A critical evaluation of tsunami records reported for the Levant Coast from the second millennium BC to the present

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Short title: Evaluation of tsunami records for the Levant coast

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ABSTRACT

We present here a compilation of known, reliable, historically documented tsunamis that have affected the Levant coast between about the 14th century B.C. in Syria, up through the 1956 Jaffa tsunami. The list is based on a careful review of published studies and catalogs that have previously reappraised the original contemporaneous sources. In total, 23 events are included within our compilation, whereas 40 other events were found questionable and excluded.

We first describe the dependable tsunamis in detail, including their probable source, whether they were generated from a close or distant earthquake source, or whether they were likely the consequence of an earthquake-triggered submarine slump. This is followed by a critical evaluation of the dubious (uncertain) tsunami reports, as an aid to future investigations that may include a search for new data, fieldwork, modeling and hazard assessments. Next, the list is parameterized in accordance with the format used by the tsunami catalog of the European community.

Finally, the historical descriptions are used to assess the impact and effects caused by the tsunamis. The most regularly mentioned (about 90%) is a significant change in sea level. Damage and loss of life in coastal cities and harbors are reported for only one third of the events, leading to the conclusion that the majority of tsunamis on the Levant coast may have resulted in only moderate to no damage. Yet, this is not to mean that the Levantine coast is not at risk. The modern coastline is now far more populated and developed than before, and a similar tsunami that resulted in only moderate damage in the past might be more disastrous in the same location at present.

INTRODUCTION

There is only a single modern record of the occurrence of a tsunami in the Levant; the 1956 Jaffa event (Goldsmith and Gilboa, 1986). In addition, there are some possible tsunami related deposits documented from Caesarea (Reinhardt et al., 2006; Goodman-Tchernov et al., 2009), some assumed findings of tsunami deposits along the Mediterranean coast of Israel by Pfannenstiel (1960; discussed by Dominey-Howes, 2002), and dubious evidence of tsunamites in the Neolithic village of Atlit-Yam (Pareschi et al., 2006, 2007; disproved by Galili et al., 2008). Thus, the limited number of records of historical tsunamis in the Levant is by far the most comprehensive database available.

Recent efforts have focused on constructing reliable historical earthquake and tsunami catalogs which rely directly on accounts from original contemporaneous sources (e.g., Guidoboni et al., 1994; Guidoboni and Comastri, 2005; Ambraseys, 2009). This contrasts with a considerable number of previous works that unintentionally introduced spurious accounts into the published literature. It seems that a critical mass of reliable information has now been accumulated, enabling a preliminary integration and evaluation of the full set of observations. Indeed, such a study was conducted by Salamon et al. (2007), who presented a specific list of reliable and doubtful historically reported tsunamis for the Levantine coast.

More recently, a new earthquake catalog was published (Ambraseys, 2009) and another tsunami catalog of the eastern Mediterranean have appeared (Fokaefs and Papadopoulos, 2007). The list presented by Ambraseys and Synolakis (2010) is only a critical evaluation of the parametric catalogue of Fokafes and Papadopoulod (2007). Even though Ambraseys and Synolakis (2010) claim to "… propose a new list", their paper still miss several significant Levantine sea waves such as the Mid 2nd century B.C., 1033, 1068 and others. Interestingly enough, the missing events were mentioned previously in Ambraseys (2009). Therefore the list of tsunamis presented by Ambraseys and Synolakis (2010) can not be considered satisfactory for the Levant.

In addition, detailed investigations and discussions of the major 365 A.D. earthquake and tsunami were presented (Shaw et al., 2008; Lorito et al., 2008; and Guidoboni and Ebel, 2009), scenario modeling and sensitivity analysis of tsunami hazard in the Eastern Mediterranean that are based on historical events were conducted (Hamouda, 2010, Yolsal and Taymaz, 2010), the extent and volume of submarine landslides along the Levant continental margins and the Nile cone is better known (Frey-Martinez et al., 2005; Garziglia et al., 2007, 2008), and new findings and discussions regarding tsunami related evidences in Israel have been raised (e.g., Pareschi et al., 2006, 2007; Galili et al., 2008; Reinhardt et al., 2006; Goodman-Tchernov et al., 2009).

Although all the above mentioned does not seem to changes the list presented by Salamon et al. (2007) significantly, we find it important and useful to present an updated list in an extended and detailed format, of what was previously presented in a brief form and at the background of the study. This, of course, does not devalue the effort needed to search for and expand the inventory of original sources. As new materials are discovered and better interpretation of existing material appears, there will be a need to reexamine the data.

We then use the updated list to construct a reliable scope of damage and associated effects that were caused by the tsunamis. It is hoped that this approach allows for a more realistic tsunami hazard evaluation for Israel, and avoids the tendency to overrate the potential impact of insufficiently investigated natural hazards as have occured previously in other places (examples in Ambraseys and Synolakis, 2010). In addition, there is a need to parameterize and quantify the historic events in accordance with the worldwide standard format to be more useful for TRANSFER (Tsunami Risk And Strategies For the European Region, 2006) and ICG/NEAMTWS (Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the North Eastern Atlantic, the Mediterranean and Connected Seas, 2009).

Methodology

We followed the methodology of Salamon et al. (2007, with the Electronic Supplement) and Salamon (2010) to assess the dependability or doubtfulness of particular events. We include essentially the same data set and verification procedures of the given tsunami reports, according to the authenticity of the primary sources. Although this work aims at reconstructing the tsunami history of the Israeli coast, it was necessary to also examine the historical reports of tsunamis that affected nearby coasts, as well as the areas from which the tsunamis may have originated, simply because tsunamis can travel from afar. Included here are the eastern basin of the Mediterranean and its easternmost coasts (Figure 1).

All in all, the listing of the reliable events that first appeared in a condensed format in Salamon et al. (2007) is now presented in a broader form with extended details. The list is then constructed, organized and parameterized (table 1) in accordance with the European format (TRANSFER, 2006; ICG/NEAMTWS, 2009). Complementary to the dependable records is the list of doubtful events that in fact presents the reader the full scope of the existing information (Table 2). Reference to reports of seismic sea waves in the Sea of Galilee, Dead Sea and Gulf of Elat (Aqaba), are given in Table 3. Summaries of the effects and damage from each of the reliably reported tsunamis are provided in Table 4. The synopsis of all of these reports gives a perspective through time and space of what has occurred in the Levant. Finally, the findings of this work are discussed along with some important implications that relate to tsunami hazards to Israel.

Descriptive list of the dependable historical tsunamis

From the earliest known historical tsunami, in about 1365±5 B.C. in Ugarit, Syria, until the latest seismic sea wave of July 9, 1956, which was recorded in Jaffa, there have been reliable reports of about twenty tsunamis that occurred in the study area. Unlike earthquakes that usually are cataloged according to their areas of origin, the tsunamis are listed here by the coasts that they affected, for this is the concern of this work. It therefore involves tsunamis originating from various sources, both near and far.

The tsunamis are described by the time of occurrence of the tsunamigenic source in terms of the range of dates, or the year, month, day, hour or part of the day or night, as detailed as known; the areal extent of the tsunami, whether local, regional or basin-wide; the presence of a receding phase, and the associated effects. Unfortunately, most of the sources are not specific in describing the tsunami parameters, such as an accurate time, cause and the localities affected, and therefore the description is only partially complete. References to publications that refer and rely directly on the original sources, and reliably analyzed the events in addition with other relevant data and interpretations, including problematic and contradictory information, are also mentioned. Finally, the most probable tsunamigenic source is suggested.

1365±5 BC: Ugarit, Syria, was flooded and half destroyed

Ambraseys (1962) and Ambraseys et al. (2002) note a tablet from Tel Amarna in Egypt that contains a report of the King of Tyre sent to Amenhoteph-IV (1353-36). The King of Tyre reports that half of the town of Ugarit has been destroyed by fire. According to other contemporary tablets (Dussaud, 1896; Virolleaud, 1935), the other half of the town was allegedly destroyed by a sea wave. Ambraseys (2009), however, does not mention this event again.

Ambraseys (1962) enters another tsunami in the 2nd millennium B.C. on the Syrian coasts, but seems to rely on the same sources as for the 1365 B.C. event. It therefore can be assumed that the two entries refer to the 1365 B.C. event. Soloviev et al. (2000) suggest that these writings refer to the events of 1380 ± 100 B.C. and to the period between 1700 B.C. and 1380 B.C. However, they seem to consider this as the Thera (Santorini) Late Minoan (LM) tsunami rather than the Ugarit sea wave.

The tsunamigenic source is not mentioned. Furthermore, analyzing the tablets, Ambraseys et al. (2002) make the point that the fire and the flood might not have occurred at the same time, and that there is no mention of an earthquake associated with it. They add that archaeological excavations in Ugarit do reflect its destruction by several earthquakes (Schaeffer, 1939), but there is no indication of seismic activity at the time of the proposed tsunami. Interestingly, Goren et al. (2004) examined the clay material the tablets were made of, showing it originated from Syria, which thus strengthens its authenticity.

Mid 2nd century B.C.: The sea rose between Tyre and Ptolomais, southern Lebanon and northern Israel

Following the literature, the sequence of events during the 2nd century B.C. can be interpreted as follows:

I. Second century B.C., earthquake. According to Guidoboni et al. (1994), Ambraseys and White (1997) and Ambraseys (2009), there was an earthquake in Sidon, Phoenicia and Syria in 199–198 B.C. Karcz (2004) raises the possibility that the report about the earthquake and submergence at nearby Sidon could be associated with the mid 2nd century B.C. tidal wave between Ptolemais and Tyre.

II. Mid 2nd century B.C., tsunami. Karcz (2004) interprets the sea wave that occurred between Tyre (southern Lebanon) and Ptolemais (Acre or Akko, northern Israel) in

Phoenicia, probably in 143/142 B.C., as a tsunami. Following the original sources, Karcz (2004) describes: "… wave from the ocean lifted itself to extraordinary height and dashed upon the shore engulfing all men and drowning them…". Ambraseys (2009) and Ambraseys and White (1997) suggest that the wave flooded the shore between Ptolemais and Sidon. They date the event to 139 B.C. and note that there is no evidence that this event was associated with an earthquake. Shalem (1956) suggests it occurred in about -140 B.C..

III. 148 02 21 or 130 B.C., earthquake. Ambraseys and White (1997) and Guidoboni et al. (1994) note an earthquake in Antioch. Karcz (2004) dates this event possibly on 146 B.C. or 140 B.C.

IV. 92 02 28 B.C., false earthquake and false tsunami. According to Karcz (2004), this earthquake and tsunami were imported into the Israeli catalogues from elsewhere, most probably from the mid 2nd century B.C. earthquake and tsunami in the Eastern Mediterranean. The wrong entries are referred to, for example, Shalem (1956), Ben-Menahem (1991), Amiran et al. (1994), and others. Ambraseys (2009) also regards this as a spurious event.

