



A revision of the Catalogue of tsunamis on the Spanish coast

Elena Ros¹ and Juan V. Cantavella¹

¹Instituto Geográfico Nacional (IGN). Madrid, Spain.

Correspondence: Elena Ros (meros@transportes.gob.es)

Abstract. Spain faces significant exposure to tsunami risk due to its extensive coastline and location between the Atlantic Ocean and the Mediterranean Sea. Historical records confirm that tsunamis have impacted the Spanish coast in the past, although such events have been relatively infrequent. In this context, a comprehensive review of tsunami catalogues, historical documents, scientific literature, and marigrams was conducted to compile an updated Catalogue of tsunamis on the Spanish coast, which is presented here.

To assess the reliability of the various historically claimed tsunami events, the available contemporary primary sources were critically reappraised. This process allowed the incorporation of new relevant information for some events, thereby refining their assigned reliability scores. Conversely, events included in previous compilations that lack support from credible historical sources or instrumental data were discarded.

The new catalogue comprises a total of 16 tsunami events, including those with a reliability index of probable and definite. Specifically, the compilation follows the parameterization criteria employed by the Euro-Mediterranean tsunami catalogue, where geological evidence is not considered; therefore, such information is included as complementary data.

The updated information provided for each tsunami and its generating cause, along with detailed descriptions of the observed effects in the affected localities, offers a better understanding of the tsunami hazard on the Spanish coasts.

1 Introduction

The term tsunami refers to a series of long-wavelength, long-period waves generated by the displacement of a significant volume of water, typically in an ocean or a large lake. By far, the most frequent cause of tsunamis is seismic activity occurring beneath or near the ocean floor. The next most common causes, in order of frequency, are landslides and volcanic eruptions, which can also occur in combination with seismic activity. Among these, landslides triggered by earthquakes are the prevailing cause (UNESCO/IOC-NOAA, 2023). Lastly, meteorite impacts or certain atmospheric processes can also generate tsunamis. The latter phenomenon, known as meteotsunamis, is of significant importance along the Spanish coasts (Vilibić et al., 2021); however, it falls outside the scope of this work.

Throughout history (1610 BC to AD 2023), over 2,600 tsunamis have been reported worldwide (NGDC/WDS, 2026), resulting in a total of 264 confirmed fatal events and more than 544,000 known deaths (UNESCO/IOC-NOAA, 2023). While not frequent in Spain, historical records document at least one deadly and damaging tsunami, showing the strong impact they can have.



This is the case of the tsunami that followed the 1 November 1755 earthquake, originated to the southwest of the Iberian Peninsula. The tsunami mainly affected the Portuguese, Spanish, and Moroccan coasts, with waves reaching over 10 meters in the Gulf of Cadiz. In Spain alone, casualties' estimates exceeded a thousand (Martínez Solares, 2001). The low probability of this phenomenon along the Spanish coasts, coupled with its occasional high impact, emphasizes the fundamental need for a catalogue as comprehensive and reliable as possible. Such catalogue is vital to effectively assess the tsunami hazard in this region.

Furthermore, tsunami catalogues contribute to public awareness and education about the tsunami threat. Disseminating information about past events can help raise awareness and promote preparedness among coastal communities. There are already several well-known global and regional tsunami catalogues with coverage of the Spanish coasts (e.g., NGDC/WDS, 2026; Maramai et al., 2019; Soloviev et al., 2000), others at the national level that span neighbouring countries (e.g., Baptista and Miranda, 2009; Kaabouben et al., 2009; Lambert and Terrier, 2011), and there are even tsunami catalogues exclusively for the Spanish coasts (e.g., Carreño et al., 1999; Campos Romero, 1992; Lario et al., 2011; Galindo et al., 2021). Nevertheless, despite this large number of catalogues, a certain degree of correlation exists among them, as several are at least partially derived from preexisting ones without providing significant new contributions.

The sources of information for these catalogues can be classified into three complementary categories: instrumental data, historical records, and geological-archaeological evidence, with the latter providing insights into both historical and prehistoric tsunamis.

Instrumental data are primarily derived from sea level and ground motion records. While ground motions, systematically recorded in Spain since the early 20th century, are used exclusively to characterize the earthquake source causing the tsunami, sea level records help confirm tsunami occurrence and assess its impact.

Traditionally, sea level data are acquired using tide gauges organized within networks. The inaugural network of this kind was established by the National Geographic Institute of Spain (Instituto Geográfico Nacional: IGN), which installed the first sea level measuring station in 1870 in Alicante (outer harbour) using a tide staff, followed by Santander in 1876 and Cádiz in 1880 with tide gauges. It was not until 1927 that new tide gauges were added to this network, in the ports of Alicante, Cartagena, and Santa Cruz de Tenerife. Subsequently, A Coruña (1950), inner harbour of Alicante (1957), and Almería (1978) received an IGN tide gauge. During the past few decades, the tide gauge distribution has undergone significant changes, witnessing a rise in the number of gauges in the Canary Islands and starting measurements on Alboran and Menorca Islands. The other primary network was established by the Spanish Institute of Oceanography (Instituto Español de Oceanografía: IEO). The IEO tide gauges have been recording data since 1943 at various coastal locations, including A Coruña, Algeciras, Ceuta, Málaga, Santander, Tarifa, and Vigo. Shortly after, in 1945, Cádiz joined the network. Three tide gauges were added to the Canary Islands (Arrecife, Puerto de la Luz, and Santa Cruz de Tenerife) in 1949. To extend the sea level records to the Balearic Islands, a tide gauge was installed in 1963 in Palma. Later, additional Spanish institutions such as Ports of Spain (Puertos del Estado: PdE), the Balearic Islands Coastal Observing and Forecasting System (Sistema de Observación y Predicción Costero de las Illes Balears: SOCIB), and the Spanish Hydrographic Office (Instituto Hidrográfico de la Marina: IHM) began the installation



of permanent tide gauges (in 1992, 2009, and 2021, respectively), substantially expanding the sea level monitoring network (Pérez Gómez et al., 2022).

Initially, these tide gauges were of mechanical type, documenting sea level observations in the form of paper-based marigrams. Upon reviewing the historical marigrams for the dates indicated by different tsunami catalogues (e.g., NGDC/WDS, 2026; Maramai et al., 2019; Carreño et al., 1999), several tsunami records were identified, although some of them are damaged or difficult to interpret due to equipment malfunctions or data recording errors. Furthermore, additional obstacles arise during the search for tsunami records, such as interruptions in the continuity of sea level observations at different periods or the loss of certain marigrams. After the 1980s, electronic instruments began replacing mechanical tide gauges, marking the shift to digital recording, which significantly improved the accuracy of tsunami signal recording and enabled more precise determination of arrival times compared to paper marigrams. This change not only enhanced precision but also allowed for a higher frequency of sea level measurements, enabling more continuous recording.

In addition to instrumental data, historical documents provide valuable information about the occurrence of tsunamis in the past. Chronicles, diaries, literature, and press can provide knowledge of tsunamis before the instrumental period. Unfortunately, historical accounts of tsunamis are scarce due to their reliance on observations from the population, which requires significant wave heights and harbour impact to avoid being overlooked. Additionally, subjective narrations lack the necessary scientific rigor (Campos Romero, 1992), hence, a critical evaluation of the sources is needed to compile a trustworthy catalogue of events.

Finally, along with instrumental data and reliable contemporary historical sources, tsunami catalogues also integrate findings from archaeology and geological research. These studies provide either confirmation of historical tsunamis or the uncovering of paleotsunamis.

Geological evidence suggesting past tsunami activity consists of several key characteristics. Among these are the presence of displaced boulders of exceptional size, the formation of tsunami washover fans or deposits of gravel, and remains of open-sea marine fauna (e.g., Gracia et al., 2010; Rodríguez Vidal, 2016; de Martini et al., 2021; Costa et al., 2022). Typical tsunami-related features found in coastal stratigraphic records include basal erosional unconformities and abrupt grain size increases, rip-up clasts and mud caps, and coarsening-upward sequences and layers that thin landward (de Martini et al., 2021). These geological indicators enable the dating and identification of past tsunami events (e.g., Rodríguez Vidal, 2016; Silva et al., 2023). However, in many cases, it is not possible to unambiguously associate them with a tsunami, as similar features may result from other high-energy events, such as storms (e.g., Kortekaas and Dawson, 2007; Lario et al., 2011; Costa et al., 2022). Moreover, there is uncertainty in dating these geological observations (Costa et al., 2022), which can span hundreds of years in prehistoric events (e.g., Lario et al., 2011).

Complementing geological evidence, the study of material remains, including paleontological elements and ancient buildings, provides valuable insights into past tsunami events (e.g., Rodríguez-Ramírez et al., 2016; Silva et al., 2023).

In this study, we review historical accounts and marigrams to validate the tsunami events previously attributed to the Spanish coasts or to inspect any evidence of tsunamis following large earthquakes in the area. A compilation of available tsunami measurements, along with detailed descriptions of each tsunami event, is provided. The information associated with each event is



further complemented with data from prehistoric studies. The tsunami catalogue resulting from this research provides new insights into the occurrence of these events along the Spanish coast. It is publicly available at <https://doi.org/10.7419/162.04.2023> and is subject to future updates as new information and evidence become available.

This work presents a new Catalogue of tsunamis on the Spanish coast. In the Methods section, we explain the structure of the catalogue and the indicators to assess the reliability of each tsunami event based on the compiled information. Afterwards, we elaborate on the 16 reliable tsunami events observed along the Spanish coasts, present the catalogue contents, and describe 2 additional potential tsunami events. Later, we address 13 events that were previously claimed to impact Spain but, due to insufficient evidence, have been discarded. Finally, we provide a thorough discussion of the study findings and draw conclusions that contribute to a broader understanding of tsunami events along the Spanish coast.

2 Methods

The methodology used to compile the Spanish tsunami catalogue involved a careful and critical revision of preexisting entries found in various tsunami databases (e.g., NGDC/WDS, 2026; Maramai et al., 2019; Carreño et al., 1999). Primary sources supporting these entries—such as original contemporary accounts from the time of each event—were actively sought. In addition, a comprehensive investigation was carried out to identify potential tsunamis not included in previously published catalogues. This process included an in-depth review of both academic and mainstream publications related to specific events, as well as an examination of the global seismic catalogue and available tide gauge records along the Spanish coast.

The main criterion for including events in the new catalogue is evidence of their impact on the Spanish coastline. Therefore, tsunami events that have been presumed to affect the Spanish territory in previous studies based solely on evidence from neighbouring countries have not been included, as they lack support from local observations within Spain. Another criterion is that the reliability index used to assess a past tsunami event must be greater than or equal to 2.

