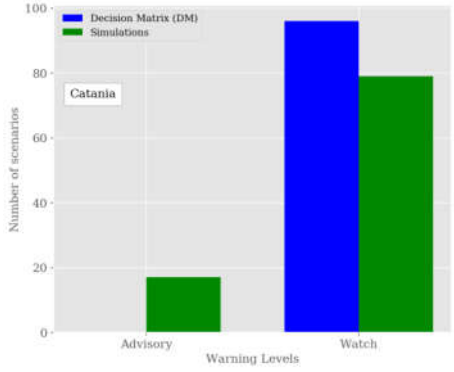
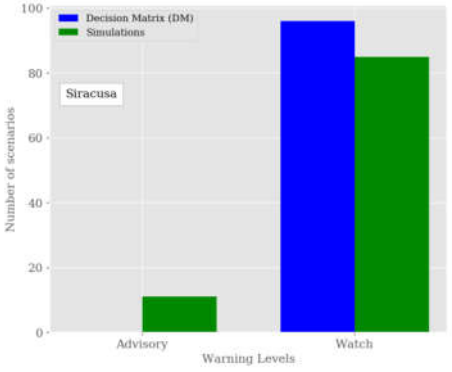
EGU2019-17866

Corresponding author: roberto.tonini@ingv.it



Inundation extension calculated with explicit numerical simulation (blue lines) are plotted together with the Watch (red) and Advisory (orange) zones defined for Catania

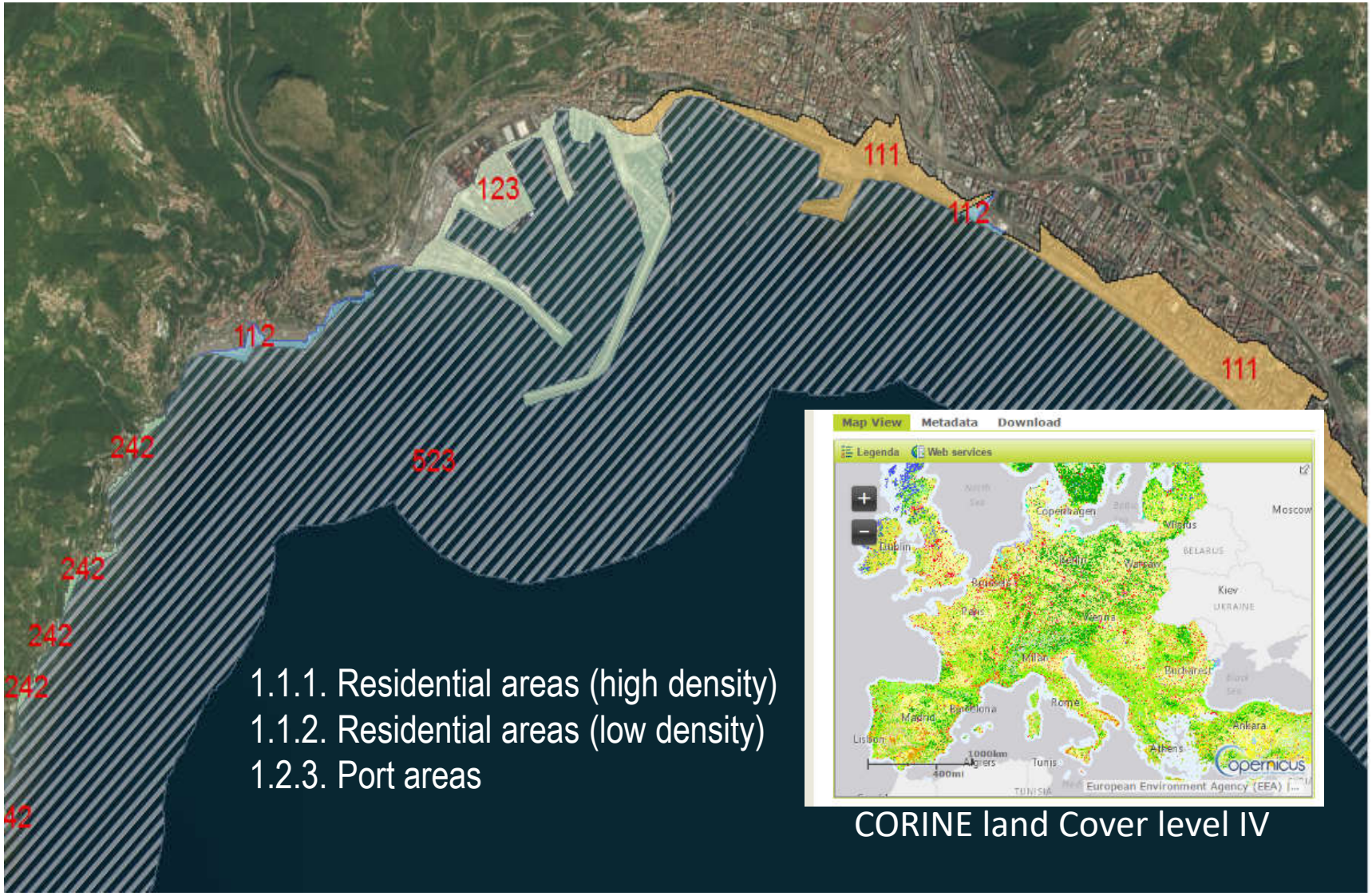




Tsunami scenarios are modelled with *Tsunami-HySEA (Macías et al., 2017)*, a non-linear hydrostatic shallow-water multi-GPU code