V. Ca. 90 B.C., earthquake. Ambraseys and White (1997), Guidoboni et al. (1994), Karcz (2004) and Ambraseys (2009) mention an earthquake in Apamea Kibotos that is in Phrygia, Asia Minor.

In addition to the historical sources, Karcz (2004) mentions the significant paleoseismic event that was found by Gomez et al. (2003) on the Serghaya fault, Syria, and dated to 170 B.C – A.D. 20. Karcz (2004) maintains that although this was a considerable event (~2 m left lateral slip, Mw 7 - 7.2.), there is no direct evidence to associate it with the Mid 2nd century B.C. tsunami.

20 B.C.: Tsunami between Alexandria and Pellusium*, Egypt*

Ambraseys (1962) and Antonopoulos (1979) mention a tsunami along the Egyptian coast between Alexandria and Pellusium. Ambraseys (2009) dates it to 20 B.C. and summarizes after Strabo: "… the sea about Pelusium and Mt Casius rose and flooded the country and made an island of the mountain, so that the road by Mt. Casius into Phoenice became navigable…". Shalem (1956) places it in the Sirbuni (?) area *(Pellusium, Sabachat al-Bardawil)*, in the period of 20-24 B.C.

The cause of the tsunami is unknown. It could have been associated with the 17 B.C. earthquakes in Cyprus, but no tsunami was reported in relation with this earthquake. Ambraseys et al. (1994) list no earthquakes in Lower Egypt within this period of time.

115 12 13 morning: *Tsunami between Caesarea and Yavne, Israel*

Based on Judaic sources, Shalem (1956) suggested that the coast between Caesarea and Yavne was hit by a tsunami. Reinhardt et al. (2006) followed this and interpret underwater marine and geoarchaeological findings offshore Caesarea as reflecting a tsunami that occurred between the 1st century B.C. and 2nd century A.D., and which point to the tsunami of 115 A.D. as a contributing cause of the early destruction of Herod's harbor there. The recent study of Goodman-Tchernov et al.

(2009) defined several thin units in several cores taken offshore Caesarea, as deep as 10 to 20 m below sea level, as tsunamite deposits. This interpretation was based on several characteristics of the sedimentary deposits that are considered as tsunamigenic indicators, especially the anomalous particle-size distribution.

Much of these records are not equivocal and hence, verifying the occurrence of this tsunami is not a simple matter. Although the 115 A.D. earthquake happened while the Roman Emperor Trajan was visiting Antioch, and many cities in northwestern Syria were badly damaged including Antioch (Guidoboni et al., 1994, and Ambraseys, 2009, mainly after Dio Cassius), contemporary sources do not mention a tsunami. Regarding the Judaic sources, Karcz (1987) suggests that the "Talmudic references are not specific neither in time nor location, but Yavne may have been affected." Of note is the observation that the affected coast of Caesarea is far south of the interpreted location of the 115 earthquake, whereas most of the other tsunamis that followed earthquakes along the Dead Sea Transform system seem to have hit the shores more or less opposite to the inferred rupture zone.

As for the destruction of Herod's harbor, it was suggested (e.g. Reinhardt and Raban, 1999; Reinhardt et al., 1994; Raban, 1992; Hohlfelder, 2000; Galili E., and Zviely, D., personal communication, 2009) that the frequent strong winter storms may have destabilized its foundations, which in its western part were based on a sandy seafloor. This is a more plausible explanation that does not need to invoke a catastrophic tsunami, although the occurrence of a tsunami cannot be ruled out. Regarding the tsunamigenic indicators pointed by Reinhardt et al. (2006) and Goodman-Tchernov et al. (2009) in Caesarea, sea storms may affect the seafloor in shallow water in a similar way as do tsunamis. Therefore, relying on interpretation of possible shallow sedimentological indicators from cores at depths of 10 to 20 m as strong evidence of the tsunamis associated with the Santorini eruption or the 115 A.D or 551 A.D. earthquakes, should be done with care.

Meghraoui et al. (2003) associated the 115 earthquake with a left-lateral surface rupture of 4 - 4.5 m (Mw=7.3 - 7.5) along the Missyaf fault segment in Syria, about a 100 km south of Antioch. Ambraseys and Jackson (1998) estimated that this was a large, $7.0 > Ms \geq 7.8$, event.

Overall, while some of the historical accounts seem questionable, the accumulation of tsunami related physical findings in Caesarea, which is the only evidence beyond historical text available for the Levantine coast at present, may supports the occurrence of a tsunami. Nevertheless, further investigations are certainly needed in this case.

365 07 21 before sunrise: *Major tsunami in Alexandria, Peloponnesus, Adriatic and Sicilian coasts*

The earthquake and associated tsunami of July 21, A.D. 365 are considered as one of the most destructive events in the eastern Mediterranean during historical times (studies by Ambraseys et al., 1994; Ambraseys et al., 2002; Dominey-Howes, 2002; Guidoboni et al., 1994; Shaw et al., 2008; Stiros, 2009; Ambraseys, 2009; and others).

Following the historical accounts, Ambraseys et al. (1994) conclude that "… in Alexandria alone 50,000 houses were flooded and 5,000 people were drowned; ships were carried by the waves over the city walls and boats in the Nile were deposited on dry land about three and a half kilometers from the river […] The sea-wave had equally destructive effects in other parts of the eastern Mediterranean region […]. In Crete, the Peloponnese, the Adriatic and Sicily it was far more serious than the shock itself". More details are given by Ambraseys (2009). The repeat time of such events along the Hellenic Arc was estimated by Shaw et al. (2008) to be on the order of 800 years.

Geophysics of the AD 365 earthquake and tsunami

By far, this earthquake and tsunami is the most thoroughly investigated historical event in the eastern Mediterranean. The uplift of the western end of Crete, with a maximum that is estimated at about 10 m, was first reported by Captain Thomas Spratt in 1851 (Spratt, 1865), and opened a new round of interest in this event. New work started with the research of Pirazzoli and Thommeret (1977), and was developed further by Pirazzoli et al. (1982, 1992, 1996), and still continues until today. Following Guidoboni and Ebel (2009), the recent findings are briefly summarized herein.

Two of the most recent interpretations have been published in parallel (Lorito et al., 2008; and Shaw et al., 2008), and both of them infer that the co-seismic uplift of western Crete was associated with the 365 earthquake; they estimated its magnitude to be in the order of Mw8.4. However, Price et al. (2002) proposed that this uplift occurred around AD 480–500, which is considerably later. Regarding the tsunamigenic source, Lorito et al. (2008) assumed that this uplift resulted from slip on the subduction interface, whereas Shaw et al. (2008) suggested the faulting occurred in the overriding plate. With these elements at hand, the authors worked out a predictive scenario for a possible tsunami.

The tsunami simulated by Lorito et al. (2008) predicted wave heights of greater than 1 m, with the largest peaks up to 5 m at some non-specified locations along the coast of northern Africa. For Egypt, an area for which there are available descriptions of the effects from written sources, Lorito et al. (2008) did not provide quantitative estimates, but indicated only that "probably as a result of edge waves, significant energy was trapped and carried along the coast of Egypt". Regarding Alexandria, the simulation of Shaw et al. (2008) showed that the waves generated off the shore of the city reached ~0.6 m in the open ocean. However, because of the many non-linear effects of the near-shore bathymetry and changes in the local conditions since 365, it was difficult to calculate the run-up in ancient Alexandria. In any case, the authors surmised, in analogy with the tsunami of Sumatra in 2004, that the onshore effects would be devastating.

As much as the new studies improve the understanding of the A.D. 365 event, the tsunami propagation models are still unable to account for the historical descriptions. Thus, it is still not possible to more accurately simulate the effects of the resulting run-up for a single locality, which in fact reflects our partial understanding of the tsunami hazard in this region.

Finally, it is perhaps relevant to remember that only the 1303 earthquake in central–eastern Crete caused a tsunami that was very similar to that of 365 (Guidoboni and Comastri, 1997, 2005). The effects were widely witnessed in Venetian sources, which at that time ruled the island. The 1303 tsunami hit Alexandria in particular, as given credence by numerous and authoritative Arab sources. Another large and destructive earthquake in Crete occurred on 12 October 1856 (Ambraseys et al., 1994), but this time, no tsunami hit Alexandria. It is this overall picture that needs a unifying explanation, which probably remains to be formulated.

551 07 09: *Tsunami in Lebanon, between Tyre and Tripoli*

This event has been mentioned by many authors, and all of them seem to refer to the same area although by different names. Ambraseys (1962) indicates a tsunami on the Syrian coast while Ambraseys et al. (1994) mention the coast of Phoenice. Amiran et al. (1994) locate the tsunami at the Lebanese coast and suggest it also may have affected Caesarea. Darawcheh et al. (2000) are more specific and restrict the tsunami to between Tyre and Tripoli. Detailed descriptions are given mainly by Guidoboni et al. (1994) and Ambraseys (2009) who state that "Along the coast of Phoenice the sea receded for many hours …, stranding sailing boats in the shallows. Then the sea came back, throwing ships on land, causing great havoc before returning to its original level."

Most studies (e.g., Ambraseys and Jackson, 1998; Ambraseys et al., 1994; Guidoboni et al., 1994; and references therein) place the tsunamigenic earthquake in, around, or offshore Lebanon, because of the many cities along the Lebanese and Syrian coasts, including Beirut, mentioned to have been destroyed. In Ambraseys's (2009) opinion, the most likely epicenter was inland, not far from the coast, while Darawcheh et al. (2000) are more specific and suggest the Roum fault as the source.

Recent studies of Daëron et al. (2004) and Elias et al. (2007), both of which were focused on the bathymetry offshore of Lebanon and the uplifted marine terraces along the Lebanese coast, suggest an earthquake on the Beirut (Mount Lebanon) thrust offshore of Lebanon as the probable source for the destruction and the tsunami. Based on several tsunamigenic indicators, Goodman-Tchernov et al. (2009) interpret some sedimentary deposits offshore Caesarea to have originated from this tsunami. This is further discussed in association with the 115 A.D. event.

746 01 18 morning: *Tsunami, possibly on the Levant coasts?*

Guidoboni et al. (1994), after Michael the Syrian, describe: "In the sea, too, there was an extraordinary storm, so that the waves rose up to the sky; and, just as a cauldron is made to boil by the flames of fire, so the waves surged with a horrible and terrifying noise. The sea boiled and overflowed, and it destroyed most of the cities and villages along the coast." This event is difficult to explain since this is the only source that deals with these waves and there is no mention of where the waves rose. Therefore, locating this tsunami is a matter of interpretation, and although the stormy waves and scope of damage (cities and villages) may suggest that the tsunami occurred in the Mediterranean, the Dead Sea and Sea of Galilee should not be ruled out. Ambraseys (2009), however, interprets the same information differently, and says that the storm hit at the northeastern coast of the Dead Sea and was not associated with the earthquake. This event is also mentioned by Karcz (2004) and Ambraseys (2005).