In this study, we follow Tinti et al. (2004) to evaluate this index based on the quality of available data regarding the generating cause, the description of the tsunami, and the contemporaneity of sources with respect to the event. Each aspect is independently scored from 0 to 2. A score of 0 is assigned when no specific information about the cause or tsunami is known, or when sources are significantly posterior to the event date (according to Tinti et al. (2004): "the author or authors lived several generations later, i.e., several tens of years or centuries"). A score of 1 is assigned when information about the cause or tsunami is scarce or uncertain, or when sources are posterior to the event date. Finally, a score of 2 is assigned when good information about the cause or tsunami is available, or when sources are coeval with the event. These partial scores are combined to obtain the reliability index, which ranges from 0 (very improbable tsunami) to 4 (definite tsunami), as shown in Table 1. Thus, each tsunami event description is accompanied by the assigned partial scores and the resulting reliability index.

As mentioned above, although this study also discusses tsunamis with reliability indices of 0 and 1 in the section titled 'Improbable tsunami events', these events are excluded from the Catalogue of tsunamis on the Spanish coast due to the insufficient evidence supporting their occurrence.



Table 1. Reliability scale employed in the Catalogue of tsunamis on the Spanish coast, derived from the work of Tinti et al. (2004). Scores: 2 = condition fulfilled; 1 = condition partially fulfilled; 0 = condition not fulfilled.

Cause	Tsunami	Sources	Reliability index	Description
2	2	2	4	Definite tsunami
2	2	1	3	Probable tsunami
2	1	2	2	Questionable tsunami
1	2	2		
0	2	2		
2	1	1	1	Improbable tsunami
1	2	1		
0	2	1		
1	1	2	0	Very improbable tsunami
1	1	1		
0	1	2		
All other combinations			No	No tsunami

In the evaluation of tsunami descriptions, a key parameter is the maximum observed wave height. When recorded by a tide gauge, this is measured as the largest peak-to-peak excursion within the tsunami signal, representing the maximum height between two adjacent peaks. The peak-to-peak approach is adopted due to the considerable variability in how tsunami wave heights have traditionally been measured. Thus, this method procures greater consistency in measurements obtained from marigrams and facilitates comparison between events.

3 Description of reliable tsunami events

3.1 The 22 September 1522

On 22 September 1522 an earthquake struck Almería and generated a tsunami that was observed at the harbour (Martínez Solares and Mezcua, 2002; Table 2). This event is documented in a letter sent to the Marquis of Villareal, which was subsequently translated and published in Germany in 1523, and later rendered into Spanish by Hervías and von Waldheim (1948). The letter contains the following passage: "...a ship or brigantine anchored in the harbour where Almería is located. On board, there arrived brethren from Burgos (...). On Monday, the 22nd of September, these brethren embarked to cross to the port of Vélez de Gomera. At that time, a great storm and sea wind arose between 8 or 9 in the morning, causing their ship to be forcefully cast ashore". This letter suggests that the witnesses' ship may have been cast ashore by a tsunami, likely connected to the



earthquake documented on the same day (López Marinas, 1977; Espinar Moreno, 2021). However, it is important to note that the historical account does not explicitly state that "several tsunami waves were observed at the port of Almería between 08:00 and 09:00 a.m.", as reported by Kaabouben et al. (2009) and subsequently cited in tsunami compilations such as Macías et al. (2013), as well as in global and European catalogues like NGDC/WDS (2026) and Maramai et al. (2019).

The narrative also has a cover featuring an illustration of coastal flooding and people drowning, accompanied by the following text: "About a terrible landslide and earthquake. Also about a great deluge, which collapsed cities, lands and men. And about many and very strange things that happened on the island of San Miguel, located near Gran Canaria; as well as in the Kingdom of Granada, Africa and Berbery on October 22, 1522, and translated from the Portuguese language into German, all of which is very pitiful to read" (Hervías and von Waldheim, 1948). The text provides the date of October 22 that corresponds to the earthquake suffered by the Azores islands, and which coincided with significant flooding caused by a deluge. Therefore, the combination of different events makes it difficult to determine which location is depicted in the illustration.

Another source describing the occurrence of an earthquake and a tsunami is the seismic catalogue compiled by Galbis Rodríguez (1932), which states that "...The city was submerged for the most part, under the waves of the Mediterranean". For this seismic record, the author relies on various documentary sources to describe the effects of the event, among which, only two are contemporaneous with the event date. On the one hand, there is the account of the journey through Spain (1524-1526) by the Italian traveler Navajero, which can be consulted in Fabié et al. (1879), and which describes a major earthquake but makes not mention to a tsunami. On the other hand, the minutes of the Ecclesiastical Council of Almería dated 22 October 1522 name some of the places where the earthquake had the greatest impact in the city of Almería. However, according to Francisco J. Escámez Mañas, Cathedral Archivist of Almería (personal communication, 2023), this date appears to be erroneous, as no such council is known to have taken place on the indicated date, the cited text has not been identified in any other known ecclesiastical council minutes, and the names of the streets mentioned in the account were established much later. For these reasons, he suggests that Galbis may have relied on hearsay rather than on a direct consultation of the archival records. Even though the author uses additional non-contemporary sources, a review of these references reveals no reference to the tsunami event.

Galbis extends the information about this earthquake in Part II of his seismic catalogue (Galbis Rodríguez, 1940) by discussing its effects on Peñón de Vélez de la Gomera, a small Spanish fortified rock located on the Mediterranean coast of present-day Morocco. While he mentions that "the Peñón de Vélez disappeared under the waters", he also expresses doubts regarding a possible exaggeration in the underlying source *Lettera scripta al Pontefice* (1522). The original document, preserved in the State Archives of Florence, was examined directly. The translation of the text is open to different interpretations, and there are no explicit references to the sea or to the phenomenon that may have caused the reported event. Therefore, any connection to a tsunami should be regarded as hypothetical or possible rather than conclusive.

On the other hand, Kaabouben et al. (2009) and Kaabouben (2010) suggest that there is strong evidence for a tsunami in this area, stating that "the effects of a devastating earthquake and tsunami waves on the village of Bades Ghomera, on the Mediterranean coast of Morocco, have been described in the municipal archives of Constance". Unfortunately, these archival sources could not be identified or located during the present study, preventing their direct evaluation.



Turning to the geological record, shallow drilling in the Cabo de Gata lagoon revealed sedimentary evidence of a paleo-tsunami nearly contemporaneous with the 1522 earthquake, as noted by Reicherter and Becker-Heidmann (2009). The study attributes this earthquake to the submarine part of the strike-slip Carboneras fault and proposes that the earthquake triggered a landslide (evidenced by the morphology of the seabed) that generated the tsunami. Regarding the number of tsunami waves, the study interprets the three observed coarse-grained intervals, each separated by a silty mud drape, as deposits of a tsunami train corresponding to three individual waves.

3.2 The 9 October 1680

On 9 October 1680, a major earthquake occurred close to the city of Málaga and was felt in much of the Iberian Peninsula (Martínez Solares and Mezcuca, 2002; Table 2). Among the written accounts reporting the effects of the earthquake, four documents (Relacion sucinta de lo sucedido, 1680; Relacion verdadera de la lastimosa Destruicion, 1680; Relacion verdadera en que da quenta de la Ruina, 1680; Segunda relacion del horrible Temblor, 1680) describe several common effects observed in the sea. Despite initially calm conditions, the waters became exceptionally turbulent, causing medium-sized boats to sway and some even to capsize. The largest boats rose out of the water, exposing their keels, and the noise of the movement of the water frightened those on board. Also, the fish were seen jumping out of the water. Moreover, the document Segunda relacion del horrible Temblor (1680) indicates that there was a sea level rise of 5 m, which is also mentioned in an additional document identified by Goded et al. (2008).

While these historical sources were originally intended for a broad audience, sometimes leading to exaggerations, they still contain valuable information about the event that needs critical analysis (Muñoz and Udías, 1988). In their review of these and other sources associated with the event, Goded et al. (2006) noted that some accounts suggest that the effects on the sea occurred during the earthquake rather than afterwards.

Conversely, seismic catalogues indicate an initial calm sea that became furious after the earthquake: Moreira de Mendonça (1758) describes the observed effects as "the sea, having been still, while the earthquake lasted, became furious in a way that wreaked great havoc" and Galbis Rodríguez (1932) indicates "the sea at the beginning of the earthquake remained calm, but then it became extremely agitated, raising a large wave, and the fish were seen violently leaving".

Despite Goded et al. (2008) dismissing the possibility of a tsunami due to the lack of evidence for flooding and their proposal of an inland epicenter at a depth of 40-50 km, the historical documents and the uncertainty regarding the epicenter's location suggest that a tsunami cannot be entirely ruled out. Therefore, it remains a plausible scenario.

3.3 The 1 November 1755

On 1 November 1755, an Mw 8.5 earthquake located in the eastern domain of the Azores-Gibraltar fracture zone triggered a transatlantic tsunami (Martínez Solares and Mezcuca, 2002; Table 2). The tsunami was observed along the North Atlantic coast, from Barbados to the United Kingdom, and was catastrophic in southern and western Iberia as well as in northwestern Morocco (Maramai et al., 2019). In Spain, the primary source of historical data is the collection held at the National Historical Archive, which originated from a survey ordered by King Fernando VI of Spain through the Circular Order dated 8 November 1755.



210 This survey requested information about damages and deaths in significant localities. Numerous responses from coastal areas highlighted observations of the sea. According to the findings of Campos Romero (1992) and Martínez Solares (2001), who extensively reviewed these contemporary documents, the tsunami had a more significant impact on the population, resulting in far more victims than the earthquake itself. The documented numbers in Spain are 1214 for the tsunami compared to 61 for the earthquake. These numbers, in any case, are rough estimations, as there are contradictions between different references for the same city and, most probably, many corpses were not recovered or counted.

Martínez Solares (2001) summarizes the most interesting aspects of all the places in Spain that perceived the movement of the sea, mainly affecting the peninsular provinces of Cádiz, Huelva, Málaga, Lugo, Pontevedra, A Coruña, Cantabria and Vizcaya, as well as the two provinces of Canary Islands, namely Las Palmas and Santa Cruz de Tenerife. From the contemporary synthesis of Bevis (1757), more provinces can be added to the list: València, that witnessed "very terrible agitations of the water", also Sevilla, located about 100 km inland along the Guadalquivir River, where "the waters were so greatly agitated, that all the vessels in the river were driven ashore", or even Toledo (around 600 km inland along the Tagus river from its mouth in Lisbon), where "the river rose ten feet". Figure 1 shows the location of these observations. Furthermore, there is evidence that the tsunami was felt by some ships sailing on the high seas near Cádiz and València (Bevis, 1757).

A particularly illustrative account of the tsunami is the one cited by Campos Romero (1992), which describes the impact of the sea on the beaches of Chiclana de la Frontera (Cádiz): "like a wall, even higher than that fort, followed by another of greater height, and another afterwards even higher than the two (...) flooding and submerging all those places, and the beaches within the boundaries of Cádiz (...)". The account also notes that "these surges were observed three times with notable force" and that the seawater entered through the river's mouth.

