Some Remarks on the M_w=6.6 Earthquake of 2 May 2020 and the Local Tsunami in South Crete, Greece

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Introduction

This short technical report analyzes briefly the M_w=6.6 earthquake of 2 May 2020 and the local tsunami that followed it in south Crete, Greece, as it is documented from tide-gauge records, eyewitness accounts, pictures and videos. Information about the tsunami alerts issued ~10 min from the origin time of the earthquake is also provided.

Earthquake and tsunami history

Crete island occupies the central segment of the Hellenic arc and trench system, which is characterized by very high seismicity due to the subduction of the Nubia lithosphere underneath the south Aegean Sea area (e.g. Bocchini et al., 2018 and references therein). Historically the largest earthquakes ruptured at the west and east of Crete area on AD 21 July 365 and AD 8 August 1303 (e.g. Guidoboni et al. 1994, Guidoboni and Comastri, 2005, Ambraseys, 2009) with estimated magnitudes of 8.3 (±0.3) and 8.0 (±0.3), respectively (Papazachos and Papazachou, 2003, Papadopoulos, 2011, 2015) (Fig. 1). Both earthquakes were

associated by very strong, destructive tsunami waves that inundated large parts of the eastern Mediterranean basin.

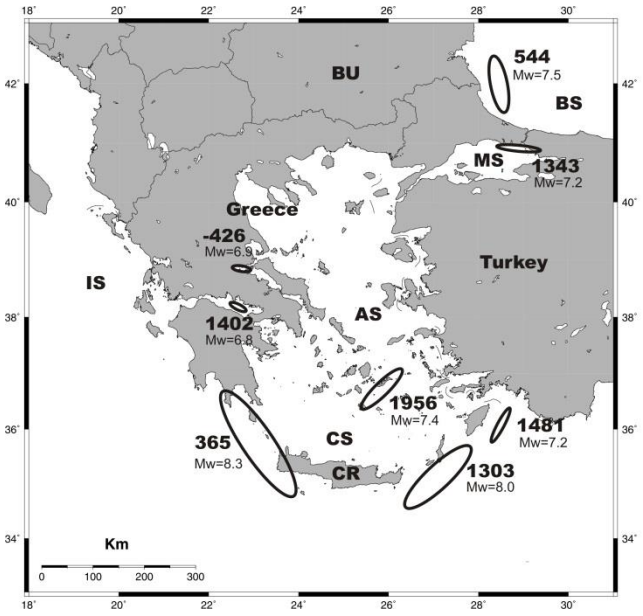

Fig. 1. Source areas of the largest tsunamigenic earthquakes which are historically known in Greece and the surrounding areas. Key for geography: AS=Aegean Sea, BS=Black Sea, BU=Bulgaria, CR=Crete, CS=Cretan Sea, IS=Ionian Sea, MS=Marmara Sea. Symbol key: Figure near source area=year of earthquake occurrence; - means BC date; M_w=moment-magnitude (after Papadopoulos and Papageorgiou, 2014).

However, no strong tsunamis are known to have been generated along the south side of Crete with the possible exception of a tsunami recorded at Gortyn and perhaps further to the west Crete occurring in AD 66 (± 1) after a ~6.4 (±0.2) earthquake (Papadopoulos, 2011). This is consistent with that no very large earthquakes of magnitudes comparable to those of 365 and 1303 have been recorded at the south of Crete. From an exhaustive review of the geological, archaeological, historical and instrumental data it results that strong earthquakes with magnitudes ranging from~6.3 to 7.0 occurred there in 1805, 1815, 1952 and 1972 (Papadopoulos, 2011). On 1 July 2009 a strong earthquake (M_w=6.5) to the south off Ierapetra caused a local tsunami of ~0.3 m wave height (Bocchini et al., 2020). This event is of particular importance for better understanding the recent earthquake and tsunami of 2 May 2020.

The 2 May 2020 earthquake

The tsunamigenic earthquake (Fig. 2) occurred on 2 May 2020 at 12:51:06.5 UTC. According to the determinations of GFZ (http://geofon.gfz-potsdam.de/eqinfo/event.php?id=gfz2020ipwv&from=email) the hypocenter has been located at 25.75°E/34.27°N/h=10 km, while its magnitude was M_w=6.6. The Institute of Geodynamics, National Observatory of Athens (NOA), initially determined magnitude M_L=6.0 and a hypocenter lying further to the south. NOA, INGV and KOERI determined different initial focal parameters which were used to issue tsunami warning messages.