As for the probable tsunamigenic source, Guidoboni et al. (1994), after Theophanes, note that "… there was a powerful earthquake in Palestine, along the river Jordan and throughout Syria, and countless thousands of people were killed, and churches and monasteries also collapsed, especially in the desert near the Holy City (Jerusalem)." Paleoseismic evidence that were found along the Jericho segment of the Dead Sea Transform (DST) (Reches and Hoexter, 1981) and in Tiberias along the western coast of the Sea of Galilee (Marco et al., 2003), as well as seismogenic mixed layers at the Dead Sea basin (Migowski et al., 2004; Agnon et al., 2006), were associated with this event. Ambraseys (2005) estimated this as an Ms=7.0 event.

For this time period, several authors suggest different scenarios: Shalem (1956) suggests an earthquake and a tsunami on 746 01 18; Ambraseys (1962) list a tsunami on 746 01 18; Ben-Menahem (1991) note an earthquake on 746 01 18; Ambraseys et al. (1994) place the date of the earthquake on 747 01 18, Amiran et al. (1994) report an earthquake and a tsunami on 749 01 18; and Soloviev et al. (2000) mention an earthquake and possibly a tsunami in 746. Recent studies of Karcz (2004) and Ambraseys (2005, 2009) however, suggest the occurrence of at least three events: an earthquake and a sea storm in Israel on 746 01 18; another event in 749 or early in 750 that affected Mesopotamia and presumably the adjacent part of northern Syria; and an earthquake on March 9, 757, that affected Palestine and Syria.

803 06 23: *Massisa coasts, northwestern side of the Gulf of Iskenderun*

Antonopoulos (1980b) lists "… earthquake and an inundation at Massisah (Mopsueste) on the river Kjaihan, on 187 AH [AD 30 December 802 – 19 December 803]", which is in the northwestern side of Iskenderun Bay, Turkey. This tsunami was also mentioned by Ambraseys (1962) and Altinok and Ersoy (2000). Ambraseys (2009) dates this event to June 23, 803 but mentions a flood only.

1033 12 05: *Tsunami in Acre, and possibly nearby coast*

This earthquake and tsunami were widely referred to in the published literature. Ambraseys (1962) and Ambraseys et al. (1994) relate this tsunami to the coasts of Lebanon and Israel. Amiran et al. (1994) suggest that the tsunami occurred on January 4, 1034, in Jaffa and that the port of Akko fell dry for an hour. Soloviev et al. (2000) mention that tidal waves were observed in Gaza and Ashkelon, and that the seaport of Akko became dry for a long time and then it was half destroyed by a wave. Guidoboni and Comastri (2005) interpret that the tsunami effect is confined to Acre, but it is reasonable to suppose that the tsunami affected more of the coast. Ambraseys (2009) constrains the tsunami to Acre and suggests that it did not cause damage or loss of life inland. Shalem (1956), however, suspects it could have been duplicated from the 1068 event. Following the detailed analysis of Ambraseys et al. (1994) and Guidoboni and Comastri (2005), the tsunami can be constrained to the northern and central coasts of Israel only.

Regarding the cause of the tsunami, Amiran et al. (1994) mention a swarm of earthquakes during the winter of 1033/4, probably in the Jordan Valley, including the strongest shock on 1033 12 10 and another one on 1034 01 04. Ambraseys and Jackson (1998) and Ambraseys et al. (1994) also locate the earthquake in the Jordan Valley but date it on 1033 12 05. A detailed analysis by Guidoboni and Comastri (2005) suggests that the earthquake occurred on 1033 12 05, although Arabic sources give the date of 1033 12 05 as 1034 01 04. In their opinion, the date 1032 03 06 is confused with 1033 03 06, the date of the earthquake that occurred in Constantinople.

1036 03 12 - 1037 03 11: *Sea in Cilicia (?) billowed back and forth, southern Turkey, near the Gulf of Iskenderun*

Guidoboni and Comastri (2005) relate that "…the vast Mediterranean sea billowed back and forth…" in Cilicia, a region in southern Turkey facing the Gulf of Iskenderun. The earthquake occurred in Cilicia, southern Turkey, the northern side of the Bay of Iskenderun, probably not along the Dead Sea fault system. Ambraseys (2009), however, indicate that the original source provides no location for this event.

1068 05 29: *Sea in southern Israel receded and returned*

Ambraseys (1962) and Ambraseys et al. (1994) note a tsunami on 1068 03 18, along the coasts of Israel at Holotz Ashod *(Ashdod sands?)* and Yavneh. Ambraseys (2009) also refers to the event of March and mentions the retreat and return of the sea on the Mediterranean coast of Palestine and that a large number of people were drowned. Shalem (1956) and Soloviev et al. (2000) refer to this tsunami as well. Recent evaluation by Guidoboni and Comastri (2005), however, resolved two earthquakes at that time and associated the tsunami with the second one that occurred on May 29, 1068: "….The sea sank into the earth…".

Several earthquakes are mentioned within this time period, and they are mostly attributed to the event that occurred on March 18, 1068 in southern Israel. Ambraseys et al. (1994), Guidoboni and Comastri (2005) and Ambraseys (2009) refer also to other dates associated with this event, namely 1067 04 20, 1067 11 11, 1068 04 20, 1070 02 25, 1168 03 18 and 1169, and conclude that these are duplications and misreports of the earthquakes that actually occurred on 18 March and 29 May 1068. Amiran et al. (1994), who mention an epicenter in Antioch and destruction in Elat on 1063 +, may have confused reports from the event of 1063 in Tripoli, Lebanon, with those of the 1068 event in Elat.

Paleoseismic evidence attributed to the 1068 earthquake in the Southern Arava Valley (Amit et al., 1999; Zilberman et al., 2005) and also in the Northern Arava (Haynes et al., 2006) cannot distinguish between the March and the May options, although it might be assumed that a rupture in the southern Arava Valley is too far away from the Mediterranean and therefore is not likely to have been tsunamigenic.

1202 05 20 02:40 UT: *Severe tsunami on Levant coast and Cyprus*

Many authors have related this tsunami, describing it as a considerable event. Shalem (1956) mentioned a tsunami on the Syrian coast and at Akko; Ambraseys (1962) noted the Syrian coasts, Cyprus and Egypt that have been affected; Amiran et al. (1994) described a severe tsunami on the Levant coast and serious damage at Akko; Soloviev et al. (2000) listed a tsunami near the coast of Syria. This was also mentioned by Ambraseys and Barazangi (1989) and Ambraseys and Melville (1995).

Recent works of Guidoboni and Comastri (2005) and Ambraseys (2009) point to a tsunami along the coast of the historic Syria (present day Syria, Lebanon and northern Israel) and Cyprus. The former authors report the impression of the original sources: "Gigantic waves rose up in the sea between Cyprus and the coast of Syria. The sea withdrew from the coast, ships were hurled on to the eastern coast of Cyprus, fish were thrown on to the shore, and lighthouses were damaged."

The tsunami followed a destructive earthquake that affected the oriental Mediterranean coast and hinterland of what are now Lebanon, Syria and Israel (Ambraseys and Melville, 1988; Ambraseys et al., 1994; Guidoboni and Comastri, 2005; Ambraseys, 2009). Surface rupture along the Yammouneh fault (Daëron et al., 2004, 2005; Nemer et al., 2008) and the Jordan Gorge segment of the DST (Marco et al., 1997, 2005; Ellenblum et al., 1998) indicate that this was an on-land earthquake. It is therefore possible to assume that one or more seismogenically-triggered sub-marine landslides offshore the Levant coast generated the tsunami. An estimated magnitude of this event was given by Ambraseys and Barazangi (1989) as Ms=7.5, Ambraseys and Jackson (1998) determined this as a large event, and Ambraseys (2006) assumed an Ms=7.2.

1222 05 11 06:15 UT: *Tsunami in Cyprus: Limasol and Paphos*

Evaluating original sources, Ambraseys (1962), Ambraseys et al. (1994) and Guidoboni and Comastri (2005) mention that Limasol and Paphos were struck by a tsunami and that the harbor at Paphos was left completely without water. Soloviev et al. (2000) however, merged this tsunami with that of 1202. Recent work of Ambraseys (2009) notes that elsewhere in Cyprus, the sea 'abandoned its habitual limits and dried up for some distance offshore'. He also concludes that there is no evidence of any damage on land because of the influx of the sea. The tsunami was caused by an earthquake in southern Cyprus (Ambraseys et al., 1994; Guidoboni and Comastri, 2005).

1303 08 08 03:30 UT: *Widespread tsunami in eastern Mediterranean, including Acre*

Following a wide range of historical accounts, the comprehensive studies of Ambraseys et al. (1994), Ambraseys (2009) and Guidoboni and Comastri (2005) describe a widespread tsunami in Crete, Acre, Alexandria, and some effects in the Adriatic. The latter authors quote from contemporaneous sources that in Acre "The sea flooded the shore as far as the tower of Dayan…The sea flooded in almost as far as Tall al-Fudul; the sea off Acre receded about two parasangs (12.8km)…".

This tsunami was caused by a major M~8 earthquake in the Hellenic Arc, possibly in or around central and eastern Crete where most of the damage occurred. Damage was reported also from the Nile delta, northern and southern Egypt, Palestine, Syria, southern Turkey and Greece. Of note is the study by El-Sayed et al. (2000) who modeled this earthquake and tsunami.

Ambraseys (1962) listed a false tsunami in 811 that was mistakenly duplicated from the real August 8, 1303, tsunami. Following the chronological order of the events and the references he mentioned, it seems that he intended to write 881, but mistakenly misprinted it as 811. Thus, he introduced unintentionally a new false event, which in turn was added into later catalogs (e.g. Amiran et al., 1994). Ambraseys et al. (1994) mention two earthquakes on 881, one in the Hellenic Arc and the other in the Western Mediterranean, both of them with no tsunami. Similar evaluation was also given by Guidoboni et al., (1994). Soloviev et al. (2000) however, suggest that the 1303 was erroneously duplicated from the 881/2 tsunami. Later evaluation by Guidoboni and Comastri (2005) shows that the information regarding the 881 05 16 earthquake is too vague to conclude that it originated along the Dead Sea fault system. Overall, it is concluded that there were no tsunamis in the eastern Mediterranean in the years 811 and 881.

1408 12 29: *Tsunami, near Mt. Cassius, western Syria*

Guidoboni and Comastri (2005) summarize the historical sources and describe "… a tsunami, perhaps in the stretch of sea opposite or to the south of Mt. Cassius [north of Laodicea (Latakia)]… The tsunami threw boats out of the sea on to the shore. A high tide stretched over 10 parasangs [64 km]. Sailors said that boats at sea were pushed on to the land by the tide; when the sea fell back, nothing proved to have been damaged". Ambraseys (2009) proposes that "The sea wave could have been associated with the collapse of the mountain side or submarine slumping". Ben-Menahem (1991) dated the event to the day after, on 1408 12 30.