Regarding the maximum height reached on the Spanish coast, the *Report of the Royal Academy of History* (1756) (Noticia individual, 1756; Campos Romero, 1992) describes the event in Ayamonte (Huelva) as follows: "The sea left its center with unusual violence (...). At the Canela tower, located at the Port's Bar, the waves rose so high that they covered more than half of it". According to Solares (2001), the wave must have reached nearly 13 m, given that the tower is 17.9 m tall and assuming its elevation above sea level (4 m) has remained unchanged since then.

According to some historical documents, the tsunami wave may have been significantly higher in the city of Cádiz. Two letters published in the *Philosophical Transactions*, written by Bewick (1756) and de Ulloa (1756), refer to wave heights of sixty feet—approximately 18 m—either "higher than common" or "above the ordinary level of the water". However, these appear to be the only sources reporting such heights. In addition, a critical review by Blanc (2008) argues that these values are likely overstated, especially when contrasted with historical descriptions of the flood's impact on Cádiz and its defensive walls. The author suggests that the numbers may have been altered during the transcription of the original sources. Further supporting a more moderate estimate, Campos Romero (1992) concludes that the wave must have been at least 5 m high, based on contemporary descriptions of the sea overtopping the city walls, which were approximately five varas tall. A *vara* is a length unit that was used in different regions of Spain with different values, which ranged between 768 and 912 mm.

Moving from historical accounts to geological findings, Costa et al. (2022) reviewed the sites where tsunami deposits have been correlated to the 1755 event and provided a summary of the existent knowledge. Research has been conducted in the

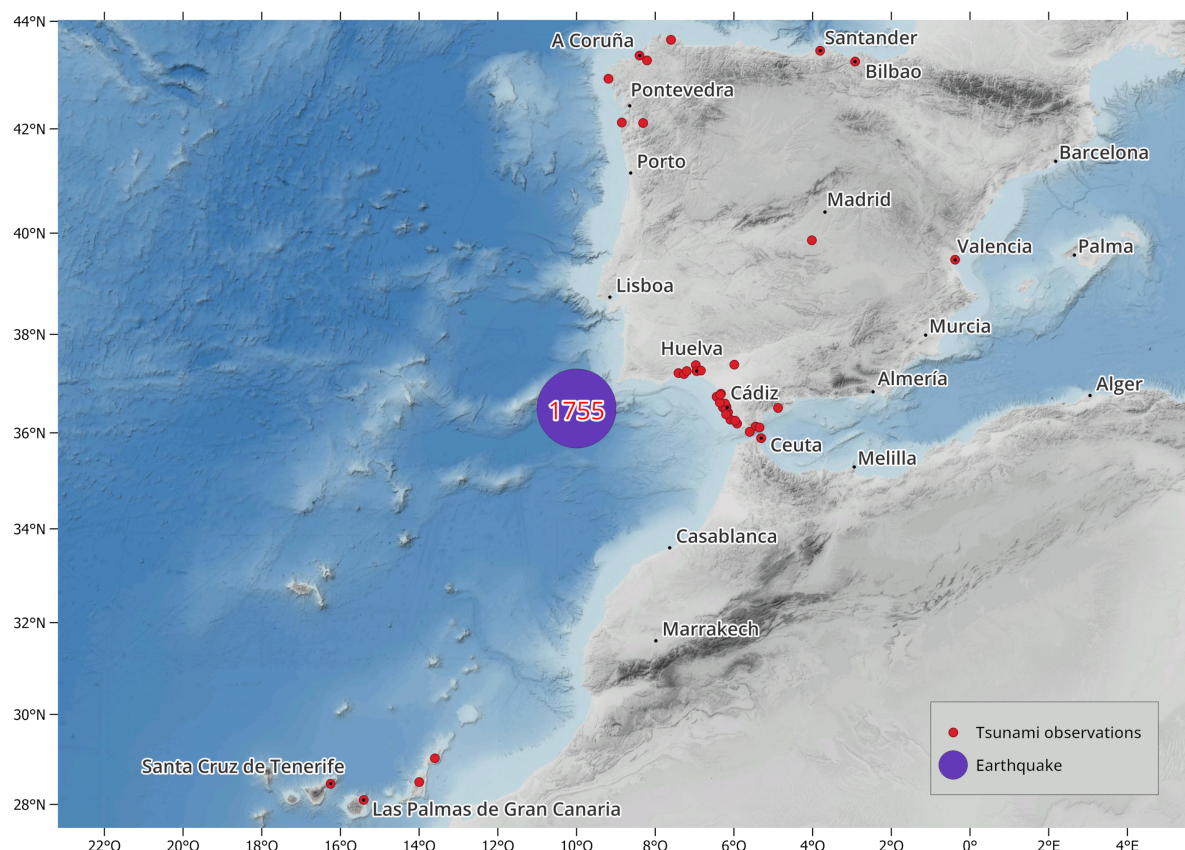


Figure 1. Documented observations of the 1755 tsunami along the Spanish coast, compiled from historical sources. The earthquake epicenter is indicated by a purple circle, while tsunami observation sites are shown as red circles.

245 Guadiana, Rio Piedras, Tinto-Odiel, and Guadalete estuaries, located in the provinces of Huelva and Cádiz, as well as the coastal region between Cádiz and Gibraltar. These deposits typically consist of coarser sandy layers sandwiched between muddy sediments in estuarine, alluvial, or lagoonal environments, characterized by their palaeontological peculiarities such as marine shell fragments (Costa et al., 2022, and references therein). Additionally, tsunami boulders along the coast of Lanzarote in the Canary Islands have been interpreted as a consequence of the tsunami waves (Galindo et al., 2024).

250 3.4 The 31 March 1761

An Mw 8.5 earthquake occurred on 31 March 1761, with its epicenter in the Azores-Gibraltar region, specifically southwest of the Coral Patch Seamount (Baptista et al., 2006; Table 2). The resulting tsunami was observed across the North Atlantic, with effects reported from the Azores and Barbados to Ireland, the Netherlands, the Iberian Peninsula, and the United Kingdom (Baptista et al., 2006). In a letter to Dean of Exeter (England), Reverend Borlase (1761) reports that, several leagues to the west



255 of Cape Finisterre, "an unusual agitation was felt, as if the ship has struck on sunken rocks". This information was echoed a century later by Perrey (1847) and Von Hoff (1841), and repeated in the Galbis' seismic catalogue (Galbis Rodríguez, 1932).

According to de la Torre (1997), the President of the Royal and Supreme Council of Castile, Dr. Diego de Rojas y Contreras, sent a circular letter to the local authorities of the Kingdom of Spain asking them about the possible damage and victims caused by the earthquake. From the responses received, elementary drafts were created at the Secretariat of the Supreme Council of
260 Castile. These documents were later reviewed by de la Torre (1997), who compiled information on the sea's behavior in four different cities. In Cádiz, a gradual restlessness of the water during ebb and flow was observed on three occasions. In Puerto de Santa María (Cádiz), a rise in water levels in toilets was reported. In Ayamonte (Huelva), the sea surged three times, although "with little force". Even in Barcelona, some sea disturbance was reported.

A more recent revision of contemporary documents related to this event by Galindo et al. (2021) concludes that along the
265 northern coast of Tenerife Island, in the Canary Islands, there was a "previous withdrawal from the sea and then its rise, which frightened the inhabitants and led them to think on the occurrence of a distant earthquake like the one felt five years earlier". Notably, their only reference to the tsunami comes from the memoirs of the perpetual alderman of the island of Tenerife at the time (Guerra y Peña and Roméu Palazuelos, 2002), who wrote "...and it was noted that the sea had withdrawn more than usual, leading to the belief that there had been some significant upheaval on land; for it was the same as what was observed on
270 November 1st of the year 1755 during the great earthquake of Lisbon". According to Perrey (1847), "This earthquake was very violent in the Azores and the Canaries. The waters were very rough on the eastern beach".

Although the existence of a tsunami in mainland Portugal, the Azores, Ireland, the United Kingdom, and the Netherlands is well documented (de la Torre, 1997, and references therein), the evidence along the Spanish coasts is much more limited. Nevertheless, some sources suggest that a tsunami may have occurred without causing damage in Cádiz, Puerto de Santa María,
275 Ayamonte, and La Laguna. In contrast, the reference to "the sea was altered" in Barcelona is vague and could be attributed to other causes, such as a meteorological event. Moreover, the absence of similar reports of sea disturbance along other Mediterranean coastal locations further weakens the interpretation of the Barcelona observation as tsunami-related. Therefore, it seems unlikely that the tsunami reached that far east.

3.5 The 9 October 1790

280 On 9 October 1790, an Mw 6.7 earthquake in Oran struck northern Africa and southeastern Spain, generating a tsunami that affected coastal cities on both shores (Kaabouben et al., 2009; Buform et al., 2019; Table 2). The Spanish contemporary publication of December, *Memorial literario* (1790), included a section called "News of the earthquakes in the city of Almería" affirming that "the sea went into land more than forty varas" (about 50 m).

According to López Marinas and Salord (1990), there is a letter in which the Marquis of The Tilly House, captain of the
285 Cartagena Department, reports to Don Antonio Valdés, head of the Ministry of the Navy, that the waters within the port and dock were in motion, with currents so strong they lifted the dock and unmoored a fishing boat and several barges. However, on the Promenade of the Grand Dock (Malecón del Dique Grande), no one noticed the slightest sensation, even though the water level rose by six feet (1.8 m). Within the port, a few boats were set adrift, and the rising waters briefly exposed some areas,



leaving them dry for a short period. The newspaper *Hamburgischer Correspondent* (Hamburgischer Correspondent, 1790) on
290 13 November 1790 describes how the sea rose violently in Cartagena, forcing the workers at the shipyards to abandon their
posts.

3.6 The 13 January 1804

On 13 January 1804, an Mw 6.1 earthquake occurred in the Alboran Sea (Martínez Solares and Mezcua, 2002; IGN, 2013;
Table 2). The Spanish newspaper *La Gazeta de Madrid* reported on 27 January news from Granada describing the earthquake
295 and the retreat of the sea: "On the 13th of the current, at prayers, an earthquake was felt (...) In Málaga, Vélez, Adra, Motril,
and other coastal towns, it has been greater: it repeated up to 6 times at different times of the night, occupying the startled
people in the streets and squares, and causing ruins and two deaths in Motril: it was noted that the sea had retreated about 22
varas" (La Gazeta de Madrid, 1804). This is the only coeval reference to a tsunami; however, it is unclear where exactly the sea
retreated, although it could be inferred to have occurred along the coast near Motril (intensity VI) or Adra (intensity VII-VIII),
300 where the earthquake caused the most damage (Martínez Solares and Mezcua, 2002). This may explain why literature often
cites Adra or Motril as the locations affected by the tsunami.

