Establishing a Tsunami Warning Center in Turkey

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ABSTRACT

Historical and instrumental studies reveal the complex nature of plate interactions and crustal deformation in an around Turkey, that are mainly presented by devastating earthquakes accompanied sometimes by catastrophic tsunamis. In addition to earthquakes as tsunami sources, massive land movements, such as in the case of the Santorini event around 1600 BC or the Fatsa Tsunami triggered by the Erzincan (Turkey) earthquake in 1939 gives a clear indication that the entire region surrounding Turkey is prone to tsunami events. Therefore, it is evident that a Tsunami Warning System needs to be put in place especially covering the Eastern Mediterranean, since tsunamis in the future could be even more damaging than the past events, when considering increased population density and economic activity in the coastal zones, such as ports, shipyards, marinas, nuclear and thermoelectric power plants, oil refineries and coastal airports.

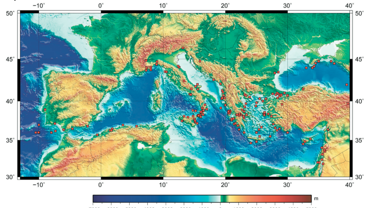

Figure 1: Distribution of tsunamis in the southern European Region, covering the period from 1600 BP to 2006. The most important tsunamigenic regions are in the Gulf of Cadiz, north of Algeria, southern Italy, along the Hellenic Arc, with its eastern continuation involving Cyprus and Marmara Sea. (Stefano Tinti, 2009)

To address the needs of a Tsunami Warning System, KOERI has taken the lead to set up a Tsunami Warning Center, which is expected to act also as a regional center under the UNESCO IOC – ICG/NEAMTWS initiative. The project is fully supported by relevant national institutions and agencies. KOERI is responsible for the operation of the National Earthquake Monitoring Network for Turkey consisting 116 broadband and 22 short period seismometers. KOERI is also in the process of enhancing its observational capabilities with the deployment of 5 sea bottom observation systems in the Sea of Marmara, including broadband seismometers and differential pressuremeters, pressure transducer, strong-motion sensor, hydrophone, temperature measurement device and flow meter. The deployment phase is finalized in December 2010 and the system is fully operational. The seismic component of the sea-bottom observation system will improve the spatial distribution of the existing seismic network, especially after the integration with the land-based stations. Existing seismological network is being improved especially in the coastal regions and bilateral agreements were concluded with several neighboring countries to exchange seismological data. A protocol with the responsible national agency for sea level monitoring has been concluded and currently three tide-gauge stations are transmitting data to IOC Sea Level Station Monitoring Facility. In addition, KOERI is considering to set-up its own tide gauge network consisting of 10 stations. NAMI DANCE Tsunami Simulation - Visualization Code has been installed in KOERI and some of the tsunami scenarios have already been simulated. The near-future goal is to create a tsunami model database based on deterministic approaches (scenarios) and to derive tsunami hazard and risk maps for Turkey. KOERI is currently functioning as the de facto National Tsunami Warning Center and is expected to provide regional coverage to Eastern Mediterranean, Aegean and Black Sea in 2012.

DECISION SUPPORT SYSTEM FOR TWC

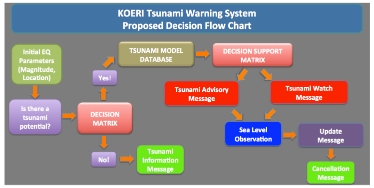

Figure 2: Proposed Decision Support System for KOERI - TWC.

The Decision Support System (Fig.2) proposed for the TWC relies primarily on the initial earthquake data, from which the tsunamigenic potential of the earthquake can be assessed based on the [Draft] Decision Matrix (Fig.3) proposed by ICG/ NEAMTWS. The type of the Tsunami Message will also be determined based on the same matrix in connection with the Decision Support Matrix (Fig.12).

Decision Matrix for the Mediterranean

Depth	Location	Mw	Tsunami Potential	Tsunami Message Type: Local	Regional	Basin-wide
<100 km	Under or very near the sea (D < 30 km)	5.5-6.0	Small potential for a destructive local tsunami	Advisory	Information	Information
		6.0-6.5	Potential for a destructive local tsunami	Watch	Advisory	Information
		6.5-7.0	Potential for a destructive regional tsunami	Watch	Watch	Advisory
		>7.0	Potential for a destructive basin-wide tsunami	Watch	Watch	Watch
	Inland (D<30 km)	≥5.5	No tsunami potential	Information	Information	Information
≥100 km	All locations	≥5.5	No tsunami potential	Information	Information	Information

Figure 3: NEAMTWS [Draft] Decision Matrix for the Eastern Mediterranean.

SEISMIC MONITORING

Figure 4: Seismic stations with real time data transmission to KOERI.

KOERI Seismic Network comprises 116 broadband and 22 short period seismometers operated by National Earthquake Monitoring Center (NEMC) and satellite systems are being used for the communication since 2004. NEMC is also receiving real-time data from 72 stations from 10 networks in SeisComp3 compiled by GEOFON, reaching up a total of 223 stations with the agreements concluded with some other countries in the region (Fig. 4). SeisComp3 software, provided by GFZ, is now being used successfully and NEMC is able to produce analysis within 2 minutes for earthquakes in Turkey and within 30 sec. to 15 minutes for earthquakes in its surrounding region according to the event magnitude and distance.

AGREEMENT WITH CTBTO

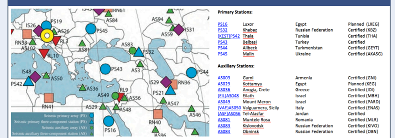

Figure 5: List and locations of IMS stations selected for real-time data transmission to KOERI.