The tsunami followed a tremendous earthquake in western Syria that caused damage in the region of Aleppo and Tripoli, Laodicea, Balatunus, and as far as Cyprus (Ambraseys and Jackson, 1998; Guidoboni and Comastri, 2005; Ambraseys, 2009). The magnitude of this event was estimated by Ambraseys and Barazangi (1989) as Ms=7. Based on paleoseismic findings at the Hacipasa and Amik Basin segments, northern DST, Akyuz et al. (2006) determined its magnitude as ~M7.

1546 01 14 afternoon: *Sea withdrew and returned, southern Israel*

Evaluation by Ambraseys and Karcz (1992), Ambraseys et al. (1994) and Ambraseys (2009) conclude that "…the sea withdrew from the coast of south Palestine and returned as a tsunami […] flooded the coast between Gaza and Jaffa, allegedly causing additional loss of life…". This was also mentioned by Ambraseys (1962), Antonopoulos (1980d) and Amiran et al. (1994) who note that at Jaffa the sea receded the distance of a day's walk. Shalem (1956), however, suspects that the origin of the tsunami is not known and it certainly needs to be verified. In his opinion, it might have been duplicated from the tsunami of 1068 03 18.

The tsunami was apparently caused by a moderate magnitude earthquake, MS ~6.0, in the Jordan Valley, Israel (Ambraseys and Karcz, 1992; Ambraseys et al., 1994; Amiran et al., 1994; Ambraseys, 2009). This seems problematic in that the region of Jaffa to Gaza that was struck by the inferred tsunami is fairly far from the inferred earthquake source. Alternatively, if correct, then why was there no additional submarine sliding north of Jaffa, or are there just no reports? Furthermore, the relatively small size of the earthquake, as suggested, might not be strong enough to have triggered a tsunamigenic offshore slide. Or was the 1546 earthquake farther south, and larger? Interestingly, recent study of Haynes et al. (2006) suggested the northern part of the Wadi Araba fault as the source of that earthquake. This way or another, further investigation is needed.

1759 10 30 03:45 LT: *Sea wave flooded Acre and docks at Tripoli*

According to Ambraseys and Barazangi (1989) and Ambraseys (2009), the earthquake was felt onboard ships a day's sailing from Beirut and caused a seismic sea wave that flooded Acre to a height of 2.5 m above normal sea level and the docks at Tripoli, but there was no apparent damage. The tsunami is also mentioned by Shalem (1956), Ambraseys (1962) and Amiran et al. (1994), who located it along the coasts of Israel and Lebanon and note that in Acre "The water rose to 8' …" (~2.5 m). This is the only case where the inundation height (height of the flooding water above sea level) can be inferred from historical sources. Unfortunately, this cannot be simply interpreted as the actual inundation depth (height of the tsunami above the ground) because the location and height of the flooded area above sea level are not mentioned.

The cause of the tsunami was attributed to an Ms ~6.6 earthquake in southern Lebanon and northern Israel (Ambraseys and Barazangi, 1989; Amiran et al., 1994). Ben-Menahem (1991) mentions a seiche in the Sea of Galilee. A paleoseismic study by Gomez et al., (2001, 2003), later interpreted by Daeron et al. (2005), relates the earthquake to the Rachaiya fault, Syria, and paleo- and archaeoseismic investigations by Marco et al. (1997, 2005) and Ellenblum et al. (1998), suggests the surface rupture extended southwards to the Jordan gorge segment.

Ambraseys and Barazangi (1989) described a tsunami for each of the two earthquakes in this sequence (October 30 and November 25), while Amiran et al. (1994) and Soloviev et al. (2000) determined that a tsunami followed the first one only.

1759 11 25 19:23 LT: *Sea wave in Acre and as far as the Nile Delta*

As of the second earthquake in this sequence, Ambraseys and Barazangi (1989) mention a seismic sea wave that was noted as far south as the Nile Delta, where the sea was discolored for many days, but it caused no damage there. In Acre, ships were thrown onto the shore, and there were some casualties. Ambraseys (2009), however, notes that the sea in Alexandria was discolored over a large area the day after the earthquake, without mentioning the tsunami and other effects. Amiran et al. (1994) and Soloviev et al. (2000) do not list a tsunami for the November event.

A destructive earthquake in southern Lebanon and northern Israel caused the tsunami. This is described by Ambraseys and Barazangi (1989): "A series of ground ruptures many yards wide were formed… along the Bekaa Valley, from Baalbek to opposite Tripoli to the plain of Satern… a total distance of about 100 km. Most probably however, the displacement occurred along the Yammouneh fault." Gomez et al. (2001) and Daëron et al. (2005), however, suspect the rupture was along the Serghaya fault based on paleoseismic evidence. The magnitude estimate given by Ambraseys and Barazangi (1989) was Ms=7.4, Ambraseys and Jackson (1998) assumed this was a large event, and Ambraseys (2006) estimated Ms=7.5.

1870 06 24 17:00 UT: *Port of Alexandria was flooded*

Following a large earthquake in the Eastern Mediterranean, Ambraseys et al. (1994) and Ambraseys (2009) describe that "In Alexandria … in the New Port area … the sea flooded the quay. The shock was felt on board ships in both the Old and New Ports…" Other references are Ambraseys (1962), Antonopoulos (1980d) who mentions a tsunami also on the Italian coasts, Ben-Menahem (1991) and Soloviev et al. (2000).

1872 04 03 07:40: *Sea rose and flooded the coast near Antakya*

Ambraseys (1989, 2009) writes that "The sea rose after the earthquake, allegedly to a great height, flooding the coast", relating to the coasts of Kabusi, Jedida and Laushiya near Antakya (Antioch), "… with the flood wave reaching as far as Suaidiya, nearly 2 km inland." It was caused by a large earthquake that almost totally destroyed Antakya, felt throughout the eastern Mediterranean, from Rhodes to Diyarbakir and from Konya to Gaza.

Ambraseys and Barazangi (1989) and Ambraseys and Jackson (1998) estimate the causative earthquake as an Ms=7.2 in the Amik Gulu, the east Anatolian fault, where it joins the Dead Sea system, while Ambraseys (2006) gives a slightly lower value, Ms=7.0. Paleoseismic investigation by Akyuz et al. (2006) suggests ~M7 at the Hacipasa segment, northern DST.

1908 12 28 04:20:27 UT: *Tsunami in Messina Straits and nearby seas*

A strong destructive earthquake in the Messina Straits, Italy, M=7.1 generated a tsunami that affected both local and nearby seas (e.g. Guidoboni and Mariotti, 2008; Pino, 2008; and others). According to Ambraseys (1962) and Antonopoulos (1980e), the waves reached the Libyan Sea, 90 miles north of Alexandria, Egyptian coasts.

The tsunami was observed in the Messina Straits 5 to 10 minutes after the earthquake. On both the Sicilian and the Calabrian coasts, the sea retreated from the foreshore and then flooded the coasts with several ensuing waves. The maximum height of the waves along the eastern coast of Sicily was between 6 and 9.5 m, and along the Calabrian coast between 6 and 11 m. The tsunami also caused the interruption of a few submarine cables (Guidoboni and Mariotti, 2008; see also Soloviev et al., 2000).

The 1908 tsunami is still today a very interesting research problem because none of the proposed models (Billi et al., 2008, 2009a, 2009b; Piatanesi et al., 2008; Tappin et al., 2008; Argnani et al., 2009; Favalli et al., 2009) is able to account in full for all of the observed phenomena.

1953 09 10 04:06 UT: *A series of tidal waves in Cyprus*

Ambraseys (1992) report an earthquake that was associated with a small seismic sea wave along the coast of Paphos, causing no damage. Soloviev et al. (2000) mention a series of tidal waves that were noted on the Island of Cyprus with no damage. Altinok and Ersoy (2000) suspect the tsunami reached to the southern coasts of Turkey as well. The was caused by an earthquake in Cyprus of M=6.2-6.5 (ISC).

1956 07 09 03:12: *Tsunami in the Aegean Sea, recorded in Jaffa, Israel*

A large earthquake and associated tsunami occurred in the Greek archipelago in the Aegean Sea, and were reported in detail by Ambraseys (1960). The tsunami may have resulted directly from the earthquake, or have been produced by a seismically triggered submarine slump after the mainshock, or just after the largest aftershock (M~7.2) that occurred 13 minutes after the mainshock (Perissoratis and Papadopoulos, 1999).

Shalem (1956) lists an "echo" or a "trace" of a tsunami in Haifa Bay, the same day of the earthquake, on 12:40 LT (09:40 UT). In his opinion, the tsunami signal might have been interfered with by the rough sea caused by a barometric low centered over the eastern Mediterranean at the time, along with its associated high wind, and thus made it difficult to be recognized.

Interestingly, Goldsmith and Gilboa (1986) presented a marigram recorded in the Jaffa port that shows a tsunami with amplitude of 28 cm and wave period of 12-15 min that lasted more than one day after the earthquake. This is the only available tsunami recording from Israel.

This tsunami was also investigated by other researchers such as Ambraseys (1962), Van Dorn (1987) and Dominey-Howes (2002). Noteworthy is the detailed simulation done by Beisel et al. (2009) that reproduced the tsunami waveform that was recorded in Jaffa and showed the signature of the causative submarine slump.

Parametric list of the historical tsunamis

The following is an attempt to parameterize the list of the reliable historical tsunamis in the format used by the European scientific community (e.g., Tinti et al., 2004; TRANSFER, 2006; ICG/NEAMTWS, 2009). Quantifying the descriptive historical data is a subjective procedure that can be applied to several parameters only, and only for the events for which there are sufficient observations. The variables relevant to the present list are:

1. Date: occurrence time of the <u>cause</u> of the tsunami as detailed as known, by the year, month, day, and hour or part of the day or night. In some cases only a range of time can be specified.
2. Date reliability: the uncertainty concerning the last item of the date string. For example, the event dated "1365±5 B.C." with date reliability 5, means that the event occurred in 1365 B.C. with uncertainty of ±5 years, or "Mid 2nd century B.C." is associated with an uncertainty of ±50 years.
3. Source region: areal location of the tsunamigenic source. LE stands for the Levant area, which includes Syria, Lebanon, Israel, Egypt and Cyprus, M1 stands for the eastern Mediterranean basin and M2 for the central Mediterranean basin.
4. Source sub-region: country of today or geography of the tsunamigenic source.
5. Short description of the tsunami. The terms 'local', 'regional' and 'basin-wide' used here refer to the spatial range of the affected coasts, up to 100 km, 100-400 km and more than 400 km, respectively.