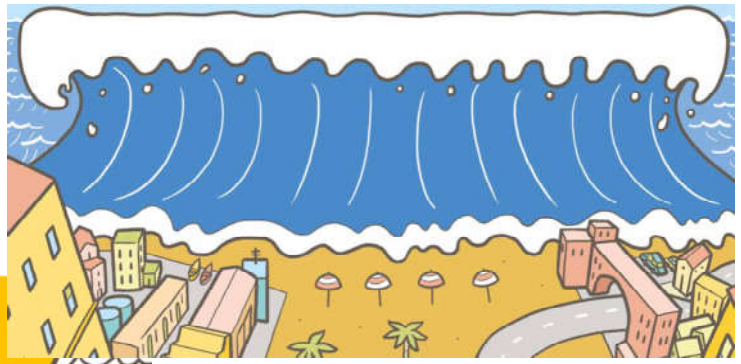
From hazard to risk – exposed structures and population

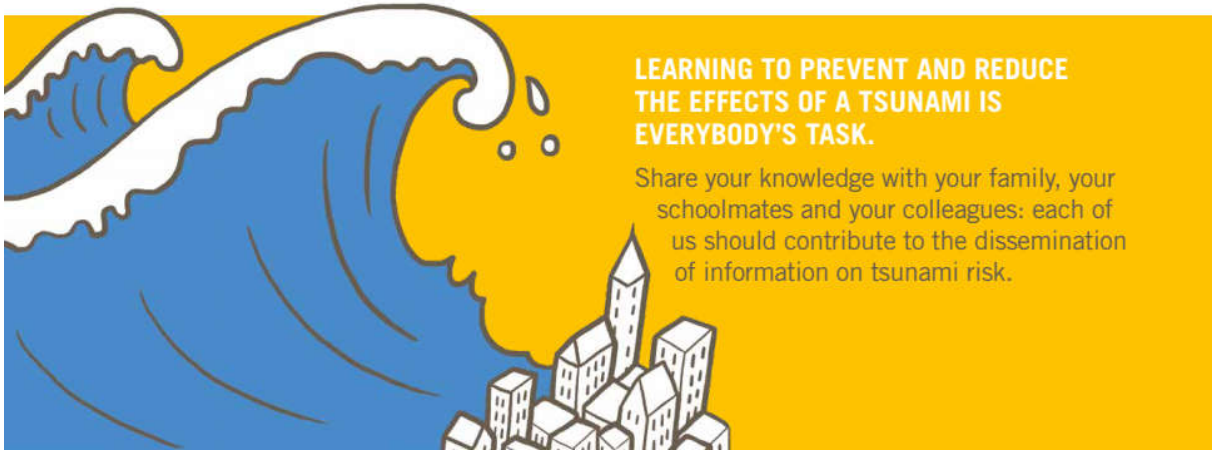
R=5m and D=1.000m → flooded area in the Gulf of Salerno



CORINE land Cover level IV

Preparedness and communication





Preparedness and communication

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What to do DURING a tsunami

If you are at the beach or in a coastal area

and receive an alert message that indicates the possible arrival of a tsunami wave, or recogni

- A strong earthquake you have felt or that you have heard about
- A sudden and unusual retreat of the sea, a rapid rise in sea level or a big wave extending acr
- A deep and increasing noise coming from the sea, like that of a train or a low flying aircraft

Move away from the water and quickly reach the nearest elevated area (such as a hill or the upper floors of a building).

Warn those around you of imminent danger

Run on foot following the fastest escape route. Do not go by car, it could become a trap.

If you are at sea,

you may not be aware of the phenomena accompanying the arrival of a tsunami, so it is important to always listen to radio press releases:

If you are in a boat and you get news of an earthquake on the coast or at sea, move further offshore; if you are in a port, leave the boat in port and move to safety in a higher place.

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What to do AFTER a tsunami

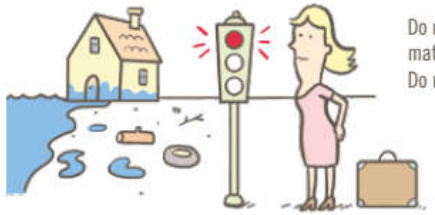
Stay in the area you have reached and discourage anyone from going back to the coast: the first wave might be followed by more dangerous ones.

Check the health conditions of the people around you and, if possible, give first aid assistance.

Listen to the authorities to find out when it's safe to leave and what you need to do.

Use the phone only for emergencies.