In collaboration with UNESCO, CTBTO began providing real-time and continuous data on a test basis in March 2005 to four Tsunami Warning Centers in Australia, Hawaii, Japan and Malaysia. Based on the success of this test phase, CTBTO has now entered into formal tsunami warning agreements and arrangements with Japan, Australia, the Philippines, the United States, Indonesia, Thailand, Malaysia, and France. Turkey concluded an agreement in February 2011 to accomplish a better azimuthal coverage and real time data from 6 primary and 10 auxiliary IMS stations would be transmitted to NEMC.

OCEAN BOTTOM OBSERVATION (OBO) UNITS

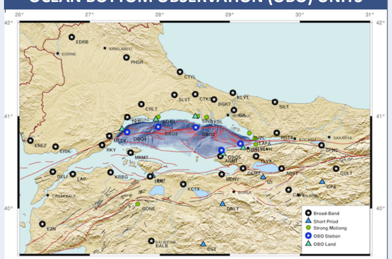

Figure 6: Locations of OBO Units deployed in Marmara Sea.

KOERI is starting a new era in its observational capabilities by installing 5 sea floor observation system in the Sea of Marmara within the Sea Bottom Observatory Project supported by Turkish Telecom, including broadband seismometer and differential pressure-meter, pressure transducer, strong-motion sensor, hydrophone, temperature measurement device and flow meter. The deployment phase is finalized in December 2010 and the system is fully operational. The seismic component of the sea-bottom observation system will improve the spatial distribution of the existing seismic network, especially after the integration with the land-based stations. It will also reduce the early warning time and the minimum magnitude threshold down to 1.0 in the Marmara Sea, especially close to the northern branch of North Anatolian Fault (NAF), which is the most active fault zone in the Marmara Sea.

Figure 7: Scenes from OBO Deployment.

STRONG MOTION NETWORK

Figure 8: Locations of strong motions sensors being installed at Base Transceiver Sites of a major GSM company in Turkey.

In cooperation with TURKCELL (a major GSM company in Turkey), KOERI is enlarging its strong-motion network to promote real-time seismology and to extend Earthquake Early Warning System countrywide. Within the scope of this project, 30 strong motion sensors are being installed Base Transceiver Station Sites in coastal regions (Fig. 8).

SEA LEVEL MONITORING

Figure 9: Tide-gauge network operated by General Command of Mapping

General Command of Mapping (GCM) is responsible for the operation of the tide-gauge network (19 stations) in Turkey. Currently 3 tide gauge stations are transmitting data on ftp to the IOC Sea Level Station Monitoring facility and work is underway to establish real time satellite data transmission. All stations are expected to be integrated to the TWS in the future. Seismic Instrumentation designer and manufacturer GURALP has produced a prototype tide gauge instrument for KOERI and it will be co-located in the Marmara Ereglisi tide gauge station for testing and calibration purposes. KOERI is planning to purchase in total 10 tide gauge instruments to establish its own tide gauge network in the areas not covered by the existing GCM network.

Figure 10: Map of tide-gauge stations transmitting data to IOC Sea Level Monitoring Facility (top left) and example data from Bodrum tide gauge station (top right). Pictures of Bodrum station (bottom left and right) and prototype GURALP tide gauge instrument (bottom center).

TSUNAMI MODELING

Initial work on the creation of the Tsunami Model Database had started in 2010 using NAMI DANCE Tsunami Simulation and Visualization Software developed by Andrey Zaytsev, Ahmet Cevdet Yalciner, Anton Chernov, Efim Pelinovsky and Andrey Kurkin. An example is shown in Fig. 11. KOERI is also in the process of signing a collaborative agreement with JRC, according to which JRC will provide KOERI its existing tsunami simulation database and an updated version of the database will be provided based on the initial conditions provided by KOERI after careful study of the characteristics of tsunamigenic source regions in the Black Sea, Aegean Sea and the Eastern Mediterranean.

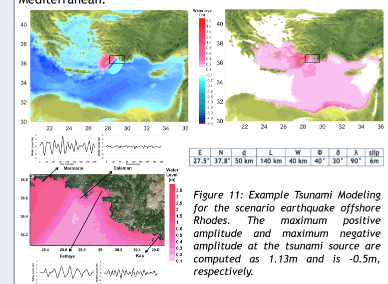

Figure 11: Example Tsunami Modeling for the scenario earthquake offshore Rhodes. The maximum positive amplitude and maximum negative amplitude at the tsunami source are computed as 1.13m and is -0.5m, respectively.

TSUNAMI FORECAST POINTS

The model database will enable TWC to assess the tsunami height at predetermined Tsunami Forecast Points, upon which the type of the warning message will be determined based on [Draft] NEAMTWS Decision Support Matrix (Fig.12). Locations of Tsunami Forecast Points are selected based on the criteria received from Disaster and Emergency Management Presidency such as locations of ports, shipyards, marinas, (future) nuclear power plants, thermoelectric power plants, oil refineries, coastal airports, touristic destinations, densely populated beaches; together with locations affected from historical tsunamis, and existing tide-gauge stations. Prof. Ahmet Cevdet Yalciner has revised the list with reference to tsunami modeling requirements.

	Advisory message	Watch message
Wave amplitude	0.2–0.5 m	> 0.5 m
Run-up	< 1 m	> 1 m
Impact	Current, bore, damage in water; possible minor inundation on beaches	Watch impact + inundation of low-lying coastal land

Figure 12: NEAMTWS [Draft] Decision Support Matrix and Tsunami Forecast Points

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