6. Event reliability of the tsunami is based on the description of the event, and particularly on the quality of the historical accounts (whether they are coeval), on the information about the generating cause (whether it is well documented), and on the information regarding the tsunami effects (whether they are reliable and detailed). A detailed decision matrix is given by Tinti et al. (2004).
7. Cause of the tsunami is coded as follows: EA- earthquake associated, that is a tsunami associated with an on-land earthquake with no clear indication of the tsunami generator, ER- submarine earthquake, UN- unknown cause.
8. Geographical coordinates (N, E) of the tsunamigenic source. Historical events are mentioned by the most severely affected area, and modern events by the epicenter location.
9. Macroseismic intensity: maximal degree of intensity in the area affected by the causative earthquake. Values were adopted mainly from Guidoboni and Comastri (2005).
10. Earthquake magnitude, inserted for modern events only and specified in the scale used by the bibliographical source from which it was taken (e.g., mb, Ms, Mw, etc).
11. Focal depth: this is unknown for the pre-instrumental historical events.
12. Tsunami intensity was attributed according to the Sieberg-Ambraseys 6-degree scale (Ambraseys, 1962).

Unfortunately there was not sufficient information to quantify any of the other variables requested by the European convention, such as, for example, the reliability or the uncertainty of the location of the tsunamigenic source, the run-up, and the tsunami magnitude. The volcanic index, VEI, was ignored because no volcanic tsunamis were listed in the area studied during historical times.

a. Regional setting

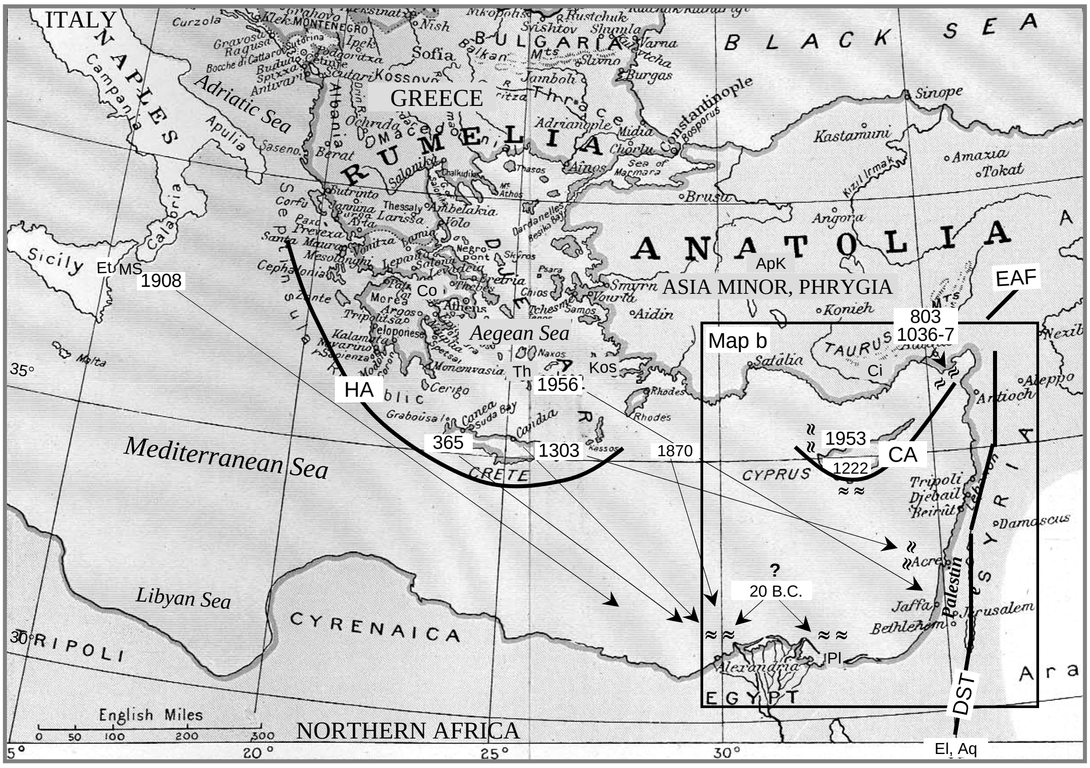

Figure 1.
Regional (a) and local (b) setting of the study area and the occurrence of remote and local tsunamis, respectively (modified from Salamon et al., 2007). Note the probable location of the tsunamigenic trigger. Local tsunamis were most probably originated from earthquakes along the DST system, while the remote tsunamis originated from sources off the DST, including the Cypriot Arc. The regional map shows the Ottoman area during the 19th century (from Miller, 1913). Plate borders (bold lines) and regions: CA- Cypriot Arc, DST- Dead Sea Transform, EAF- East Anatolian Fault, HA- Hellenic Arc, IB- Iskenderun (Alexandretta) Bay. Faults: BT- Beirut (Mount Lebanon) thrust, CF- Carmel fault, MF- Missyaf fault, P- Palmerides, RF- Roum fault, RsF- Rashaiya fault, SF- Serghaya fault, YF- Yammaouneh fault. Localities: A- Acre (Akko, Ptolemais), AB- Amik Basin (Amik Gulu), Ad- Ashdod (Holotz Ashod?), AI- Arwad Islands (near Tartus), Ak- Ashkelon, An- Antioch (Antakya), Ap- Allepo, ApK- Apamea Kibotos (in Antalia), Aq- Aqaba, AY- Atlit-Yam, B- Beirut, Ba- Baalbek, C- Caesarea, Ch- Chaizar region, Ci- Cilicia, Co- Corinth, El- Elat (Eilat), Et- Etna, Fa- Famagusta, G- Gaza, Hc- Hacipasa, Hi- Haifa, Hm- Hama, Ho- Homs, J- Jaffa, JG- Jordan Gorge, Je- Jericho, Kl- Kilis, Kt- Kition, La- Laodicea (Latakia), Li- Limasol, Me- Mersin, MS- Messina Straits, Pa- Paphos, Pl- Pellusium, S- Sidon (Saida), Sa- Salamis, SG- Sea of Galilee, TA- Tel Amarna, Th- Thera (Santorini), Ti- Tiberias, Tr- Tripoli, Ty- Tyre , U- Ugarit, Y- Yavne.

b. Local setting

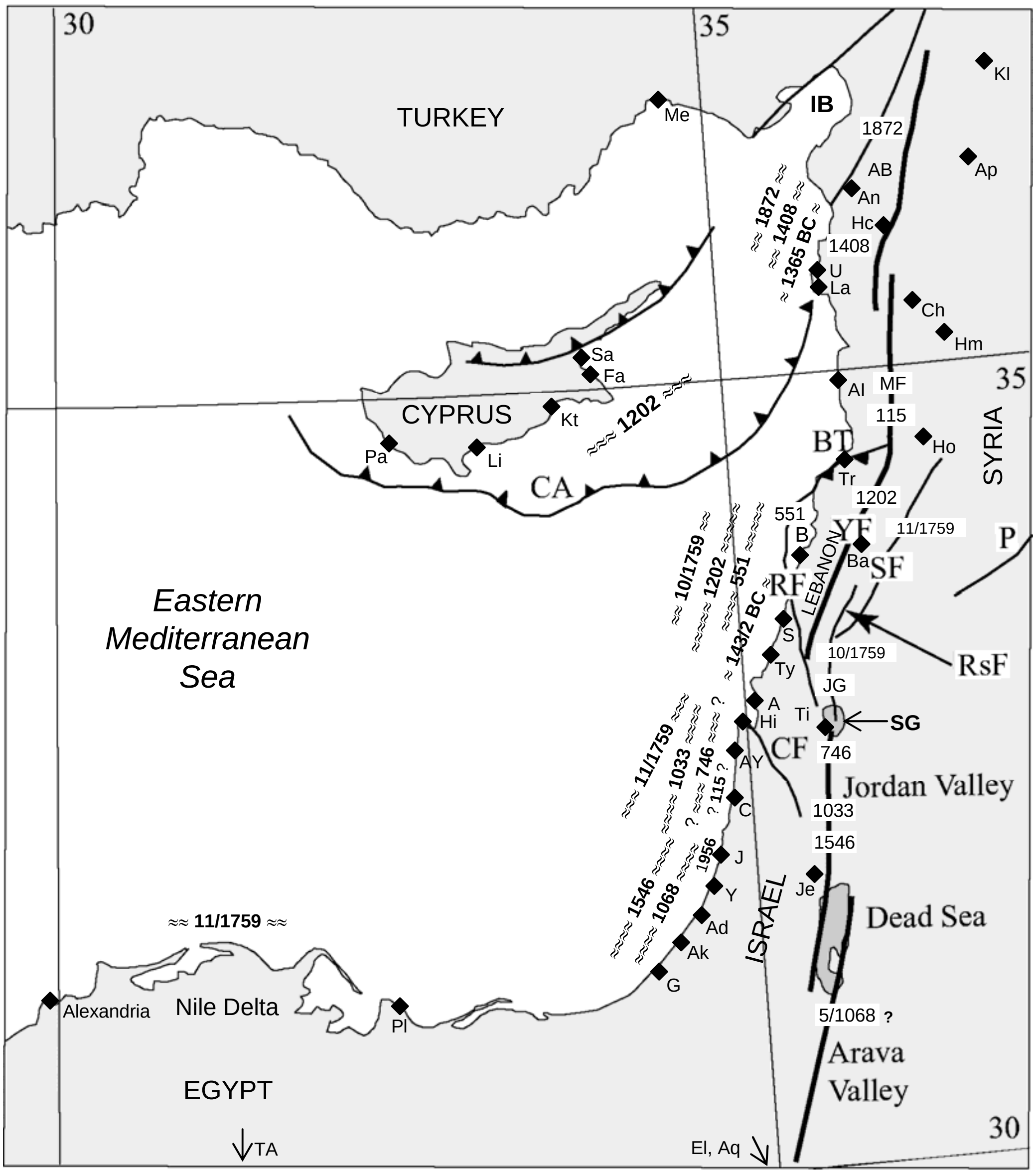

Table 1 Parametric list of the reliable historical tsunamis that affected the Levant coast

Date [a]	Date reliability	Source region	Source sub-region	Short description	Event reliability	cause	Coordinates		Macro-seismic intensity	Earth-quake mag.	Focal depth	Tsunami intensity
							N	E				
1365 B.C.	5 years	LE	?	Local tsunami. Ugarit (Syria) was flooded and half destroyed.	1-2	UN						≥4
Mid 2nd century B.C.	50 years	LE	?	Local tsunami, the sea rose between Tyre and Acre.	2	UN						4
20 B.C.	3 years	LE	?	Local tsunami between Alexandria and Pellusium.	2	UN						≥2
115 12 13		LE	Syria	Local tsunami between Caesarea and Yavne.	1	EA	36 20	36 20				≥2
365 07 21		M1	Crete	Basin-wide tsunami in eastern Mediterranean: Peloponnesus, Adriatic and Sicilian coasts, and Alexandria.	4	ER	35 50	23 50				6
551 07 09		LE	Lebanon	Local tsunami, the sea retreated and flooded Beirut.	4	ER	34 25	35 50				≥4
746 01 18		LE	Israel	Local sea waves, possibly on the Levant coasts or along the Dead Sea.	1-2	EA	32 20	35 50				5
803 06 23		LE	Southern Turkey	Local tsunami in Massisa coasts, near the Gulf of Iskenderun.	3	EA	37 00	35 50				2
1033 12 05 (1034 01 04?)		LE	Israel	Local tsunami in Acre, and possibly nearby coast.	4	EA	32 00	35 20	IX			≥3
1036 03 12 - 1037 03 11	6 months	LE	Southern Turkey	Local tsunami, sea in Cilicia (?) billowed back and forth.	4	EA						2
1068 05 29		LE	Israel	Local tsunami, sea in southern Israel receded and returned.	4	EA	32 60	35 30	IX			4