If your home has been affected by the tsunami, do not return without permission.



Do not eat foods that have come into contact with the water and materials transported by the tsunami: they may be contaminated. Do not drink tap water.

A tsunami can be generated by an earthquake or volcanic activity: be informed, therefore, about what to do in case of an earthquake or eruption.

Hang this card in a place visible to all the members of your family: it will help you to remember some useful tips in case of emergency

National tide gauge Network (RMN)

- II level Infrastructure (full instrumental scale 2 meters):
  - can confirm an ongoing event on the national coasts → serves as early warning only for coastal areas sensibly farther away!
- Need for offshore tide gauges for a fully effective early warning!
- I level infrastructure (full instrumental scale 10 m) in deployment
  - gauges mostly on islands for early offshore monitoring of wave transit

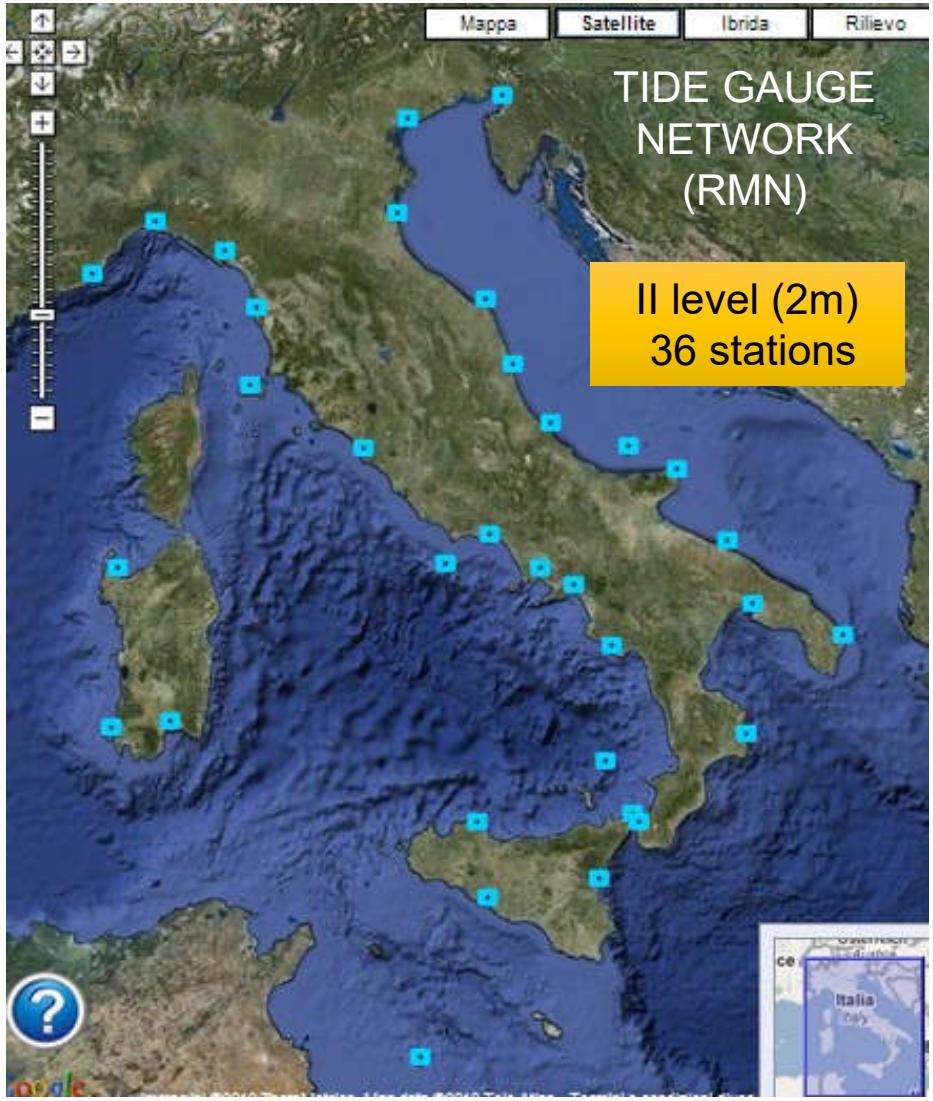
Tide Network designed for

- ❑ early detection and characterization of propagation of tidal waves (tsunami)
- ❑ characterization of exceptional breaking sea.

The stations comply with the guidelines of the Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the Northeast Atlantic area, Mediterranean and connected seas (ICG / NEAMTWS).