The perceptibility of the 2 May 2020 earthquake in Ierapetra town and in nearby villages along the southern coast of Crete has been of duration of at least 30 s, perhaps more. Considering the large magnitude of the event and the relatively long epicentral distance from Ierapetra, this duration estimation looks realistic. However, some walking people in Ierapetra reported no earthquake felt. Reliable eyewitnesses that experienced the earthquake at the northern Crete coastal zone, e.g. in Heraklion city, reported that the earthquake was either slightly felt or not felt at all. No damage was reported from this earthquake. A map of earthquake felt reports is illustrated in Fig. 3.

The 2 May 2020 earthquake has been quite similar to the one that occurred in the same area on 1 July 2009 with comparable magnitude of M_w=6.5 (Bocchini et al., 2020, first online publication in 2019). The focal mechanisms of the two earthquakes are also similar (Fig. 3), showing reverse faulting striking ~W-NNW and dipping ~N-NNE. For the 2009 earthquake it has been suggested that the seismic faulting occurred not along the main plate interface but very likely on a high angle reverse fault (i.e. splay fault) in the upper-plate (Bocchini et al., 2020).

Fig. 2. Felt reports about the earthquake of 2 May 2020 (EMSC, https://www.emsc-csem.org/Earthquake/popup_intensmap.php?id=853296&f=/FELTREPORTS/85/853296/IntensityMap.png). No intensity exceeding IV has been reported.

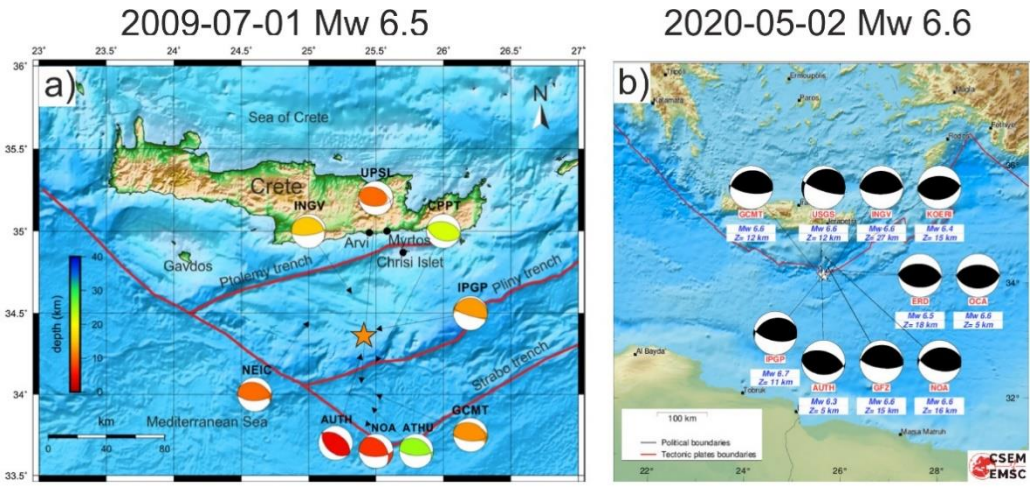

Fig. 3. A seismotectonic comparison of the tsunamigenic earthquakes of (a) 1 July 2009 and (b) 2 May 2020 to the south of Crete; (a) adapted from Bocchini et al. (2020), (b) readapted from the European-Mediterranean Seismological Centre (www.emsc-csem.org, accessed 08-05-2020).

The tsunami

Soon after the earthquake local authorities and eyewitnesses reported a tsunami along the south coast of the eastern side of Crete Isl. There are various relevant videos and pictures posted by the press as well as by amateurs (see Appendix).

From the observational material collected it is evident that the tsunami appeared as a series of relatively short-period oscillations at the harbors of Ierapetra town as well as of Arvi and Kastri villages further to west (Fig. 4). At the same time strong water currents were observed.