This tsunami has been mistakenly associated in the literature with two different earthquakes, dated 21 January and 18
February 1804. The first reference to the 21 January earthquake in a seismic catalogue appears in Von Hoff (1841), who does
not report any sea disturbance, while the earliest mention of a tsunami, in Adra, is provided by Campos Romero (1991), who
305 cites Galbis Rodríguez (1932) as the original source. However, Galbis Rodríguez (1932) does not refer to a tsunami on 21
January, but instead describes a sea disturbance linked to the earthquake of 18 February, based on Godoy Ramírez (1917). The
latter, relying on information compiled several decades after the events, reports that "The shocks that took place on 13 January
and 18 February had repercussions in Almería and Adra; in the latter location, the sea withdrew about 22 varas". It should also
be noted that the 18 February earthquake has been classified as a false event in the latest revision of the Seismic Catalogue of
310 the Iberian Peninsula (880 A.D. - 1900) (Martínez Solares and Mezcua, 2002).

Beyond these conflicting date assignments, there is ambiguity in the interpretation of the initial behaviour of the reported sea
disturbance. While Godoy Ramírez (1917) describes a retreat of the sea for both 13 January and 18 February, Galbis Rodríguez
(1932), drawing on the same source, assigns the phenomenon to 18 February and states that "the sea advanced about 22 varas".
This change in description may reflect a reinterpretation of the original account, implying an initial inundation rather than a
315 withdrawal. Subsequent studies (e.g., Espinar Moreno, 2021; Huerta et al., 2015) have adopted this interpretation as evidence
of a tsunami.

On the other hand, the newspaper *La Gazeta de Madrid* also published on the 8 May a letter received from Peñón de Vélez
de la Gomera: "On Friday, January 13, at 05:40 in the afternoon, a regular earthquake was experienced (...) In the part of the
sea, immediately to the coasts, the waves rushed with such impetus, that it seemed the sea was going to come out; and at the
320 distance of a pistol shot from the coast was the sea, almost white from the great calm that was experienced". Therefore, it can
be derived that, at least, strong waves were seen in this part of the African coast.



3.7 The 21 August 1856

On 21 August 1856, a tsunamigenic earthquake of Mw 6.6 occurred near Jijel (Algeria) (Harbi et al., 2011; Table 2). The Spanish newspaper *El Genio de la Libertad*, three days after the event, published a piece of news that reported the local newspaper *El Eco de Menorca* on 23 August: “Before last night at about half past nine, a slight earthquake was observed in this city that was preceded by a kind of meteor. During the movement there was an extraordinarily high tide that flooded the entire line of docks as if by magic, the current being so impetuous that the moorings of some ships anchored in the port broke. Unaccustomed to suffering this type of atmospheric pressure on the island, it is said that the one in question produced quite a few scares” (Eco de Menorca, 1856). The Mallorcan newspaper *El Palmesano*, dated 26 August, also describes how the earthquake in Mahon was accompanied by a high tide (Terremoto, 1856). On 12 September, the French weekly scientific journal *Cosmos* published “The tremor of the earthquake that occurred in Algeria on August 21 was felt in Mahon (Balearic Islands) around nine-thirty in the evening. At the same time, the sea suddenly swelled extraordinarily and caused a tidal wave that resulted in some damage in the port” (Moigno et al., 1856). This information is repeated in Perrey (1859), who reports the following: “In Mahon, 9 h. 30 m., slight tremor, preceded by a species of fulguration or igneous meteor. During the shock, the sea rose very high and instantly invaded all the quays with such violence that many ships broke their moorings”.

Drawing on this information, Roger and Hébert (2008) do not rule out the possibility that the sea-level rise was caused by a meteorological effect rather than by a tsunami triggered by the earthquake, which may have been limited to a localized area along the Algerian coast. This possibility is based on reports from two French journals mentioning a storm in the western Mediterranean, although these accounts could not be independently verified. Moreover, the observation that the high tide coincided with the earthquake, rather than occurring afterward, raises additional doubts. These uncertainties, together with the fact that the tsunami was observed at only one Spanish location, lead to assigning this event a reliability index of 2 (questionable).

3.8 The 25 November 1941

On 25 November 1941, an Mw 7.8 earthquake in the Azores-Gibraltar fracture zone generated a tsunami observed in mainland Portugal, the Azores, Morocco, and southwest England (ISC-GEM, 2026; Table 2). In Spain, the only reference to the tsunami appears in the *Boletín de las Observaciones Sísmicas del Observatorio Sismológico de Almería* [Bulletin of Seismic Observations from the Seismological Observatory of Almería], covering the period July-December 1941, which states: “The tsunami wave was violent in the Canary Islands”. However, according to Baptista et al. (2016), the marigram from Tenerife was unreadable. The IGN marigram for that period is currently missing, and not additional tide gauge records are available from the Canary Islands or the Gulf of Cádiz.

A review of contemporary Spanish newspapers reveals that they reported only on the earthquake, with no allusion to a tsunami affecting the Spanish coast. For instance, *Diario de Barcelona* on 26 November 1941 mentioned that the quake was felt in Huelva and Seville, without mentioning any sea disturbances. Similarly, *Falange Diario de la Tarde* from Las Palmas de Gran Canaria on 27 November 1941 made no reference to any tsunami. Galindo et al. (2021) also reviewed coeval newspapers



and concluded that the tsunami must have gone unnoticed, as they found no reports to that effect. Based on the scarce information for the Spanish coasts, this tsunami is assigned a reliability index of 2 (questionable).

Although the official seismic bulletin of Almería described the tsunami as “violent”, since no contemporary evidence has been found in local newspapers or archives to confirm the occurrence of the event or its effects, it is considered likely to have been of low intensity. Accordingly, a grade I on the Sieberg-Ambraseys scale and grade II on the Papadopoulos-Imamura scale have been assigned. These values should be revised if new relevant information becomes available.

3.9 The 9 September 1954

An Mw 6.7 earthquake in the locality of Chlef (named Orleansville in 1954 and El Asnam in 1980) (Algeria) (Mezcua and Martínez Solares, 1983; Hamdache et al., 2010) was followed by a low amplitude tsunami registered on 9 September 1954 at tide gauges along the Spanish coast (Table 2). Some studies suggest that the source of the tsunami was a submarine landslide generated by the earthquake (e.g., Heezen and Ewing, 1955; Soloviev et al., 2000). The event generated a turbidity current that resulted in damage to five submarine phone cables situated less than 100 km from the coastline. Notwithstanding, Roger and Hébert (2008) argue that the tsunami was directly triggered by the earthquake, since there is no evidence of mass movement, and the tsunami wave periods are not compatible with a landslide origin.

In Spain, the tide gauges in Málaga, Algeciras, and Ceuta, from IEO, and in Alicante, from IGN, recorded the arrival of the tsunami. At the outer harbour in Alicante, the first wave of the tsunami arrived at 01:53 and the maximum wave height of 0.34 m was recorded at 02:45. In Málaga, strong oscillations began at 03:35, and the maximum wave height reached 0.32 m at 07:20. In Algeciras the tsunami arrival was at 04:35, with a maximum wave height of 0.13 m at 07:35. In Ceuta the rise of the water started at 04:10, reaching the maximum wave height of 0.09 m at 07:30.

Soloviev et al. (1992) compares the isochronal lines of tsunami propagation with the marigrams and concludes that the apparent arrivals at Málaga, Algeciras, and Ceuta correspond to an edge tsunami wave rather than the direct tsunami wave. This observation is supported by the Málaga marigram, where less intense oscillations start at around 02:30. However, such oscillations are not visible on the marigrams of Algeciras and Ceuta before the annotated times, and the inferred travel times of about 3 hours from the source are approximately twice as long as expected. This phenomenon is explained by Soloviev et al. (1992) as resulting from “the constructive interference of the direct tsunami wave multiply reflected from the opposite shores of the sea”.

3.10 The 28 February 1969

An earthquake of magnitude Mw 7.8 occurred the 28 February 1969 in the Atlantic Ocean southwest of Cape St. Vincent (Bufo et al., 2020; Table 2). The associated tsunami was recorded by tide gauges along the coasts of mainland Portugal and the Azores, the southern coast of Spain and the Canary Islands, and Morocco (Maramai et al., 2014).

On 1 March, the Spanish newspaper *ABC* reported various accounts regarding the aftermath of the earthquake and its impact on different cities across Spain. With regard to a possible tsunami, it was only mentioned that “in some areas near Gijón, small



boats broke their moorings and began to drift". However, the report cautioned that this information requires confirmation, making this an uncertain case (Aparicio Florido, 2020).

390 The *Spanish bulletin on nearby earthquakes* from 1969, compiled by the Central Laboratory of the Seismology Service of the Geographical and Cadastral Institute (now the National Geographic Institute), mentions a tsunami of less than 1 m in the Canary Islands and the Gulf of Cádiz (del Servicio de Sismología, 1969). This information was reproduced in the *Newsletter of the International Tsunami Information Center* (ITIC, 1969), which also notes that tide gauge records were requested.

395 The first publicly available reports containing measurements of the maximum tsunami wave height along the Spanish coasts were the *Annual summary of information on natural disasters* (Rothé, 1971) and the study by López Arroyo and Udías (1972). The former cited the ITIC in Honolulu (USA) as the source for wave heights of 0.10 m in Tenerife, 0.23 m in Cádiz, 0.48 m in Chipiona, and 0.31 m in Bonanza, while the latter noted: "Tsunami observations of relatively small amplitudes have been reported (...) Sevilla 0.2 m, and Santa Cruz de Tenerife 0.2 m".

400 After conducting a review of the marigrams from the 28 February 1969, measurements of the tsunami are provided for the following locations: A Coruña, Algeciras, Cádiz, Ceuta, Tarifa, Arrecife, Las Palmas de Gran Canaria, and Santa Cruz de la Palma (recorded by the IEO), Bonanza (recorded by Puertos de Sevilla) and Santa Cruz de Tenerife (recorded by IGN).

In the peninsula, the tsunami first reached Tarifa, arriving around 03:30 and registering a maximum wave height of 0.10 m at 05:45. Shortly after, it arrived in Algeciras at 03:35, where the peak height of 0.12 m was reached at 06:20. Next, it reached Ceuta, where the tsunami arrived at 03:45, with a maximum wave height of 0.10 m recorded at approximately 05:45. Later it arrived in Cádiz, at 04:05, and the maximum height of 0.27 m was reached at 05:30. In Bonanza, the tsunami arrived at 04:21
405 and reached its maximum height of 0.34 m at 06:35. Finally, in A Coruña, the tsunami arrived at 04:30, with a maximum wave height of 0.32 m observed at 06:00.

Regarding tsunami records in the Canary Islands, the arrival of the tsunami in the marigrams from Santa Cruz de Tenerife, Santa Cruz de La Palma, and Las Palmas de Gran Canaria is read at 03:05, 03:07, and 03:20, respectively. In the case of Arrecife, the record does not show data prior to 03:00, and therefore the arrival time cannot be determined with confidence.