How SiAM is made operational

ISPRA provides in real time to the centre for tsunami alert (CAT) of INGV sea level data surveyed by its tide gauge stations mostly located in the main national ports



DATA TRANSMISSION AND AVAILABILITY

- via **TCP IP** (**FAST** UMTS connection)
- **Satellite connection** (**IRIDIUM** Short Burst Data SBD), which triggers after lack of UMTS coverage longer than 3 minutes, for 9 stations so far
- **On-line** publication, freely accessible

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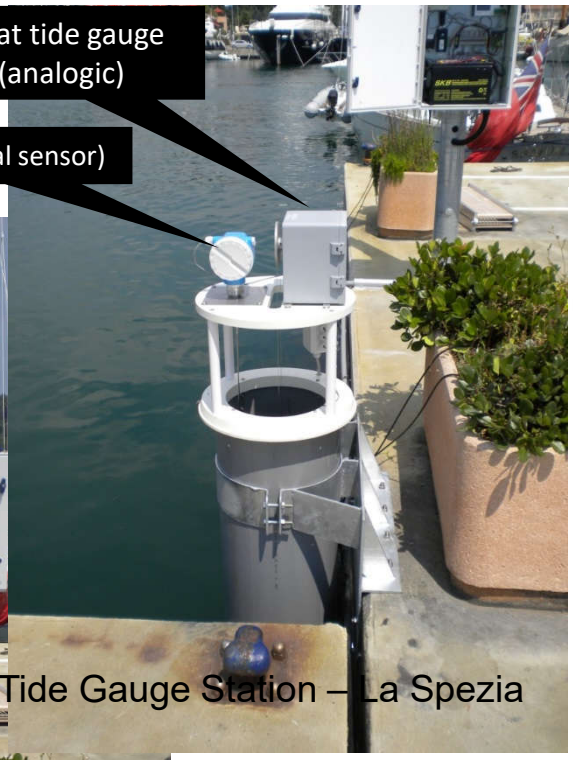
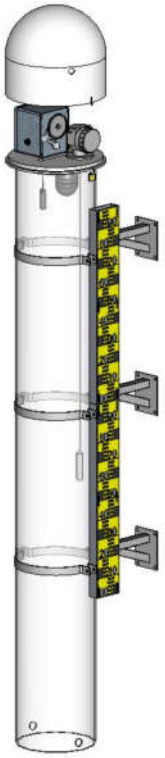
"Conventional" port gauges (Instrumental scale 2 m)