1202 05 20		LE	Lebanon	Regional (local?) tsunami on Levant coast and Cyprus. Coordinates from Ambraseys (2004).	4	EA	33 90	36 10	X			5
1222 05 11		LE	Cyprus	Local tsunami in Cyprus: Limasol and Paphos. Coordinates from Guidoboni and Comastri (2005).	4	EA	34 40	32 50	IX			4
1303 08 08		M1	Crete, East Aegean	Basin-wide tsunami in eastern Mediterranean. Coordinates from Guidoboni and Comastri (2005).	4	ER	35 10	25 40	X			6
1408 12 29		LE	Syria	Local tsunami, near Mt. Cassius.	4	EA	35 70	36 20	IX			4
1546 01 14		LE	Israel	Local tsunami, sea withdrew and returned, southern Israel.	4	EA	32 00	35 50				4
1759 10 30		LE	Lebanon-Israel	Local tsunami, sea wave flooded Acre and docks at Tripoli.	4	EA	33 10	35 60				3
1759 11 25		LE	Lebanon-Israel	Regional (local?) tsunami, sea wave in Acre and as far as the Nile Delta, the sea in Alexandria was discolored over a large area the day after the earthquake.	2	EA	33 70	35 90				4
1870 06 24		LE	East Aegean	Regional tsunami, port of Alexandria was flooded.	4	EA	35 00	29 00				2
1872 04 03		LE	Syria	Local tsunami, sea rose and flooded the coast Antakya. Coordinates from Ambraseys (1989), and Ambraseys and Barazangi (1989).	4	EA	36 40	36 50				3
1908 12 28		M2	Italy, Sicily	Regional tsunami in Messina Straits and nearby seas.	4	ER, EA	38 10	15 41	XI	7.1		6 in source region, 2 in Egypt
1953 09 10		LE	Cyprus	Local tsunami, a series of tidal waves in Cyprus.	4	EA	34 80	32 78		6.2		2
1956 07 09		M1	Aegean Sea	Regional tsunami in the Aegean Sea, recorded in Jaffa. Macroseismic intensity from Ambraseys (1960).	4	ER, EA	36 90	26 20	VIII	7.5	shallow	5 in source region, 1 in Jaffa

See the text for explanation.

List of doubtful events

Tsunamis along the Levant coast with reports that could not be substantiated by primary sources were considered as doubtful events and excluded from the list of the dependable events. Table 2 (modified from Salamon et al., 2007) presents these events with a detailed explanation of the reason for doubt, whether they were listed erroneously or because the dates are questionable, or for other reasons. It appears that not all of the doubted tsunamis are similar in status. For example, it can be assumed that some of the doubted tsunamis did occur but were very poorly recorded and that new data discovered at some future time may change their status. Such is the Late Minoan (Santorini, Thera) tsunami for which there are strong supportive findings (e.g. Bruins et al., 2008, and references therein), but the suggested evidence of its occurrence along the Levant coast (Pfannenstiel, 1960) was interpreted as questionable or equivocal by previous (Dominey-Howes, 2002) and the present authors. Similarly, the proposed Mt. Etna tsunami of the early Holocene (Pareschi et al., 2006, 2007) may have occurred, but the related evidence from Atlit-Yam have been strongly rejected (Galili et al., 2008).

In order to determine the status of the doubtful events, the distinction was made as to whether they are false tsunamis (F), or real (R) tsunamis that occurred elsewhere with no clear or unequivocal evidence of reaching the Levant, or whether they are least probable (LP) tsunamis that may have occurred but require further investigation to be elevated to confirmed status. As new information is discovered, the status of these events may be updated or even changed to real events.

Additional seismic sea waves

Along with the seismic sea waves in the Mediterranean, there are historical reports of seismogenic sea waves in the Dead Sea and the Sea of Galilee (Lake Tiberias, Lake Kinneret), most of which were already listed by Shalem (1956) and Amiran et al. (1994). In modern times, seismic sea waves were also observed in the Gulf of Aqaba (Elat). Whether these were tsunamis or seisches is yet to be determined. The present list is modified from Salamon et al. (2007).

The presence of intraclast breccia (mixed) layers within the laminated sediments of the Dead Sea basin was attributed to past earthquake in and around the basin (e.g. Marco and Agnon, 1995; Migowski et al., 2004; Agnon et al., 2006; Kagan et al., 2010, 2011). Several mechanisms were suggested to explain the generation of these layers, with the strong ground shaking playing the main trigger force (see an overview by Agnon et al., 2006). Interestingly, Begin et al. (2005) hypothesized that mixed layers that are covered by a gypsum layer may attest to a seismic lake wave (seisch or a tsunami) that followed the given earthquake. Therefore, the deposits of the various lakes that occupied the Dead Sea basin may have recorded also seismic sea waves. Thus, cross correlating the historical reports of seismic sea waves in the Dead Sea with its Late Holocene strata, can verify that hypothesis.

Table 2 Doubtful tsunamis reported for the Levant coast

Event [a]	**Sources of data and short description** [b]	**Status**	**Why doubted**
8,000 BP	Large submarine landslide deposits offshore Mt. Etna (Italy) revealed by high resolution seismic data, lead Pareschi et al. (2006, 2007) to propose a tsunami that was triggered about 8000 years ago by a sector collapse of that Mountain into the sea.	R	Tsunami may have occurred and reached to the Levant, but the proposed evidence of destruction in the submerged Atlit-Yam village was all refuted (Galili et al., 2008).
II millennium B.C.	Based on cuneiform texts, Ambraseys (1962) proposed a tsunami in the Syrian coasts.	F	Soloviev et al. (2000) suggest that: "these writings most likely referred to the events of 1380 B.C. (1380 ±100 B.C.), and to the period between 1700 B.C. and 1380 B.C,…" which was later considered as a LM tsunami. This report can relate also to the 1365 B.C. tsunami that was mentioned by Ambraseys et al. (2002), and was based on a tablet from Tel Amarna, Egypt.
1627-1600 B.C.	Pumice findings in Cyprus and Israel (Pfannenstiel, 1960) were considered as evidence for the arrival of this tsunami to Israel. Goodman-Tchernov et al. (2009) interpreted various sedimentary deposits offshore Caesarea as tsunamigenic features that have originated from this tsunami.	R	This is the tsunami that followed the Late Minoan (LM) Thera (Santorini) eruption (Ambraseys, 1960; Dominey-Howes, 2002; Antonopoulos, 1992; Bruins et al., 2008; Cita and Aloisi, 2000; Friedrich et al., 2006; Marinos and Melidonis, 1971; Mészáros, 1978; McCoy and Heiken, 2000; Minoura et al., 2000; Pararas-Carayannis, 1992; Yokoyama, 1978). However, Dominey-Howes (2002) and the present authors question the finding of pumice in Cyprus and Israel as a tsunamite deposited from this event. Regarding the suggested tsunamigenic indicators, refer to the discussion on the 115 A.D. event. Further examination of this event is certainly needed.
760 B.C.	Ambraseys (1962): Coasts of Israel and Lebanon. Ben-Menahem (1991): 759 B.C.	LP	Bentor (1989) suggests that this is just an example. It appears in the Bible, book of Amos, chapter 9, chronologically indeterminate with no clear connection to the earthquake mentioned previously in chapter 1, which in turn is reported and dated in a historical context (Guidoboni et al., 1994; Ambraseys, 2009).
590 B.C.	Ambraseys (1962): Coasts of Lebanon, Sur (Tyre).	F	Ambraseys (1962) determined this as a false event because there are no ancient sources for an earthquake or a tsunami in that year.
525 B.C.	Coasts of Lebanon. Saida (Sidon). Shalem (1956) suggested an earthquake possibly followed by a tsunami in Tyre.	F	Ambraseys (1962) and Antonopoulos (1979) concluded that this event is doubtful since there is no mention of a seismic sea wave by chroniclers who describe the earthquake.

240 B.C.	Shalem (1956): Possible tsunami between Beirut and Akko.	F	Shalem (1956): This should be associated with the tsunami of 140 B.C.
222 B.C.	Altinok and Ersoy (2000): Rhodes, Cyprus, Corinth.	F	Ambraseys (1962): doubtful event because it was mistaken for the 142 A.D. tsunami on the island of Rhodes.
198 B.C.	Soloviev et al. (2000): "Eastern coastal area of Mediterranean sea. Shortly after the appearance of a big comet, an earthquake occurred that was accompanied by an overflow of the sea water."	F	This was duplicated from the event of 373/372 B.C. which occurred in the Gulf of Corinth (Soloviev et al., 2000; Guidoboni et al., 1994; Ambraseys, 2009). Ambraseys and White (1997), Guidoboni et al. (1994), and Ambraseys (2009) list an earthquake in Sidon, Phoenicia, Syria, on 199-198 BC, but without a tsunami.
92 02 28 B.C.	Amiran et al. (1994): Tsunami on the Levant coasts of Lebanon and Israel. Ben-Menahem (1991): Big tsunami hit Levantine coasts, flooding of Pellusium. Shalem (1956): 92 BC, earthquake and tsunami.	F	Karcz (2004) concluded that "This event (92 B.C.) illustrates the role of locally composed Jewish texts in analysis of several 2nd century B.C. earthquakes that were imported into the Israeli catalogues from elsewhere in the Eastern Mediterranean". Ambraseys (2009) also agrees that this is a spurious event.
26 B.C.	Altinok and Ersoy (2000): Paphos-Cyprus	F	Guidoboni et al. (1994): The only earthquake concerning Cyprus in this period is the one dated to 17 B.C. and no tsunami is mentioned for that event.
A.D. 76	Tsunami in Cyprus, Kition, Paphos and Salamis. Also mentioned by Altinok and Ersoy (2000).	LP	Ambraseys (1962) suggests these were storm sea-waves. Antonopoulos (1980a) indicates that there is "No mention of such an event in the narrations of early chroniclers…". Ambraseys (2009) adds that "It is probable that this earthquake was associated with a seismic sea wave at Salamis and Paphos but it is not certain whether this was the result of this or of another earthquake."
293-306	Guidoboni et al. (1994): Tsunami in Salamis (Cyprus).	F	Re-evaluating the original sources for the earthquake of 293-306 ("and the greater part of it [Salamis] was plunged into the sea by an earthquake"), a landslide is a more plausible interpretation rather than a tsunami, as previously suggested by Guidoboni et al. (1994). We did not find original sources that mention an earthquake or a tsunami in this time period. Ambraseys (2009) suggests that this event was erroneously taken from the event of 341 A.D. in Salamis.
303, 306 or 308	Shalem (1956) notes a tsunami in the winter of 308, in Caesarea (?). Ben-Menahem (1991), and Amiran et al. (1994) date it to 306, at Caesarea.	F	Shalem (1956) and Amiran et al. (1994) after Shalem, doubt this event. Ambraseys (2009): "The shock was felt in Caesarea, which was not damaged, and it is said that it was associated with a seismic sea wave of doubtful origin." We suspect that the alleged tsunami was inferred from Eusebius's report of the sea casting up the body of the martyrdom of Apphian at the gates of Caesarea at the same time of the April 2, 303, earthquake in Sidon. However, a seismic sea wave is not specifically mentioned. Moreover, it is common along the eastern Mediterranean coast, even in normal weather conditions, that the sea casts up dead bodies of drowned people at the shore.