410 These marigrams lack explicit annotations regarding the time zone used, with the exception of the Santa Cruz de La Palma marigram, where T.M.G. (Greenwich Mean Time) is indicated together with another annotation that is barely legible and appears to indicate "local time." In winter, local time in the Canary Islands coincides with GMT, and therefore we consider that the time readings are given in GMT. This interpretation is supported by the publication of Rothé (1971), which places the maximum amplitude in Santa Cruz de Tenerife at 03:02, whereas the publication by Gjevik et al. (1997) places the first
415 arrival at 04:02, having therefore added one hour. From this, confusion arises when establishing arrival times; for example, Baptista et al. (2025) also place the first arrival in Santa Cruz de La Palma and Las Palmas de Gran Canaria at 04:11 and 04:14, respectively.

Using the times extracted from the marigrams, the maximum recorded heights are 0.09 m at 04:55 in Santa Cruz de Tenerife, 0.15 m at 06:05 in Arrecife, 0.45 m at 03:50 in Las Palmas de Gran Canaria, and 0.48 m at 06:00 in Santa Cruz de La Palma.
420 According to Galindo et al. (2021), the local press in the Canary Islands did not report any sea disturbance on that date.



In the province of Cádiz, in addition to the measurements reported for Algeciras and Cádiz, tsunami wave heights were also recorded at Chipiona, although the original marigram record could not be consulted for this study. It remains uncertain whether the tide gauge was under the authority of Puertos de Sevilla; neither the Hydrographic Institute of the Navy (Instituto Hidrográfico de la Marina: IHM) nor the Royal Observatory of the Armada (Real Observatorio de la Armada: ROA) holds records of tide gauge campaigns or marigrams from that period at this site. We therefore rely on the information provided in the compilation by Rothé (1971): the maximum wave height (peak to trough) was registered for Chipiona at 05:35, measuring 0.48 m, and the tsunami arrival time was 03:56 according to Baptista et al. (2025), who do show the de-tided digitized record.

3.11 The 17 July 1969

The 17 July 1969 tsunami was detected by the IGN tide gauge of Santa Cruz de Tenerife (Figure 2) and the IEO instruments in Arrecife, Las Palmas de Gran Canaria, and Santa Cruz de la Palma (Table 2). The first wave was registered at 04:15, 05:14, 04:00, and 04:10, respectively, and a maximum height of 0.24 m, 0.12 m, 0.26 m, and 0.24 m was recorded at 04:35, 05:55, 05:35, and 4:52. Both the Santa Cruz de La Palma and Santa Cruz de Tenerife marigrams indicate GMT (Greenwich Mean Time); therefore, the Arrecife marigram appears to be offset by one hour, with the actual arrival occurring at 04:14 and the maximum at 04:55.

Local newspapers did not report any damage or observations (Galindo et al., 2021). Regarding the tsunamigenic source, it could not be associated with an earthquake (Baptista and Miranda, 2009), not even with anomalous meteorological conditions (Cabral, 2021), so the origin of this tsunami remains unknown. It is worth notice that, according to Baptista and Miranda (2009) and a recent personal communication with Baptista, tide gauges records in the Portuguese cities of Lagos, Cascais, Horta (Faial Island) and Angra do Heroísmo (Terceira Island) show a clear tsunami signal of small amplitudes, which suggests that the tsunami source was located southwest of the Iberian margin.

3.12 The 26 May 1975

An earthquake of Mw 7.8 in the Azores-Cape St. Vincent Ridge region (IGN, 2026; ISC-GEM, 2026) generated a tsunami that was recorded at tide gauge stations of the Azores, mainland Portugal, the Canary Islands, mainland Spain, and southwest England (Campos Romero, 1992; Maramai et al., 2014; Table 2).

A review of the Spanish marigrams registered by IGN tide gauges in A Coruña and Santa Cruz de Tenerife, along with those recorded by IEO tide stations at Algeciras, Cádiz, Ceuta, Las Palmas de Gran Canaria, Tarifa, and Vigo, reveals a well-defined tsunami signal, although its arrival at Arrecife, Santa Cruz de Tenerife, and Algeciras is not clearly identifiable in the records.

In the Canary Islands, Las Palmas de Gran Canaria and Santa Cruz de Tenerife marigrams show the first arrival impact around 10:40, with a maximum wave height of 0.16 m recorded at 13:00 and 0.07 m at 12:20, respectively. Arrecife registered the first arrival at 12:15, with its peak wave height of 0.04 m recorded at 13:15.

In mainland Spain, the tsunami was first recorded in Vigo at 11:17, reaching the maximum wave height of 0.15 m at 11:30. In A Coruña, the tsunami arrival was recorded at 11:40, reaching its peak at 12:05 with a wave height of 0.12 m. In Tarifa, the tsunami was registered at 11:24, with a maximum wave height of 0.13 m at 15:22. The tsunami arrived in Cádiz at 11:35 and

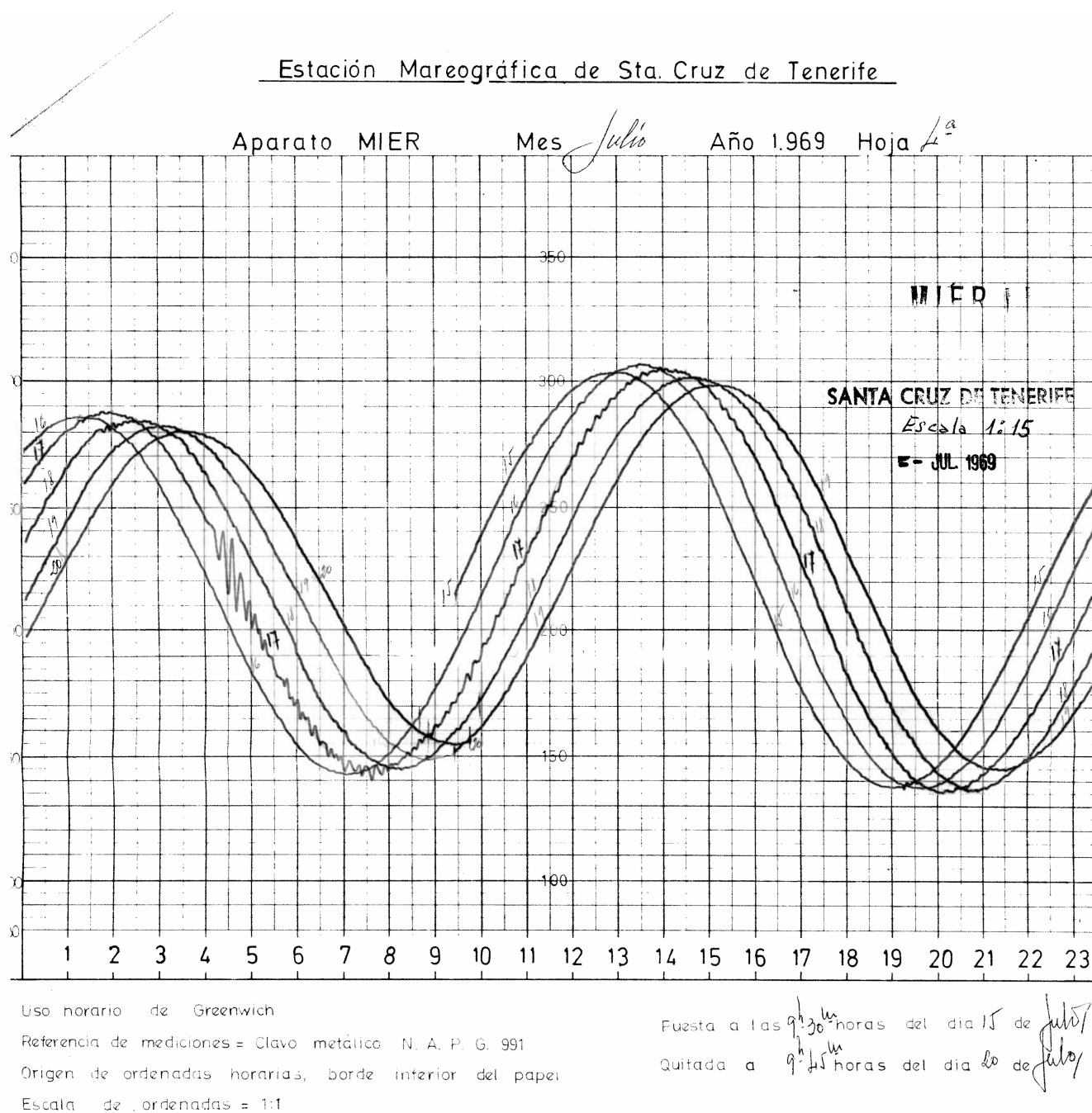


Figure 2. Santa Cruz de Tenerife marigram showing sea-level variations on 17 July 1969. IGN, National Geographic Institute of Spain.

reached a maximum wave height of 0.22 m at 16:00. In Ceuta, the tsunami arrival was at 13:10, with a maximum wave height



455 of 0.05 m at 13:55. Algeciras was the last location on the list, with the tsunami arrival at 13:20 and a maximum wave height of
0.05 m at 14:35.

3.13 The 10 October 1980

An earthquake of Mw 7.1 occurred on 10 October 1980 (IGN, 2026), with its epicenter in the north of Algeria, very close
to that of 9 September 1954, also inland (Soloviev et al., 2000; Table 2). This earthquake produced a weak tsunami that was
460 registered by IGN tide gauges in the southeast of the Spanish peninsula.

At the outer harbour in Alicante, the arrival time was 13:18, with the maximum wave height occurring at 13:45, measuring
0.16 m. The tide gauge on the inner harbour in Alicante registered the arrival of the tsunami at approximately 13:20, but
it should be noted that, according to Soloviev et al. (1992), the existence of background seiches with a 20-minute period
complicates the reading of the tsunami signal. The maximum wave height, observed at 15:10, was 0.51 m. In Almería, the
465 tsunami arrived at 13:12, with a maximum wave height of 0.09 m recorded at 17:04.

Regarding the Cartagena record, the IGN marigram is currently missing, and no published version of it is available. Soloviev
et al. (1992) reviewed the marigram, which was of poor quality, and noted the difficulty in determining the tsunami's arrival
time. The oscillations starting at 14:20 were interpreted as corresponding to a shelf (edge) tsunami wave and the maximum
amplitude was reported to be 0.70 m.

470 According to Soloviev et al. (1992), in Algeciras, the tsunami arrived at approximately 14:00, with the maximum wave
height recorded at 16:25, measuring 0.15 m. However, the scanned marigram from the IEO (see Fig. 3a) shows that the sea
level curve corresponding to the reported tsunami actually belongs to the record from 5 October, not 10 October. To clarify this
discrepancy, we examined the theoretical tidal curves for both dates. Considering that uncertainties increase the further back
in time we go, it was found that the times of high and low tides on both days are consistent with their respective theoretical
475 curves. The observed tides were also compared with the tide gauge record in Ceuta, showing agreement. Consequently, the
possibility of an error in the numbering of the days was excluded. Additionally, the engineer's notebooks were reviewed in
search of any relevant annotations; however, no further information could be identified. Finally, Soloviev et al. (1992) also
reports the tsunami arrival in the digitized Málaga marigram; in contrast, the scanned marigram provided by the IEO (see
Fig. 3b), covering the period from the 10 to the 17 October, shows no curve comparable to the one published in Soloviev
480 et al. (1992). Since these curves cannot be confidently confirmed and correspond to locations farther from the epicenter, these
observations are omitted for the time being, pending further clarification.