Tide Gauge Station - Vieste

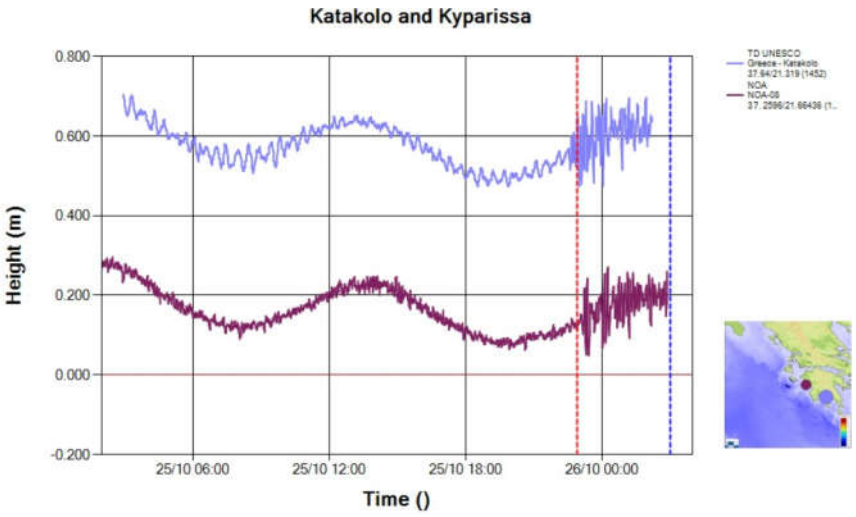


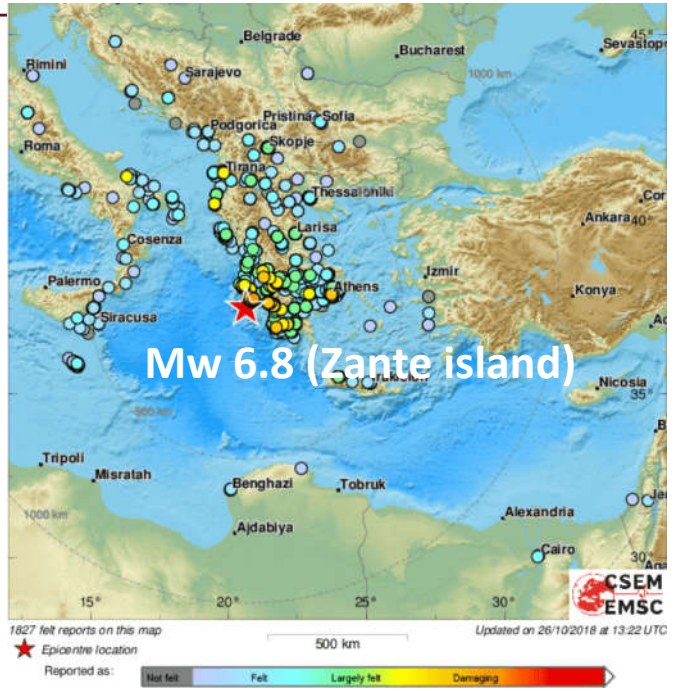
Tide Gauge Station – La Spezia

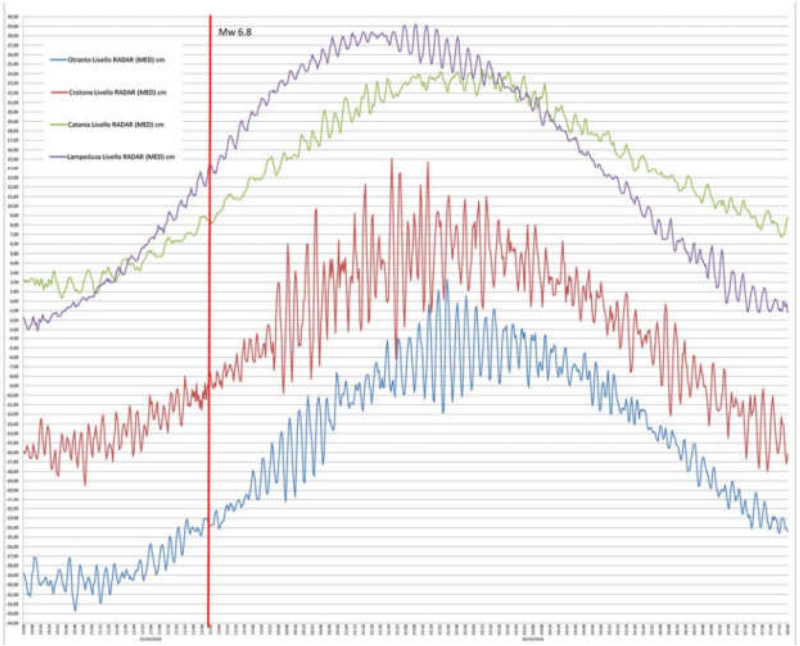


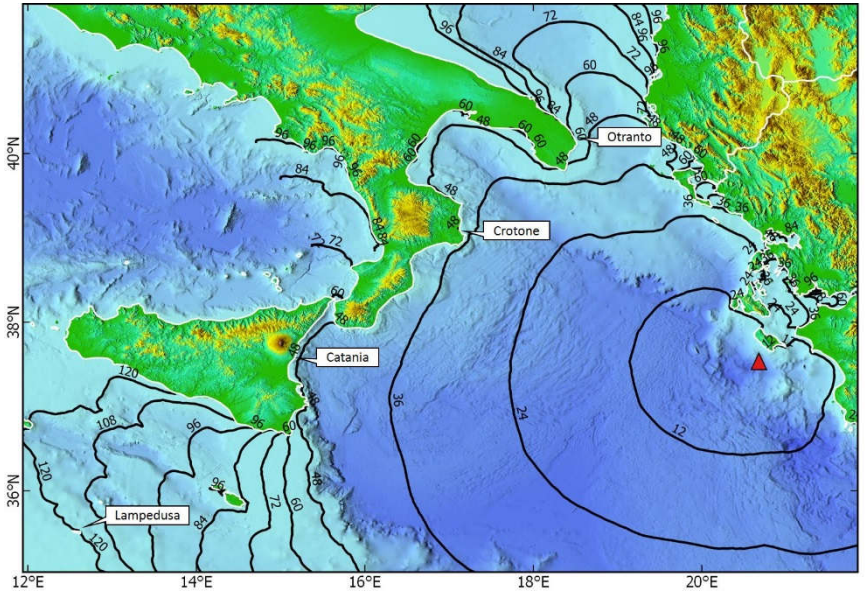
Stilling detail with the measurement system of the new tide gauge stations

