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Tsunami early warning in the Mediterranean: current and potential contributions of seismic information

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1. Introduction

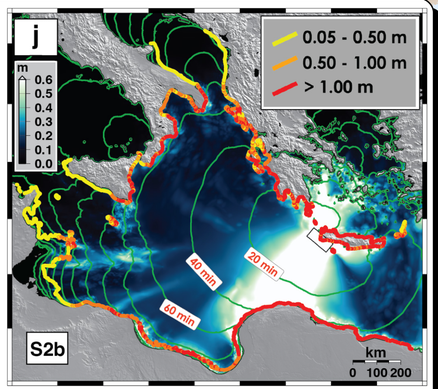
Effective tsunami early warning after an earthquake in the Mediterranean basin is made difficult by the short distances and tsunami travel-times between earthquake/tsunami source regions and coast lines at risk. For tsunami hazard and risk assessment worldwide, seismic monitoring and analysis currently provide the majority of information available within the first tens of minutes after an earthquake. In the future, information from multi-sensors buoys, GPS, airborne and space systems, real-time tsunami forecasting, citizen devices, and other technologies, along with improvements in seismic monitoring and analysis procedures will help to increase the coverage, rapidity and reliability of tsunami warning.

Here we examine the current and potential future contributions of seismic networks and analysis procedures to tsunami early warning in the Mediterranean basin.

2. Short time between earthquake and tsunami

Effective tsunami warning requires notification 5min or more before a tsunami strikes. But the typical distances and tsunami travel-times between earthquake/tsunami source regions and coast lines at risk in the Mediterranean are small. Most source regions are coincident with zones of risk, giving an effective warning time of near zero.

For larger earthquakes and larger tsunamis, the tsunami wave travel-time across the entire Mediterranean can be several hours.

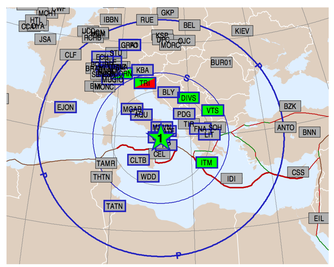


***Maximum wave heights and tsunami travel time, Mw8, Hellenic Arc**, from Basili et al. (2013)*

3. Current seismic monitoring and analysis

Seismic event detection and location requires about 5 triggered stations with good coverage around the event. The current coverage allows location within <2min in the Northern Mediterranean, but longer (up to ~5min) along the North Africa coast – an important source region for large earthquakes and tsunamis.

After location, rapid, body-wave magnitudes (mL, mb, Mwp, ...) can be obtained in <2-3min; first-motion (FM) mechanisms in <5min. CMT moment-tensors and magnitudes (Mww, MwCMT, ...) are available after 10-20min.



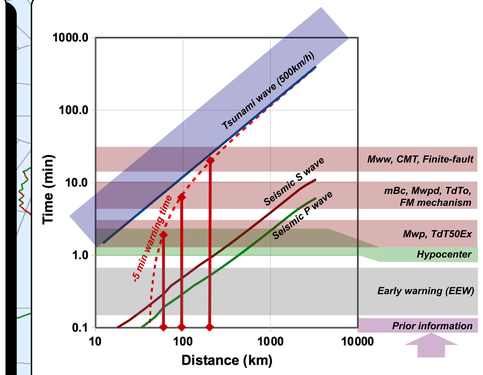
Lomax and Michelini (2012)

4. improvements in seismic monitoring and analysis

With the goal of rapid, evolutionary source and tsunami parameter calculation and display, ongoing and future improvements in seismic monitoring and analysis can greatly aid in effective tsunami warning:

- Dense, "Early-warning" (EEW) networks and Ocean Bottom Seismometers (OBS) in critical source areas.
- More stations near tsunami source regions and in Northern Africa.
- Robust, real-time data feeds with very low latency (< 5sec).
- Calculation, dissemination and effective display of rapid, non-saturating magnitudes, direct tsunami discriminant and CMT determinations (TdT50Ex, Mwpd, Mww, …) ***Lomax and Michelini (2012)***
- Comprehensive information display including decision diagrams.

5. Timing and reliability of established and newly proposed seismic methods



Within minutes after an earthquake, seismic methods can provide a hypocenter location, saturating magnitudes (e.g. mb, Mwp [44% reliability*]) and direct tsunami discriminants (e.g. TdT50Ex [74% reliability*]). For most regions, and with no EEW network, this time delay exceeds the tsunami arrival time for coast lines within a few tens of kilometers of a potential tsunamigenic earthquake. Non-saturating magnitudes (e.g. mBc, Mwpd [76% reliability*]) and additional tsunami discriminants (e.g. TdTo [72% reliability*]) are available before the tsunami arrival time for coastlines at about 50-100 km; CMT solutions and magnitudes [68% reliability*] are available for coastlines at 100-200km.

*reliability for correctly identifying tsunamigenic earthquakes, see ***Lomax and Michelini (2012)***

6. Other technologies

Warning for coastlines closer than about 50-100km from a tsunami source will rely primarily on direct, non-seismic information such as people feeling earthquake shaking and local instrumental or photographic wave-height measures.

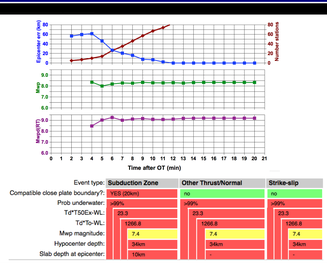
Stromboli, Italy

Multi-sensors buoys, GPS, airborne and space systems, real-time tsunami forecasting, citizen devices, and other technologies will add a spectrum of direct and derived information on various time scales after an earthquake.

7. Information and decision aids

Evolutionary presentation of graphical and text information along with color-coded decision diagrams are critical for automated and human analysis actions in response to an ongoing event.

Real-time seismic, GPS, wave-height and other information can be combined with prior information (e.g. nearby plate boundaries and faulting types, subduction slab depth) and derived information (e.g. probability event is underwater, event type from focal mechanism, CMT and finite-fault modeling).



8. Conclusions

The current and future state of seismic monitoring for the Mediterranean region can provide within 2-10 min important basic information for earthquake sources, including location, size and faulting mechanism, along with direct indicators of tsunami potential. Comprehensive physical characterizations of the source, such as CMT moment-tensors and finite faulting models may be available within 20 min.

Since effective tsunami warning requires notification 5 or more minutes before a tsunami strikes, this seismic information can contribute to warning for coastlines at greater than about 50-100 km from a tsunamigenic earthquake. For closer coastlines, warning will require direct response of the affected population, advanced seismic early-warning networks, direct GPS and wave-height measures, and other technologies. Programs emphasizing tsunami awareness and individual response actions for the general population are of utmost importance.

References:

***Lomax, A. and A. Michelini (2012)**, Tsunami early warning within 5 minutes, Pure and Applied Geophysics, 169.*

***Lorito et al. (2008)**, Earthquake-generated tsunamis in the Mediterranean Sea: Scenarios of potential threats to Southern Italy, JGR, 113.*

***Basili et al. (2013)**, Integrating geologic fault data into tsunami hazard studies, Nat. Hazards Earth Syst. Sci., 13.*

***Roudil et al. (2013)**, The French Tsunami Warning Center for the Mediterranean and Northeast Atlantic: CENALT, Tsunami Soc. Int. 32.*

Seismic stations
(from ORFEUS WG1: Broadband Station Database)

Earthquake/tsunami source regions
(Lorito et al. 2008; EDSF http://diss.rm.ingv.it/share-edsf)

0 km 1000 km

early-est.rm.ingv.it

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