It is known that, shortly after the seismic event, the only operating telephone cable connecting Alger and the Balearic city
of Palma broke (El-Robrini et al., 1985). Based on this and other similarities with the seismic and tsunamigenic events that
occurred in 1954, a number of studies propose that the 1980 tsunami was also related to a strong turbidity current generated
485 by a submarine landslide, as a consequence of the earthquake (e.g. Soloviev et al., 2000; Papadopoulos et al., 2007). On the
contrary, Roger et al. (2011) proposes that the coseismic deformation of the earthquake would be sufficient to generate a low
amplitude tsunami, without the need for a submarine slide.

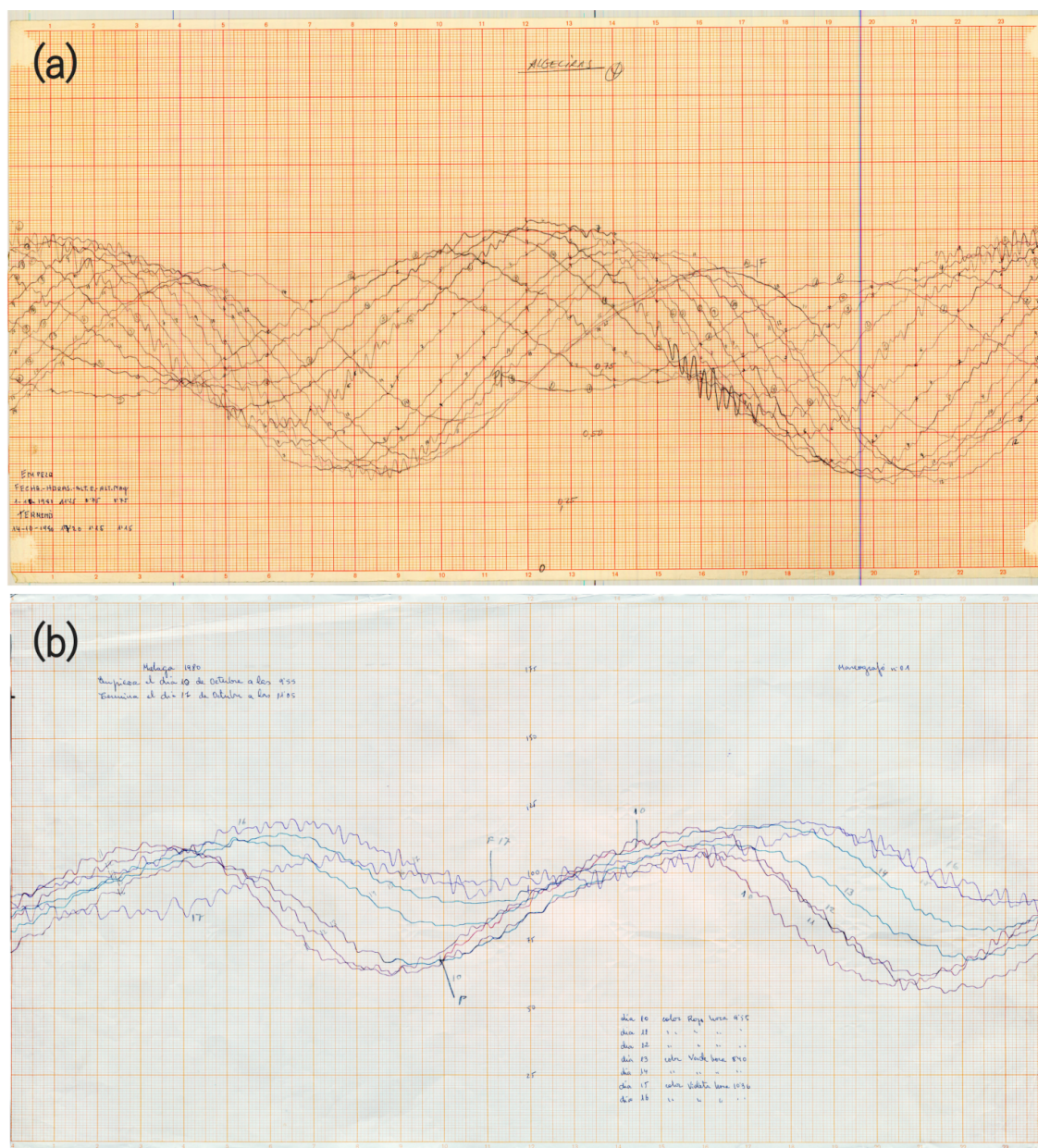


Figure 3. (a) Algeciras and (b) Málaga marigrams showing sea level variations on 10 October 1980. IEO-CSIC, Spanish Institute of Oceanography.

3.14 The 21 May 2003

On 21 May 2003, a strong shallow earthquake of Mw 6.8 struck the province of Boumerdes in Algeria and triggered a tsunami that reached the Spanish coastline (IGN, 2026; Sahal et al., 2009; Maramai et al., 2019; Table 2). The largest impact occurred



in the Balearic Islands, with the most affected ports being Maó in Menorca, Sant Antoni de Portmany and Santa Eulària in Ibiza, and Palma in Mallorca. The most significant damages in the ports occurred during the water retreat and were widely reported by Spanish newspapers, including *El Mundo*, *Periódico de Ibiza y Formentera*, and *Libertad Digital*, among others (Feliu and Gabaldon, 2003; J.M.A., 2003; L.D., 2003).

495 Maritime Rescue in Palma provided detailed information about the observed effects: the oscillations began 1 hour and 20 minutes after the earthquake, with a period ranging from 4 to 7 minutes, and the "waves" were 1.5 to 2.0 m high. What was observed was not a "wave", but a rise and fall of the entire sea, along with strong whirlpools. The water was murky (due to seabed movement) throughout the Balearic Islands. A diver at a depth of 80-90 m observed water with a lot of dust in suspension -never seen before- (5-10 nautical miles south of Pollença, towards Formentera). Objects of various kinds (logs, 500 plastics, etc.) that had been stirred up from the seabed appeared everywhere. Some fish appeared on land, as in the seafront promenade of Sant Antoni de Portmany, where flooding damaged 15 cars. In some narrow ports (such as Santa Ponça) the noise could be heard when the sea receded, like the descent of a torrent. Several tuna fishing boats on the high seas (off the continental shelf) noticed "like clutch failure" and vibrations, which stopped after a while. In some ports, docks were damaged (Santa Eulària) and anchor points and mooring chains were shifted. In Palma, water reached the seafront promenade. Some 505 bars located on the beach were also damaged. In port de Andratx, effects were significant with considerable damage. In general, in other ports, the effects were noticeable, but no significant damages were reported.

Additionally, the Maritime Captaincies, peripheral bodies of the Maritime Administration, provided more information on the effects noted along the Balearic coast and the eastern Iberian Peninsula, where the tsunami was observed at various locations in the provinces of Castelló, Alicante, and Murcia.

510 The data recorded at the different tide gauges indicate that the tsunami first reached the Balearic Islands, with Eivissa recording the first wave at 19:30 and achieving a maximum height of 0.60 m by 21:25. Palma followed closely, with its first wave arriving at 19:35, peaking at 1.20 m by 21:27. Sant Antoni recorded its first wave at 19:44, which reached a maximum height of 1.96 m at 21:04.

Along the Spanish mainland coast, both the outer and inner harbours of Alicante noted their first waves at 19:50, and arrived 515 later in Cartagena at 20:00, Barcelona at 20:05, València at 20:15, Almería at 21:00, Málaga at 21:40, Ceuta at approximately 22:00, and Tarifa at 22:55. In the case of Málaga, Heidarzadeh and Satake (2013) report a tsunami arrival time at 20:45, after which a period of about 45 minutes characterizes the tsunami signal for a short time. Their waveform analysis also identifies a shorter dominant period of approximately 20 minutes.

The maximum height recorded in the outer harbour of Alicante was 0.37 m at 20:40, whereas in the inner harbour it 520 reached 0.90 m at 22:10. In Barcelona, the maximum height was 0.45 m at 22:55 and 0.53 m in València at 23:50. In Almería, the maximum wave reached a height of 0.12 m at 23:30, while Málaga's peaked at 0.24 m at 23:20. Ceuta recorded its maximum height of 0.06 m at 23:00. Finally, Tarifa registered a maximum of 0.07 m at 01:30.

It should be taken into account that the sampling interval of the tide gauges that recorded the tsunami varies from 1 minute (e.g., Palma) to 10 minutes (e.g., Alicante), and even up to 1 hour in the case of Ceuta. Therefore, it is important to note that



525 low sampling frequencies do not allow for a correct estimate of the tsunami's arrival time and height. Tide gauge owners and
sampling intervals can be found in the catalogue table corresponding to the 21 May 2003 tsunami (see Data availability).

3.15 The 14 November 2020

On 14 November 2020, a coastal rockfall in Valle Gran Rey, La Gomera Island (Canary Islands), triggered a small local
tsunami (IGME-CSIC, 2026; Table 2). Two videos of this event, available online (GomeraActualidad, 2020; de La Gomera,
530 2020), captured the major rockslide and documented several waves reaching Argaga Beach, approximately 200 m away (Fig.
4).

According to Galindo et al. (2021), the first wave spread radially from the point where the rock mass entered the water
and reached Argaga Beach with a height exceeding 0.5 m, about 21 seconds later. Some boats, located 400 m from the coast,
detected this small tsunami, though no damage was caused.



Figure 4. Snapshot of the tsunami wave generated by the rockfall on 14 November 2020 on La Gomera Island. Source: GomeraActualidad
(2020).

535 3.16 The 12 August 2021

On 12 August 2021, an Mw 8.3 earthquake occurred in the South Sandwich Islands generating a tsunami that spread to the north
Atlantic, Pacific, and Indian Oceans (Rabinovivh et al., 2025; ISC-GEM, 2026; Table 2). The tsunami was clearly registered in
the Canary Islands at El Hierro, La Palma, and La Gomera PdE tide gauges, 14 hours after the earthquake (Fig. 5).

At El Hierro, the first wave was recorded at 10:05, with the largest wave occurring at 12:06, reaching a height of 0.17 m. In
540 La Palma, the initial wave arrived at 10:11, and the maximum wave height of 0.09 m was observed at 11:54. In La Gomera,
the first wave reached the gauge earlier, at 09:26, followed by the largest wave at 10:51, with a height of 0.20 m.