Greek mini-tsunami 25 October 2018

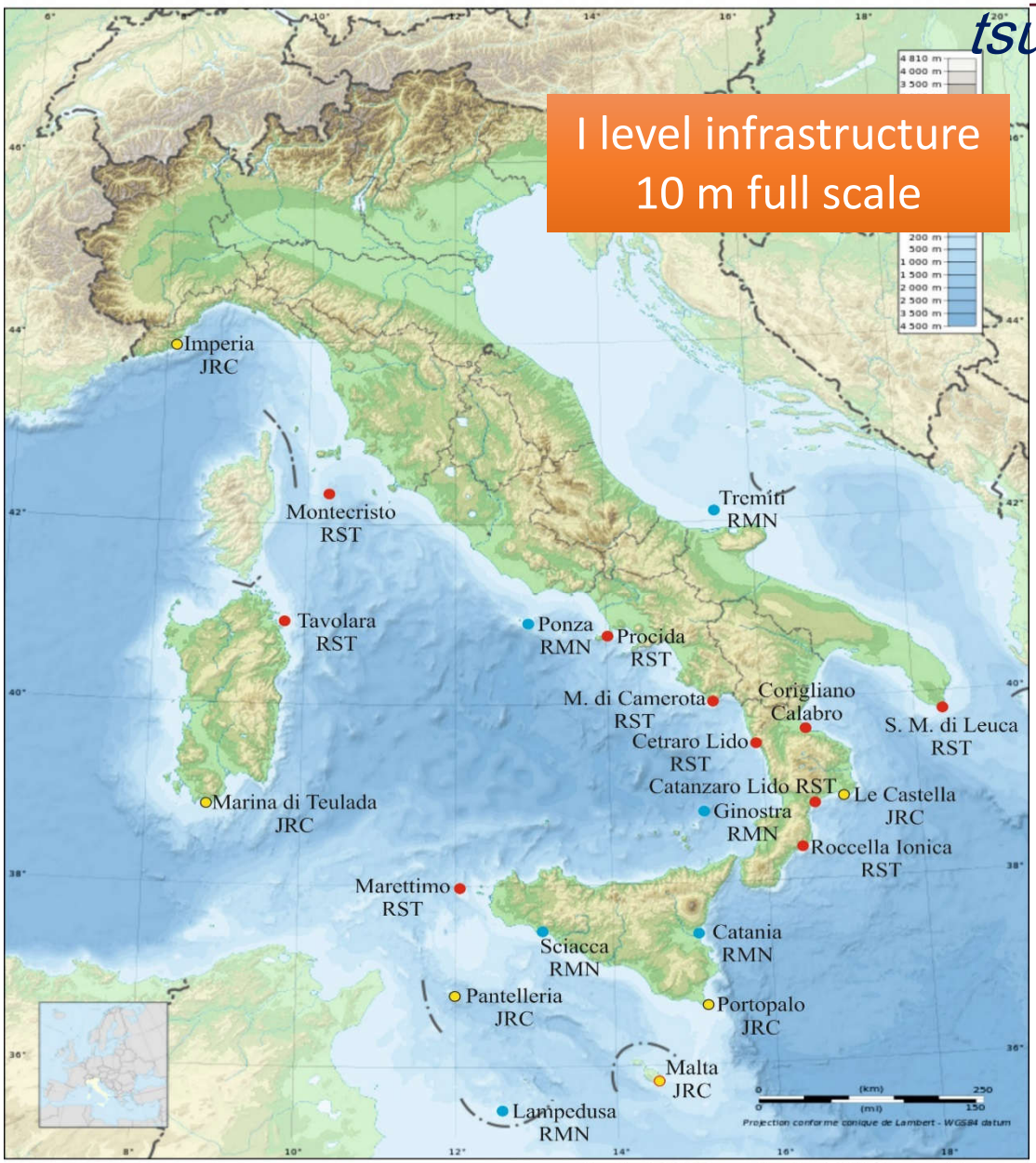








State of the art and next steps in SiAM tsunami monitoring network



Start in 2019 of a survey for the installation of 10 new stations to measure sea level with full instrumental scale of about 10 meters and resistant to operating hard offshore conditions (similar to the Ginostra station)

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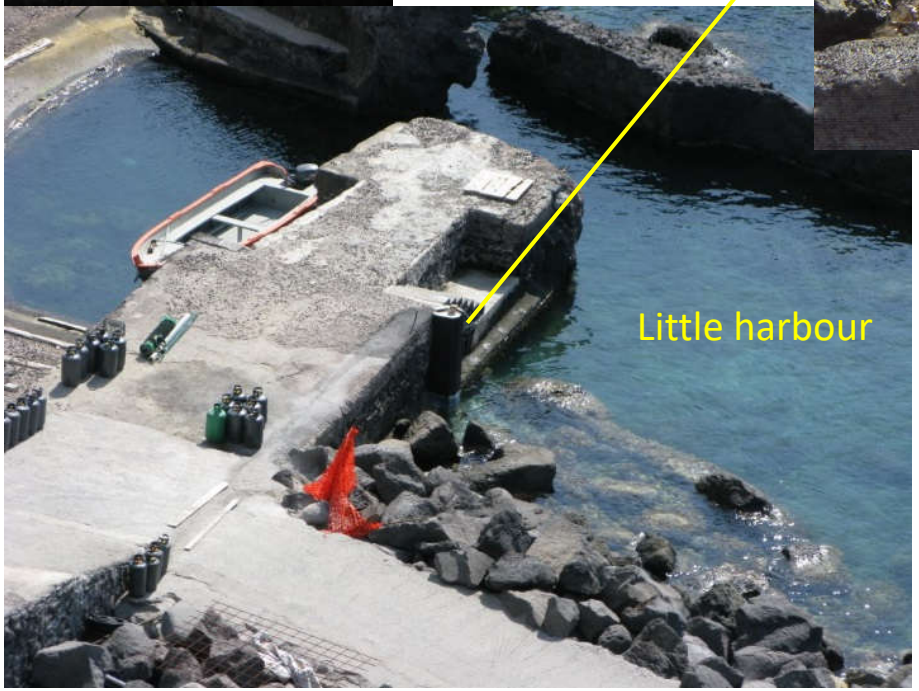
Tide gauge station - Gi ostra (Stromboli volcano)