Fig. 4. The tsunami generated by the earthquake of 2 May 2020 was documented in Ierapetra, Arvi, Kastri (to the west of Arvi) and Chrysi islet. The 1 July 2009 tsunami was observed in Arvi, Myrtos and Chrysi islet.

The maximum sea level rise and drop was macroscopically estimated at ~20-30 cm (Fig. A1). No damage was reported from the tsunami. The tsunami was also observed and documented in the small port at the north side of Chrysi islet situated to the south of Ierapetra (Figs. 4, A2). In that spot a few small vessels were stranded as if on dry land (Fig. A3). Eyewitnesses reported that the tsunami of 1 July 2009 was observed in Arvi and Myrtos villages as well as in the north side of Chrysi islet (Bocchini et al., 2020) (Fig. 4). No tide-gauges were operating in the area at the time. However, one video record which is available to us documented the strong water flow in the harbor of Arvi.

In Kasos tide-gauge record (Fig. 7) the sea water disturbance initiated at ~13:39 UTC. The wave oscillations terminated at ~22:08 of 2 May 2020. The peak amplitude A~0.05 m was recorded at 13:53 while the wave period was found T~8 min. Inspection of the tide-gauge record at the station of Zygi Marina (Cyprus, Fig. 5) showed no clear evidence for the tsunami arrival there.

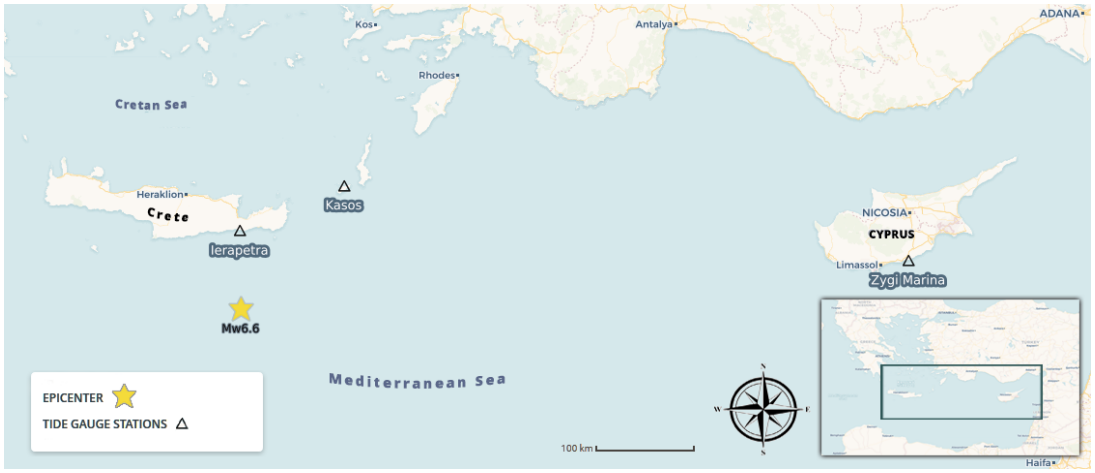

Fig. 5. The three tide-gauge stations inspected for the investigation of the 2 May 2020 tsunami.

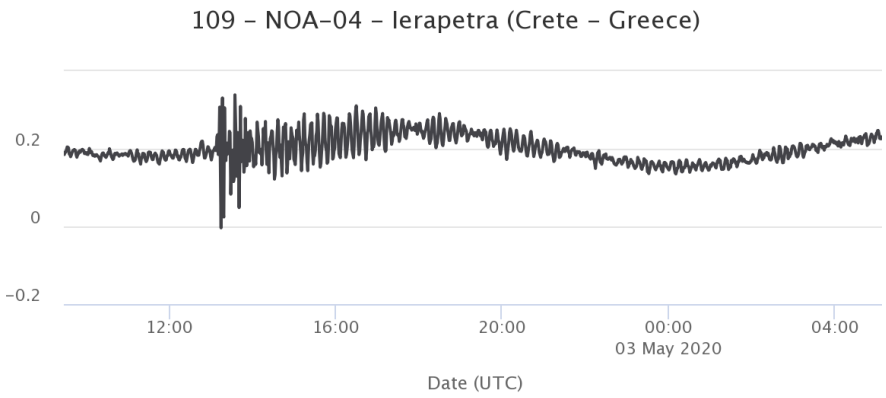

Fig. 6. Tsunami record at the Ierapetra tide-gauge station.