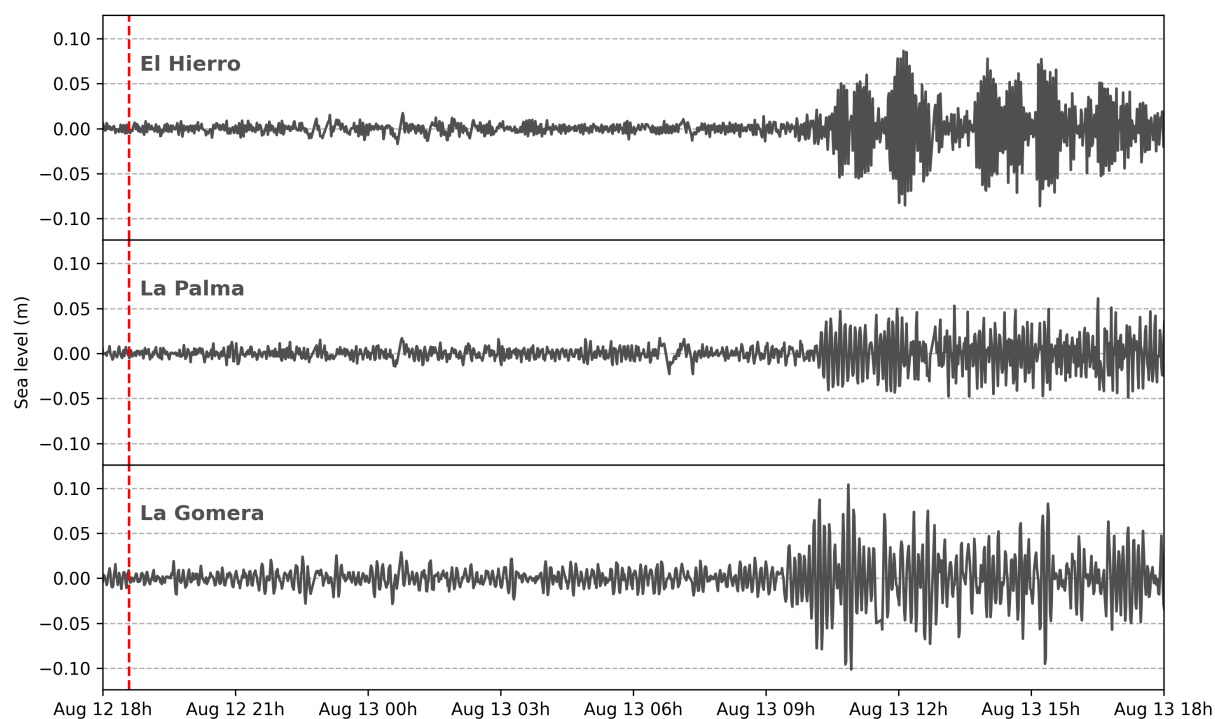


Figure 5. De-tided tsunami waves recorded on tide gauges in the Canary Islands during the 12 August 2021 tsunami. The vertical red line indicates the origin time of the earthquake (18:35:18 UTC). Data from PdE.



4 Catalogue of tsunamis on the Spanish coast

The Catalogue of tsunamis on the Spanish coast compiles information on historical and recent events that have been evaluated with a reliability index greater than or equal to 2. The main table (Table 2) presents the list of tsunamis, including the date and time of the tsunamigenic event, the location of its source (region and subregion), and information on the source, including its type, coordinates, depth, and, for seismic origins, the maximum observed macroseismic intensity and moment magnitude (Mw). The table also provides tsunami intensities according to the Sieberg-Ambraseys (Ambraseys, 1962) and Papadopoulos-Imamura (Papadopoulos and Imamura, 2001) scales, together with a brief description of the locations where the tsunami was reported worldwide. For Spain, additional information is provided on the reliability index, the number of observations, and the maximum recorded wave height (see also Data availability).

It is noteworthy that the macroseismic intensity and both tsunami intensities were assigned based on the available descriptions from all geographical regions and were not limited to the Spanish coast; therefore, they represent the maximum values. Furthermore, it is important to note that Maramai et al. (2014) highlight the limitation of the Papadopoulos-Imamura intensity scale in providing accurate estimates for historical events due to its calibration to modern coastal environments.

A second type of table is provided for each individual tsunami in the catalogue (see Data availability), which compiles the observations associated with that event. These tables gather detailed information on observation points, including location name, coordinates, arrival time and travel time for both the initial and maximum tsunami waves, and measurements such as maximum wave height, maximum inundation, measurement type, visible period, and first motion. They also record observed effects, including local descriptions and the number of deaths. When available, the reported tsunami period pertains to the first cycle or the largest wave.

Access to the tables discussed earlier is facilitated through the IGN website (<https://doi.org/10.7419/162.04.2023>). This online resource not only allows users to explore the tsunami catalogue information in both Spanish and English but also provides options to download the tables in Excel and PDF formats. Additionally, an interactive map viewer displays the locations of tsunami sources (Fig. 6). When a specific tsunami is selected, the map shows the Spanish locations where it was observed and offers information about its effects. This interactive map serves as a valuable tool for users to gain a clearer understanding of the local effects induced by each tsunami event.



Table 2. Catalogue of tsunamis on the Spanish coast. Region: AT (Atlantic Ocean), M3 (Western Mediterranean Sea); Cause: TS (submarine earthquake), TT (onshore earthquake), DST (submarine landslide triggered by an earthquake), DG (landslide caused by gravitational instability), ? (unknown cause); Lat.: latitude; Long.: longitude; EMS-98: European Macroseismic Scale; Mag.: magnitude; Int. S-A: Sieberg-Ambraseys intensity; Int. P-I: Papadopoulos-Imamura intensity; Reliability index in Spain: 2 (questionable tsunami), 3 (probable tsunami), 4 (definite tsunami), those tsunamis with reliability index of 0 (very improbable tsunami) and 1 (improbable tsunami) are excluded from the catalogue; No. of obs. in Spain: number of observations in Spain.

Origin time		Location		Source	Tsunami information									
Date	Time (UTC)	Region	Subregion	Cause	Lat. (°)	Long. (°)	Depth (km)	Maximum observed intensity (EMS-98)	Mag. (Mw)	Int. S-A	Int. P-I	Reliability index in Spain	No. of obs. in Spain	Maximum wave height (m) in Spain
12/08/2021	18:35:18	AT	South Sandwich Islands	TS	-58.56	-25.73	20	VII	8.26	I	I	4	3	0.20
14/11/2020	15:00:??	AT	Canarias	DG	28.08	-17.33	0			II	III	4	2	0.5
21/05/2003	18:44:19	M3	North Algeria	TS	36.85	3.68	0	IX-X	6.8	III	IV	4	35	1.96
10/10/1980	12:25:23	M3	North Algeria	TT	36.15	1.45	5	IX	7.1	I	II	4	4	0.51
26/05/1975	09:11:51	AT	Gloria Fault	TS	35.96	-17.58	15	VI	7.8	I	II	4	9	0.22
17/07/1969	??:??:??	AT		?	?	?				I	I	2	4	0.26
28/02/1969	02:40:34	AT	Azores-Gibraltar	TS	36.05	-10.63	31	VIII-IX	7.8	II	III	4	13	0.48
09/09/1954	01:04:37	M3	North Algeria	DST/TT	36.28	1.47	0	X-XI	6.7	I	II	4	4	0.34
25/11/1941	18:03:57	AT	Azores-Gibraltar	TS	37.30	-18.97	10	VI	7.8	I	II	2	1	
21/08/1856	21:45:??	M3	North Algeria	TS	36.82	5.79		VIII	6.6	III	V	2	1	
13/01/1804	17:53:??	M3	Alboran Sea	TS	36.70	-3.10		VII-VIII	6.1	III	IV	2	2	
09/10/1790	01:15:??	M3	North Algeria	TT	35.90	-0.60		IX-X	6.7	III	V	2	2	1.8
31/03/1761	12:10:??	AT	Azores-Gibraltar	TS	34.50	-13.00		IX	8.5	III	IV	2	4	
01/11/1755	10:16:??	AT	Azores-Gibraltar	TS	36.50	-10.00		X	8.5	VI	IX	4	39	13
09/10/1680	07:??:??	M3	Málaga	TT	36.66	-4.77	40	VIII-IX		III	V	2	1	5
22/09/1522	10:00:??	M3	Almería	TT	36.97	-2.67		VIII-IX		III	VI	2	2	

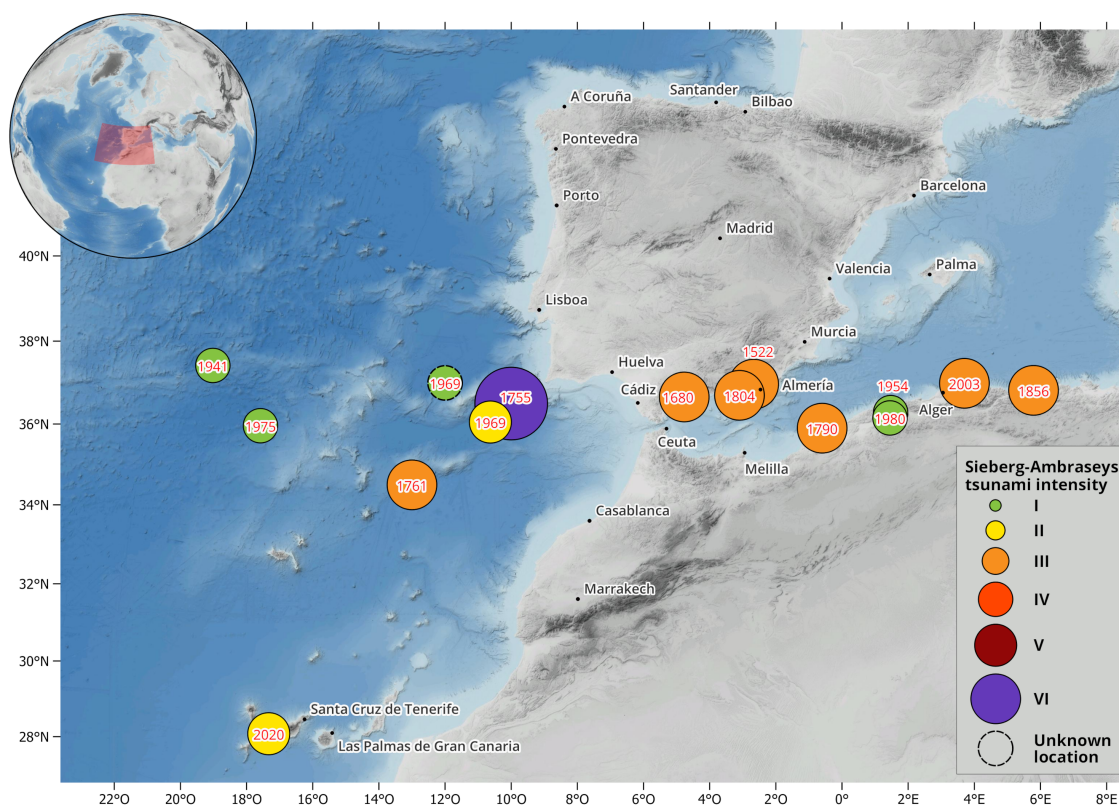


Figure 6. Geographical distribution of tsunamigenic sources from the Catalogue of tsunamis on the Spanish coast.