Tide gauge station - Ginostra (Stromboli volcano)



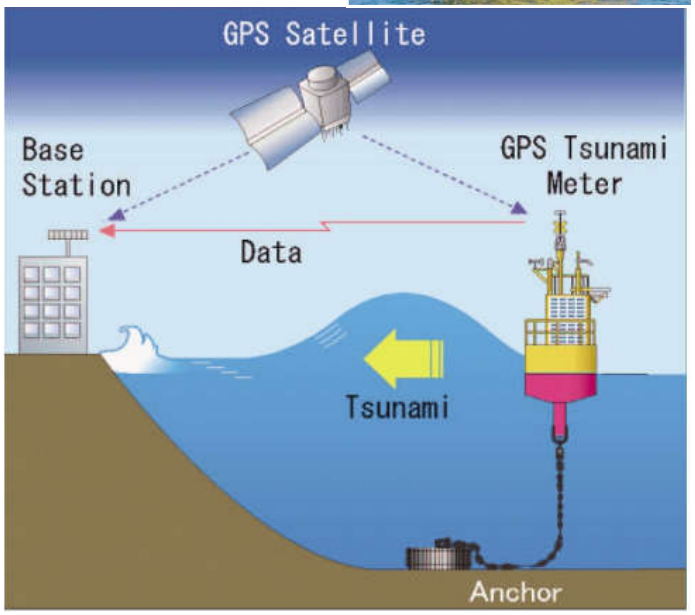
- Double pressurimeter 10 m/100 m
- Thermometer
- Low maintenance cycle (2 years)
- Complete darkness → no bio attack

GPS Floating buoys Experiments

Need of off-shore measurement for Tsunami Monitoring for.

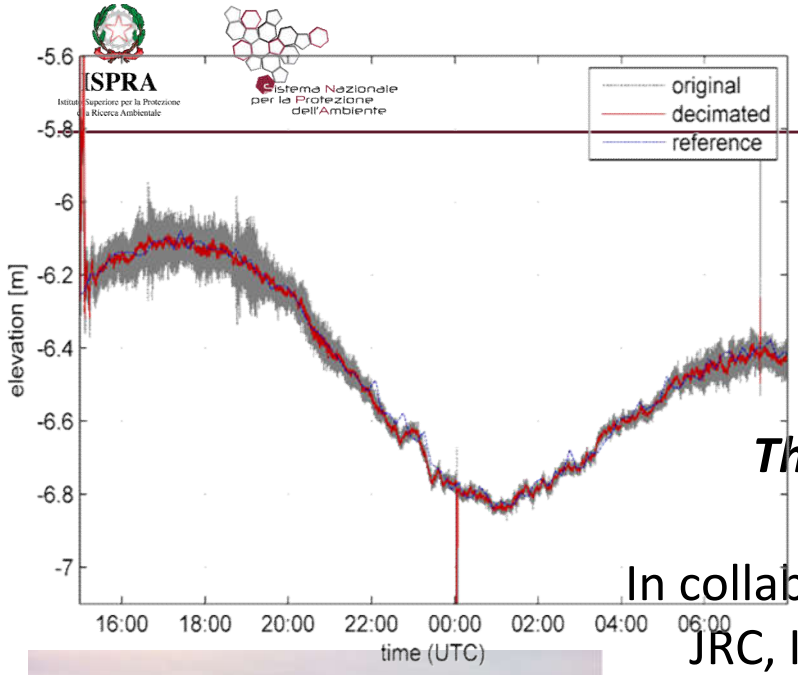
a. Early Tsunami Detection
b. Cleaner Tsunami Estimations

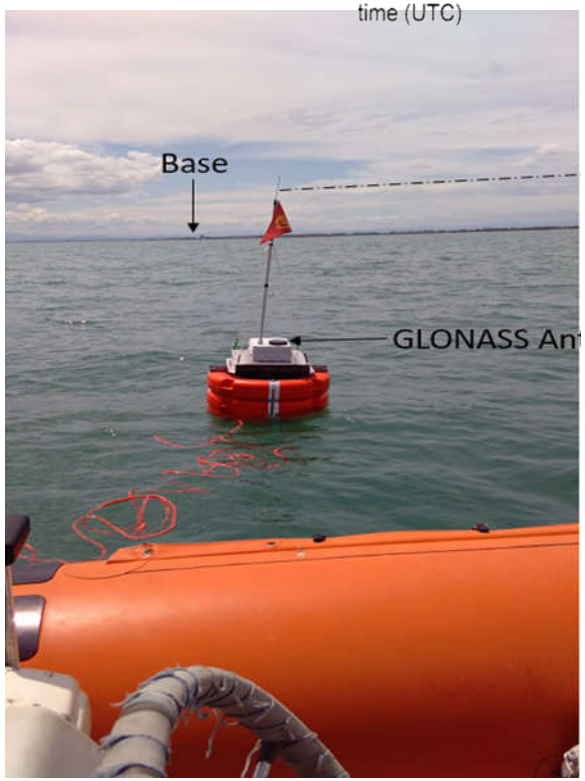
1. The measurement of Sea Level using differential GPS can be extremely useful for the monitoring of sea level around the Mediterranean Sea
2. This technique **is not** new and is already extensively adopted in Japan
3. But cost of buoy devices extremely high and problematic installation because of dimensions.
4. The availability of more affordable GNSS receivers, connected with the newly created Galileo constellation allows to develop low-cost floating GPS devices, suitable for the Mediterranean Sea.