341, 342	Altinok and Ersoy (2000): Paphos, Famagusta – Cyprus.	F	Ambraseys (1962) and Antonopoulos (1980a) conclude the absence of a seismic sea-wave because they could find no reference to such an event. Ambraseys (2009) refers to the 341 A.D. event in Salamis: "My reading of the text does not imply the occurrence of a seismic sea wave."
348/9	Syrian coasts. Beirut, Arwad Islands (near Tartus). Ben-Menahem (1991): the earthquake occurred in 349. Shalem (1956).	F	Ambraseys (1962) and Antonopoulos (1980a) found no mention of this event in contemporary writings. Ambraseys (2009) in reference to the September 347 earthquake in Beirut, does not mention a tsunami.
541	Ambraseys (2009) after Malalas, mentions a tidal wave which seems to have flooded Alexandria and the Egyptian littoral, apparently causing great loss of life. No earthquake is associated with it.	LP	In our opinion, the text of Malalas seems to be dubious and somewhat anecdotic.
Winter 542	Amiran et al. (1994): Lebanese coast of Tripoli, Beirut, Byblos (25 km north of Beirut), Laodicea (Latakia). The sea receded 2 miles.	R	Shalem (1956): this is duplicated after the tsunami of 551 07 09. Ambraseys (1962) locate the 542 winter event in the Sea of Marmara (Turkey) and the Thracian coasts of northeast Greece. Ambraseys (2009) after Theophanes, mentions a destructive sea wave in the Black Sea on 544 A.D., with no earthquake.
811	Coasts of Israel and Egypt, from Acre to Alexandria. Amiran et al. (1994): Coasts of Israel and Lebanon.	F	Ambraseys (1962) misprinted 811 instead of 881 which in turn was mistakenly duplicated after the 1303 tsunami. Soloviev et al. (2000) also suggest that this was erroneously duplicating the 881/2 tsunami. Antonopoulos (1980b) was unable to find any justification for this event.
859 04 08	Shalem (1956) mentions a great earthquake that caused a tsunami that hit the northern Syrian coast.	F	This is doubtful in Shalem's (1956) opinion, as is the tsunami of 991.
859 12 30 – 860 01 29	Ambraseys (1962), Antonopoulos (1979), Antonopoulos (1980b): Syrian coasts, near Samandag, southwest of Antioch. Soloviev et al. (2000): "In the region of Samandagi (some references give Akko) sea receded and than flooded the coast."	LP	Guidoboni et al. (1994): The description of al-Tabari is rather generic: "Mount Cassius split open and rocks fell into the sea, which was stormy that day," and can be interpreted as a landslide into the sea. The effect at sea (which was interpreted as a tsunami) was given by much later sources. Ambraseys et al. (1994) do not mention a tsunami. Ambraseys (2009) however, describes that: "Between Antioch and Latakiya, Jebal Aqra, the Bald mountain overlooking the sea, broke and a large piece of rock fell into the sea, causing it to swell." In our opinion, a possible scenario of a rock-fall that generates a small local tsunami cannot be excluded.
881/2	Amiran et al. (1994): Tsunami at Akko. Soloviev et al. (2000): "A tidal wave in Akko… sea level rose in Alexandria, the Nile overflowed its banks…"	F	Ambraseys et al. (1994) interpret that no tidal wave followed the 881/2 earthquake. Antonopoulos (1979).

991 04 05	Coasts of Syria. Shalem (1956): Earthquake in Syria, felt as far as Egypt, possibly associated with a tsunami.	F	Ambraseys (1962): doubtful event because the earthquake was not accompanied by a seismic sea-wave. Antonopoulos (1980b) and Shalem (1956) also doubt it.
1032 03 06	Amiran et al. (1994): Tsunami at Ashkelon and Gaza. Ben-Menahem (1991): tsunami.	F	Guidoboni and Comastri (2005): no written sources for this event. 1033 12 05 is confused with 1032 03 06 which actually occurred in 1033 03 06 in Constantinople, Turkey.
1115 11 29	Altinok and Ersoy (2000): Ceyhan, Antakya, Maras (around Iskenderun Bay). Amiran et al. (1994): Apparently Antiochia (Antioch). Ben-Menahem (1991): 1114 08 10.	F	Ambraseys (2004, 2009) could not substantiate the statement that as a result of the earthquake the sea got up, and suggests that this should be regarded as spurious information, perhaps belonging to the earthquake of 10 August 1114. However, the file concerning the earthquake of 10 August 1114 does not mention a tsunami.
1157 08 15	Ambraseys and Barazangi (1989) associate this event with a sea wave. Altinok and Ersoy (2000): Hama-Homs (northwestern Syria), Chaizar Region, 1157 07 15.	F (LP?)	Later studies of Ambraseys (2004, 2009) do not mention a tsunami. However, this was a large earthquake capable of producing a tsunami and it certainly deserves further investigation.
1170 06 29	Ambraseys and Barazangi (1989): this is associated with a sea wave.	F (LP?)	Ambraseys (2004, 2009) in later studies does not mention a tsunami. This was of the largest earthquakes in the region and further investigation is needed.
1261	Shalem (1956), after Makrizi, lists a strong earthquake in the coast of Lebanon that caused the sinking of seven islands between Akko and Tripoli.	F	A tsunami is not explicitly mentioned. We could not verify this event in other catalogs.
1303 12	Ambraseys (1962): …Egyptian coasts…	F	This was duplicated from the tsunami of 1303 08 08 because of mistaken chronological interpretation. It is not mentioned in later catalogs (Guidoboni and Comastri, 2005), nor in Ambraseys et al. (1994) and Ambraseys (2009) that follows Ambraseys (1962).
1402/3 11 16	Ambraseys (1962) lists a tsunami on 1403 11 16 in the Syrian and Asia Minor south coasts. Amiran et al. (1994) list a tsunami in 1402 in the Lebanese coast; the sea receded and then invaded the land. It was listed also by Antonopoulos (1980c); Ben-Menahem (1991), on 1402 11 16; and Shalem (1956). Soloviev et al. (2000) suggest that the sea receded by more than one mile near the shore of Syria and Palestine, on November 16, 1403 (1402).	R	All the catalogs directly or indirectly depend on Perrey (1850). Perrey (1850) however, erroneously located an earthquake/tsunami in Syria which had actually occurred in Greece in the Gulf of Corinth. This is explained also by Ambraseys and Melville (1995) and Ambraseys (2009).

1481 10 03	Ben-Menahem (1991) notes a tsunami at the Levantine coasts on 1481 10 03. Amiran et al. (1994) also list the 1481 10 03 tsunami at Levant coast, but write that this is not substantiated for Israel.	F	Guidoboni and Comastri (2005) conclude no tsunami effects for that earthquake. Ambraseys (2009) mentions a tsunami on May 3, 1481, in the city of Rhodes, and an earthquake that was felt in Rhodes on October 3, 1481 which was not associated with a swelling of the sea.
1493 08 18	Ben-Menahem (1991): Earthquake in Kos. Tidal wave at Jaffa. Sea receded.	F	Guidoboni and Comastri (2005): the earthquake at Kos (eastern Aegean Sea) occurred on 1493 10 18 and a tsunami was not mentioned. We did not find primary sources for this tsunami.
1534	Coasts of Israel. Jaffa. Amiran et al. (1994), Soloviev et al. (2000): Jaffa.	F	Ambraseys (1962), Ambraseys and Karcz (1992): this was not found in contemporary sources. We could not find primary sources for this tsunami.
1639	Shalem (1956): Earthquake in the sea that sunk ships that anchored in Lebanon ports.	F	Tsunami is not explicitly mentioned. We could not find which source Shalem (1956) was referring to and could not find this tsunami in other sources.
1752 07 21	Antonopoulos (1980d), Ben-Menahem (1991): Syrian coasts. Shalem (1956): Syrian coast, Latakia and Tripoli. Soloviev et al. (2000): Latakia.	F	Ambraseys (1962) report that no authority is quoted, referring to Sieberg (1932), and Ambraseys (2009) determine this as a spurious event. We could not find the primary sources for this earthquake and tsunami.
1822 08 13	Altinok and Ersoy (2000): Antakya, Iskenderun, Kilis (around the Iskenderun Bay). Amiran et al. (1994): Beirut. Ben-Menahem (1991): Tsunami at Iskenderun. Soloviev et al. (2000): Tsunami was observed in Beirut, Iskenderun, island of Cyprus.	LP	Ambraseys (1989, 2009) studied the event and concluded that "The main shock was felt by ships sailing between Cyprus and Latakia, and halfway between Alexandria and Cyprus. There is no evidence that this event was associated with a seismic sea-wave in the Eastern Mediterranean or with an abnormal fluctuation of sea-level". Further investigation is suggested regarding the shock felt by the ships.
1856 10 12	Amiran et al. (1994): Haifa, on 1856 10 10. Ben-Menahem (1991): Tsunami at Haifa and Lebanon coasts. Shalem (1956): on 1856 10 10, "During earthquake that hit the Levant coast, a strong sea storm developed in Haifa with not any wind blowing." Soloviev et al. (2000): Island of Crete. A tsunami was generated. Originated at the Hellenic Arc.	LP	According to Ambraseys et al. (1994) and Ambraseys (2009), "The earthquake was felt onboard boats sailing off Egypt. In the Eastern Mediterranean and offshore Crete there were reports of an abnormal sea current. However, there is no evidence that the earthquake was associated with a seismic sea wave, except perhaps in the region of Malta…" Papadopoulos and Chalkis (1984) question it (northern Crete?) and Papadopoulos (2001) does not mention it. This event needs further investigation, especially the report given by the boats sailing off Egypt.