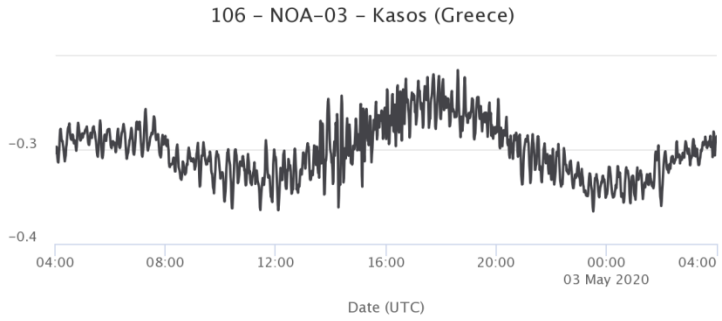

Fig. 7. Tsunami record at the Kasos tide-gauge station.

Tsunami alerting

In the upstream component of the North-East Atlantic and Mediterranean Tsunami Warning System (NEAMTWS) and of the national systems supporting NEAMTWS, the Tsunami Service Providers (TSPs) of INGV (Italy), KOERI (Turkey) and NOA (Greece) issued a series of tsunami warning messages classified in three types: Initial message (I), Ongoing message (O), End message (E). The I-type messages are based on the very first solutions of the seismic event available to each TSP. The O-type messages are issued when updated earthquake solutions and/or real tsunami observations are available. The E-type messages are issued when TSPs decide that there is no more information of operational interest available for dissemination.

The three TSPs issued I-type messages within an average time of 10 (±2) min from the earthquake origin time, which is equal to the target time adopted by the Intergovernmental Coordinating Group (ICG) of NEAMTWS at the current

stage of the system development. The messages were released some minutes before the first wave arrival, thus allowing a little time for operational actions on behalf of the authorities. The forecasted times of arrival at the closest forecast points in south Crete as contained in the I-type messages fit well-enough the recorded wave arrival.

O-type messages were also issued by the three TSPs when tide record data and/or revised earthquake solutions were available to them. As regards the issue of O-type messages no target time has been set up by the ICG/ NEAMTWS but it relies on the best practices applied by each TSP and the data available at the moment. The three E-type messages were issued by the three TSPs within a narrow time window of 14 min about 3 hrs from the earthquake origin time. Roughly speaking it looks like a realistic time interval to end the alerting procedure. Central and local civil protection authorities responded to the alerting released by NOA. However, going through more operational details is beyond of the scope of the present report.

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Appendix: Tsunami observational material

(a) List of video shooting documenting the tsunami in Arvi coastal area

https://www.youtube.com/watch?v=9Qobru4x4WQ&feature=youtu.be

https://www.facebook.com/100001618268477/videos/3088854047845174/

https://www.youtube.com/watch?v=ePnn4g64LeM&feature=youtu.be

https://www.youtube.com/watch?time_continue=1&v=0JrdCBKssn8&feature=emb_logo

(b) Pictures

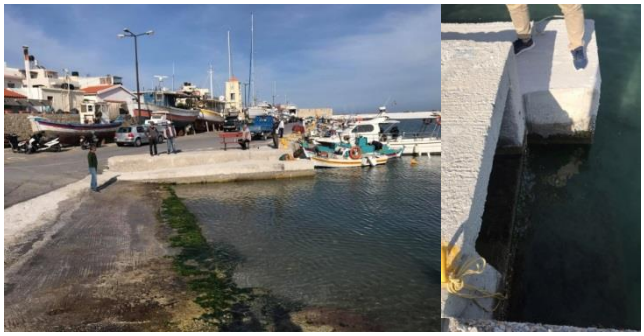

Fig. A1. Sea water retreat (left) and sea level drop (right) at the Ierapetra harbor .after the earthquake of 2 May 2020.

Fig. A2. The small port at the north side of Chrysi islet at normal sea level.

Fig. A3. Initial (left) and final (right) sea retreat in the small port of Chrysi islet. The boat was tied to avoid drifting away during the sea retreat.