Japanese approach

INNOVATIVE COMPONENTS





The Floating GNSS system

In collaboration with the JRC, ISPRA is testing a floating GNSS system to detect tsunami waves. A large oceanic buoy will be instrumented with the latest satellite receivers (Galileo and GPS) to provide an accurate sea level measurement off-shore (15-20 km from the coast).

ISPRA- JRC

The present sea level infrastructure is undergoing a development and innovation process.

Inexpensive Device for Sea Level Measurement (IDSL)

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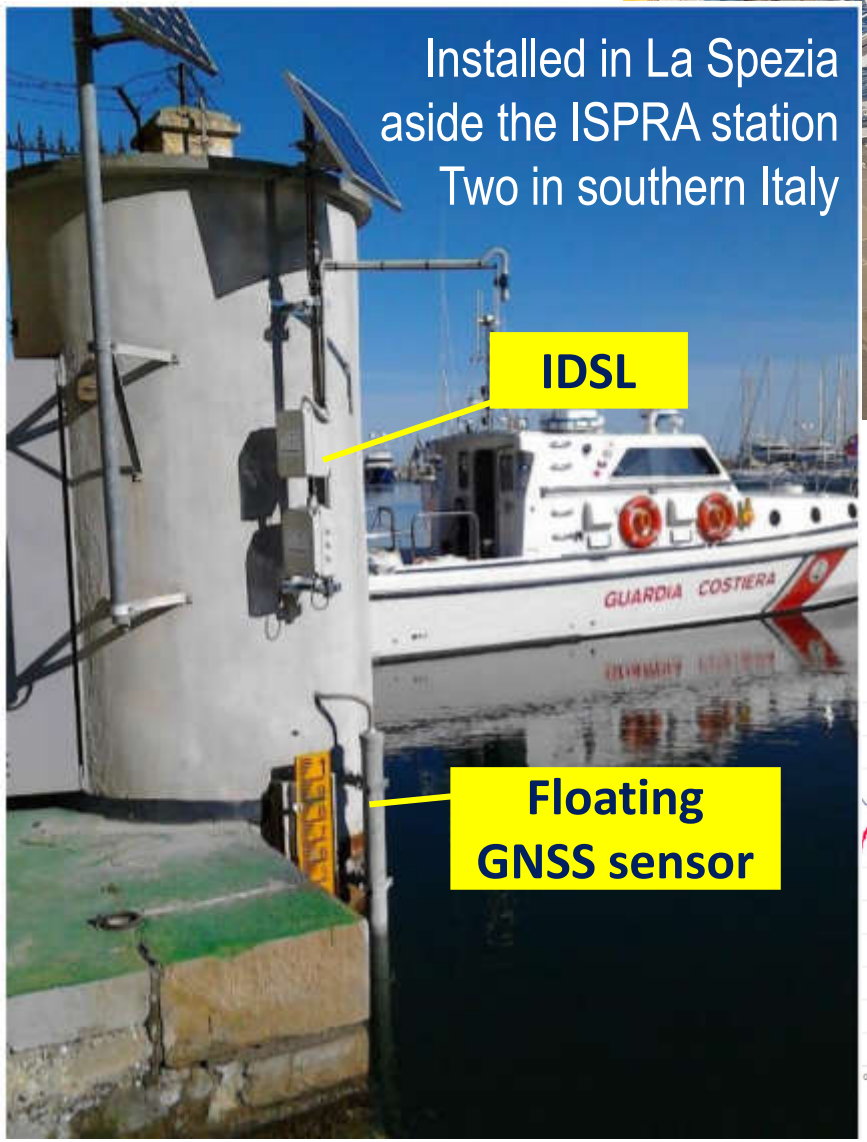
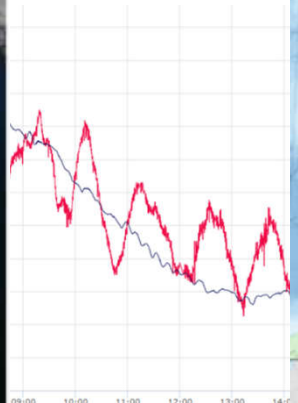
JRC
EUROPEAN COMMISSION





Ongoing initiatives

a. Delivery of inundation zone maps to municipalities and assistance (including correct communication)
b. Refinement of inundation zones based on high resolution DTM
c. Comparison with numerical models at reference localities
d. Installation of a new real-time sea level monitoring network based on low-cost instruments (floating and fixed tide gauges)

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