1865 04 22	Shalem (1956) describes an earthquake along the Syrian coast, in the southern coast of Anatolia and the islands, and that a large storm was felt in Tripoli (a tsunami?).	LP	We did not find an earthquake or a tsunami on that day in other sources. Soloviev et al. (2000) mention an earthquake and a storm on March 22nd, 1863, 22:15, in the Aegean Sea, island of Rhodes, and that the report on the earthquake got mixed up with information on the storm. They add that: "The sea near Tripolis (Tarabulus esh Sham, Lebanon) was furrowed by huge waves at midday on March 22." (before the earthquake?). Ambraseys (2009) notes that a ship sailing from Mersin to Rhodes was badly shaken and lost two of its masts, and that abnormally large waves were reported from ports in the region but most probably these were standing waves due to the exceptionally bad weather at that time.
1941 01 20	Ambraseys and Adams (1993) list an Ms=5.9 earthquake in Cyprus, and note that "The earthquake was accompanied by a small seismic sea-wave on the coast of Palestine", most probably after Shalem (1956)?	LP	Shalem (1956) wrote about an earthquake that was felt in Palestine and was associated with a strong sea storm. However, marigrams were not systematically examined in order to determine if this was a seismogenic sea storm. Needs further investigation.
1949 06 18	Shalem (1956) reports about a seismic sea wave at the coast of Israel as a result of an earthquake in Greece (Santorini!?) on June 17. Amiran et al. (1994) follow Shalem and list a light tsunami on the coast of Israel.	F	ISC (2009) lists a moderate M_L=5.5 event, on 1949 06 17 04:20, at N34.4 E28.5 (east Mediterranean). A tsunami, if generated, should have arrived at Israel about two hours later. However, none of the catalogs we searched listed a tsunami at that time or a few days later.

[a] Events are marked by time of occurrence as detailed as known, by the year, month and day.

[b] The list of sources for the doubtful tsunamis is not complete; only a few examples are mentioned.

Table 3 Seismic sea waves in the Dead Sea, Sea of Galilee and Gulf of Aqaba

Dead Sea

i.	315	Ambraseys (1962)
ii.	363 05 19	Amiran et al. (1994), Ambraseys (1962), Ben-Menahem (1991) Shalem (1956)
iii.	746 01 18	Ambraseys (2005), Amiran et al. (1994), Ben-Menahem (1991) Shalem (1956)
iv.	1546	Amiran et al. (1994), Ben-Menahem (1991), Shalem (1956)
v.	1927 07 11	Amiran et al. (1994), Shalem (1956)
vi.	1969 03 31	Ben-Menahem (1991): "Small waves (~30 cm) in the Dead Sea".
vii.	2004 02 11	Salamon (2005).

Sea of Galilee

i.	3rd century?	Shalem (1956)
ii.	746 01 18	Ben-Menahem (1991), Karcz (2004)?
iii.	1759 10 30	Amiran et al. (1994), Ben-Menahem (1991)
iv.	1837 01 01	Amiran et al. (1994), Ambraseys (1962, 1997), Ben-Menahem (1991), Shalem (1956).

Gulf of Aqaba

i.	1969 03 31	Ben-Menahem (1991): "Sea at Eilat Gulf became stormy", after M_L=6.8, northern Red Sea earthquake.
ii.	1995 11 22	Wust (1997): a wave up to a meter high after the Mw 7.2, Nuweiba earthquake.

The damage from the tsunamis

The effects caused by the tsunamis vary from sea level changes along the coast to damage and loss of lives in the coastal cities and harbors. Harbors drew much attention because the people there were familiar with the behavior of the sea and the tsunami effects could be easily noticed. Vessels very close to the coast as well as harbor installations were the most vulnerable and thus were affected first. Table 4 summarizes the tsunami effects and damage in the Levant, listed by the change in sea level, damage and loss of lives in the coastal cities and the harbors. This is all interpreted from the sources mentioned in the list of dependable historical tsunamis. The event of 1956 is disregarded here because it was not felt (only recorded) in Israel.

Table 4 Tsunami effects and damage in the Levant

The tsunami	Sea level changes in…		Damage in…		Loss of lives in…	
	Coasts and cities	Harbors	Coastal cities	Harbors	Coastal cities	Harbors
1365±5 B.C.			Ugarit half destroyed			
Mid 2nd century B.C.	High wave between Tyre and Acre				People were engulfed and drowned	
20 B.C.	The sea rose between Alexandria and Pellusium					
115 12 13				Caesarea?		
* 365 07 21	+	+	Nile delta	Alexandria	Nile delta	Alexandria
551 07 09	Sea withdrew and retreated	Sea withdrew and retreated	In Phoenician cities	In Phoenician cities, Beirut	Phoenicia	In Phoenician cities, Beirut
746 01 18	Waves rose up to the sky		Most of the cities and villages destroyed			
803 06 23	Inundation					
1033 12 05 (1034 01 04?)		Water in Acre receded for an hour				
1036 03 12 1037 03 11	In Cilicia (?), the sea bellowed forth and back					
1068 05 29	In Palestine, sea withdrew and flowed back				Many people were drowned	
1202 05 20	Gigantic waves rose up between Cyprus and Syria		Serious damage to lighthouses	Ships were thrown on shore	+	

1222 05 11	Sea (between Paphos and Limasol withdrew from the shore	Paphos was completely dried	Paphos and Limasol were completely submerged			
* 1303 08 08	Sea receded and flooded Acre				People who went to pick objects in the sea were swept away and drowned	
1408 12 29	High tide stretched in western Syria		Boats were pushed onto the land, but nothing proved to have been damaged			
1546 01 14	The sea withdrew from the coast of south Palestine and returned				Many people	
1759 10 30	Sea wave flooded Acre	Sea wave flooded docks at Tripoli	No apparent damage			
1759 11 25	Sea wave noted as far as the Nile delta		No damage in the Nile Delta	In Acre, ships were thrown onto the shore	Some casualties in Acre	
1870 06 24		Sea flooded the quay in Alexandria				
1872 04 03	Sea flooded the coasts of western Syria					
* 1908 12 28	Tsunami observed in the region of Alexandria		No damage in the Levant			
1953 09 10	Series of tidal waves in Cyprus		No damage			
Number and percent out of 22 events	18 events, 82%	6 events, 27%	7 events, 32%	4 (5) events, 18%	8 events, 36%	2 events, 9%
	20 events, 91%		7 (8) events, 32%		8 events, 36%	

* Tsunamis that caused additional effects and damage outside the Levant coast; see section of "Descriptive list of the dependable historical tsunamis" for references.

DISCUSSION AND CONCLUSIONS

Unlike earthquakes that are usually cataloged according to their area of origin, the tsunamis are listed here by the coasts that were affected, for this is the aim of this work. It therefore involves tsunamis originating from various sources, both near and far. Overall, 23 reliably reported tsunamis are listed, whereas another 40 entries in the literature are doubted or require further work. Seven reports of seismic sea waves in the Dead Sea, four in the Sea of Galilee and two in the Gulf of Aqaba (Elat) are also identified. Unexpectedly, only about a third of the published reports of tsunamis in the Levant were verified. This problematical issue was already extensively dealt with by Guidoboni and Ebel (2009) and Ambraseys and Synolakis (2010). It appears that once a false tsunami (or earthquake, for that matter) gets into the literature somehow, it is difficult to remove and it tends to get repeated from work to work. It is hoped that by listing doubtful tsunamis separately, the ones that actually did occur can become the focus of future work.

Thus, this work is only a stepping stone that enables examination of the available materials and presents the current state of the knowledge on historical tsunamis that affected Israel. Hopefully, it will enable future workers to focus on the search for hidden accounts, and provide directions for future fieldwork, tsunami modeling, and hazard evaluation. By the very nature of the historical data, it is partial and limited, and severe limitations are imposed as to their usefulness. Nevertheless, ignoring this potential would be counterproductive, and there should be an ongoing effort to expand the database of original materials in order to better constrain the list of events and improve its reliability.

Similar to accounts of historical earthquakes as reported in various lists and catalogues, only reported tsunamis can be considered. Events that were not reported, or reports which did not survive to the present, are lost. Seismic sea waves that caused no damage were very likely ignored, and small events may have been missed because they occurred in remote areas, occurred during the night or happened during a low tide. Thus, the list accounts for only some of the actual occurrences, although it seems that the completeness of the listings improves towards modern times.

In most cases it was possible to mention the specific earthquake associated with the tsunami, and thus infer the distance it traveled. However, the time delay of the tsunami in regard with the earthquake is not mentioned. Many of the reports of tsunamis that followed DST earthquakes mention that only a few nearby coastal localities were affected. This may simply reflect the incompleteness of the historical reports, yet not surprisingly this is also the nature of submarine landslide tsunamis that result in large run-ups but over a limited area or stretch of a coast.

Some implications regarding the tsunami hazard to Israel

Since the majority of the tsunamis that affected Israel during the past two millennia followed local on-land earthquakes, most likely by triggering submarine landslides, then the ground shaking should be regarded as the tsunami early warning signal. Less frequent, yet not to be underestimated, are the basin-wide events that may come from the Hellenic and the Cypriot arcs. The warning message of these is expected to arrive from the forthcoming European tsunami warning centers (e.g., ICG/NEAMTWS, 2009). Volcanic tsunamis, such as the Santorini event, are rare and will be incorporated into the Mediterranean tsunami warning system in the future.

The cyclic appearance of earthquakes is well recognized and its mechanism is relatively well understood, although any attempt of prediction is not practical. Given that tsunamis in the Mediterranean are usually earthquake-driven either by seafloor rupture or submarine slumping, and not every earthquake is 'successful' in generating a tsunami, then the occurrence of tsunamis is expected to be much less ordered in time than earthquakes.

Mechanically, seismogenic slumping along the continental margins of Israel shows that the sediments that compose the margin are dynamically unstable. As time passes, new potential accumulates along the continental slopes, either by ongoing sedimentation or another degradation processes, and these areas of potential instability wait to be cleared off by the next earthquake. Thus, it appears that some preparation time is required between large earthquakes in order for a tsunami to be generated.

Tsunamis in Israel are generally less hazardous than earthquakes because they primarily affect the coastal region. Furthermore, not all of the damaging earthquakes in the past have generated tsunamis, and the number of people exposed to tsunamis was considerably smaller than those who were affected by shaking effects. Moreover, it appears that only a third of the historical tsunamis produced fatalities, at least as reported at the time of their occurrence (Table 4), a conclusion that may reduce the attention needed for tsunami hazard awareness. Nevertheless, that tsunamis can be harmless should not be taken for granted because nowadays, the Israeli coast is disproportionately more developed and inhabited than before, including harbors and heavy infrastructure facilities. Furthermore, properties are more valuable and cultural and leisure time activities along the coast, mainly during summer time and holidays, are very intense.

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