5 Improbable tsunami events

Tsunami events with reliability index of 0 and 1 are considered very improbable or improbable tsunamis, here we review them.

5.1 The 16 November 1755

570 On 16 November 1755, an earthquake was felt in Compostela and La Coruña, causing significant damage (Ribeiro Sanches, 1756). According to Portuguese Ribeiro Sanches in his "Account of the Earthquake that was felt in Europe, Africa, and America after 1 November 1755", written on 19 January 1756, the destruction was not only due to the earthquake itself but also because of the extraordinary ebb and flow of the sea. Portuguese Moreira de Mendonça (1758) also records this event, building upon the previous account and attributing the earthquake time to 15:30, as stated in the following passage: "On the 16th, around half
575 past three in the afternoon, there was a great explosion. It was strongly felt in Compostela and in La Coruña, where it caused some damage, as did the ebb and flow of the sea". Later, the Collection Académique (de Montbeillard, 1761)—a French series of 11 volumes from the 18th century, which compiled articles mostly previously published in smaller journals—reports an event that affected the city of Lisbon: "November 16th, 3½ hours in the afternoon, in Lisbon, the earth sank and had the same effect as the hull of a ship at the cape; the sea swelled prodigiously", which recalls Mallet (1854).

580 To assign a reliability index, contemporary letters sent from different parts of Spain reporting the 1755 earthquake were reviewed (Solares, 2001). Only the letters from different localities in the provinces of Córdoba and Sevilla mention the occurrence of an earthquake on 16 November at around 01:00. However, no reports from Galician cities referring to this event were identified. Moreover, no additional Spanish or Portuguese accounts—beyond the ones already cited—have been found that describe the event.

585 Based on the available information, both the description about the cause and the event receive a partial score of 1, due to the uncertainty surrounding the exact time and location of the earthquake, as well as the alleged tsunami effects. Consequently, the event is ultimately assigned a final reliability index of 0, indicating that its occurrence is considered very improbable.

5.2 The 31 January 1756

On 31 January 1756, the sea reportedly advanced more than 2.4 km inland in Santanyí, Mallorca. The earliest account of this
590 event comes from the contemporary chronicler Nicolás Ferrer, whose description was later reproduced by the 19th-century historian Campaner (Campaner y Fuertes, 1881), and subsequently cited by Fontserè (Fontserè, 1918).

The text states: "News has arrived that in the town of Santanyí the sea entered the land more than half a league, and left so much fish that the hills were full: it was a wave that brought in the water: the lighthouse keeper of the tower managed to escape, and the water filled the tower and carried away a rock that weighed more than a hundred thousand quintals". Fontserè suggests
595 that the wave described in Santanyí was likely of seismic origin rather than meteorological, despite possible exaggerations by the chronicler. He hypothesizes a nearby submarine epicenter, as no significant land earthquakes were recorded on that day.

The presence of large cliff-top boulders could provide geological evidence. Roig-Munar et al. (2023) radiocarbon dated two samples from Mallorca, with results concentrated around the periods 438–565, 1508, and post-1826. Dissolution pan data



indicated an average boulder emplacement year of 1792. Considering all sampled localities—including Mallorca, Menorca,
600 and Ibiza—the authors suggested a boulder emplacement window between 1591 and 1894, and they concluded that this range
aligns with the 1756 tsunami.

This event is included in the Balearic Seismic Catalogue, published in the Official Gazette of the Balearic Islands (BOIB
Num. 149 EXT. 07-10-2005). However, no specific source for the tsunamigenic cause has been identified, and the available
information about the tsunami is scarce and uncertain, which, following the criteria established by Tinti et al. (2004), classify
605 this event as a very improbable tsunami.

6 Discarded tsunami events

In this section, we compile those events that have been considered in recent tsunami compilations or specific studies to have
caused effects on the Spanish coast but are not included in this catalogue. This is mainly because the application of the reliability
index proposed by Tinti et al. (2004) results in their classification as “No tsunami”, or because, although the tsunami affected
610 other coasts from nearby countries, no verified reference has been found confirming its effects in Spain. It is worth noting
that this list is not intended to be comprehensive; rather, it selectively includes events that have raised doubts or have received
broader acceptance in the past.

6.1 218 (216) B.C.

The first account describing a sea flood in Cádiz after the occurrence of earthquakes in 218 B.C. comes from Ocampo (1553),
615 the royal chronicler of Charles V. He relates this event to the start of Hannibal’s expedition to Italy (218 B.C.), although he
mistakenly dates it to 216 B.C.: “The island of Cádiz and the entire coastal area of Andalucía suffered great earthquakes,
or tremors, that destroyed buildings and killed people, causing terrible damage there: the sea flooded many places that were
previously above water: it cast out a multitude of fish, some common and known, and some never seen before”. Álvarez-Martí-
Aguilar (2017b, 2022) explains why Ocampo’s narrative suggests that his sources were “the two Julians”—the Bishop and the
620 Presbyter of Toledo from the 7th and 8th centuries, respectively—whose historical reliability is highly questionable.

Geological evidence from multiple sites along the southwestern Iberian coast suggests a high-energy marine event dated
to 2700–2200 cal BP. In this context, paleo-research (e.g. Rodríguez-Vidal et al., 2011; Luque et al., 2002; Ruiz et al., 2013)
largely takes for granted the historical tsunami records compiled by Campos Romero (1991), which are based on Galbis Ro-
dríguez (1932, 1940), to correlate this event with a supposed tsunami between 218 and 209 B.C., despite the uncertainties
625 regarding the reliability of these sources (Álvarez-Martí-Aguilar, 2017b, 2022; Rodríguez-Ramírez et al., 2016).

This event is included in some tsunami catalogues as a questionable tsunami (Maramai et al., 2019; NGDC/WDS, 2026).
However, considering that Ocampo’s account lacks specific and reliable original sources and is dated much later than the event,
the score assigned to contemporary bibliographic material should be revised to 0, indicating that the event classifies as “No
tsunami”. Therefore, it is no included in the revised version of the Catalogue of tsunamis on the Spanish coast.



630 **6.2 213 (210, 209) B.C.**

Ocampo (1553) cites "...but also when the inhabitants of Cádiz suffered some earthquakes, and the sea was rough for many days, with fierce conditions and excessive currents that went much further than usual". According to Álvarez-Martí-Aguilar (2017b), this excerpt is related to the year 213 B.C. (rather than 210 B.C.) based on the historical context, and it appears to be a summarized repetition of the event from 218 B.C. On the other hand, Sánchez-Navarro Neumann (1921) takes this 210
635 B.C. event from Ocampo and mistakenly changes the date to 209 B.C., which Galbis Rodríguez (1932) assumes is another event apart from the one mentioned in Ocampo (1553), thus duplicating this catalogue entry (Álvarez-Martí-Aguilar, 2020). This tsunami is included as very doubtful in the NGDC/WDS (2026) global tsunami catalogue, but again, no reference to any contemporary source is given, which results in "No tsunami" for the reliability index.

6.3 63 (60) B.C.

640 The oldest known source is de Brito (1597), chronicler of the kingdom of Portugal as of 1614, who explains in the account of the year 63 B.C. that "Almost in these years, or shortly before, that notable earthquake occurred on the coast of Portugal and Galicia, by which many places were ruined (...). And the sea, in some parts, exceeding its usual limits, occupied a large part of the land, leaving it uncovered in other places where it had never shown signs of being able to reach". This source is very posterior to the described tsunami and, in addition, there are serious doubts about the veracity of the passage (Álvarez-Martí-
645 Aguilar, 2017a). The other date used in some seismic and tsunami catalogues is 60 B.C. (e.g., Sánchez-Navarro Neumann, 1921; Galbis Rodríguez, 1932; Maramai et al., 2019; NGDC/WDS, 2026), written in the margin of the text from Sousa (1678): "During these years, a horrible and dangerous earthquake occurred on the coasts of Portugal and Galicia (...). The sea, exceeding its usual limits, flooded fields, uncovering them in other places as well". Sousa seems to have taken this information from de Brito (1597), although he only mentions Portugal in the first edition (Sousa, 1677), as pointed out by Udías (2015).

650 Although Maramai et al. (2019) assigns a high reliability to the tsunami, with a reliability index of 3 (probable tsunami) and NGDC/WDS (2026) considers it as questionable; following the criteria of Tinti et al. (2004), the conclusion is that it cannot be affirmed that it occurred.

6.4 The 21 July 365

An earthquake and tsunami occurred on 21 July 365, likely near Crete (Greece) (Maramai et al., 2019). The contemporary his-
655 torian Ammianus Marcellinus reported the tsunami in Alexandria and the city of Mothone in the south of Greece (Marcellinus, 1950). According to Kelly (2004), "Some have seen an almost universal archaeologists disaster, responsible for destruction from Palestine to Sicily, or even as far as Spain". However, Udías (1983) notes that Ammianus did not mention Spain, dismissing its impact on the Iberian Peninsula. Contrarily, other sources claim it affected the coasts of Málaga (Galbis Rodríguez, 1932; Soloviev et al., 2000; Macías et al., 2013). The confusion arises from Galbis Rodríguez (1932), who incorrectly attributes
660 information about the impact on the Spanish coastal localities of Adra and Málaga from Gómez Pereira and Ruiz de Villanueva (1862) as part of Ammianus's original account. According to Álvarez-Martí-Aguilar (2022), the first to introduce a false refer-



ence to Spain is Lafuente Alcántara (1843), a text on which Gómez Pereira and Ruiz de Villanueva (1862) is based, and which falsely mentions Málaga, Adra and also Almuñécar. Taking into account this information, the 365 tsunami is not included in the Catalogue of tsunamis on the Spanish coast.

665 6.5 The 26 May 881

On 26 May 881 a large earthquake hit southern Spain and northwest Africa, according to the Moroccan authors of the thirteenth and fourteenth centuries Aben-Adhari and Ibn Abi Zar (Fernández González, 1860; Huici Miranda, 1964). However, none of the Arabic sources mention a tsunami. Historian Conde (1820), based on other Spanish-Arabic texts without explicit references, describes a tsunami: "The sea retracted and moved away from the coasts and islands and reefs disappeared in the sea".

670 This is the only known independent reference describing a tsunami, and the author does not specify the original source of this passage. From here, other seismic and tsunami catalogues have included this information (Sánchez-Navarro Neumann, 1921; Kaabouben et al., 2009; Macías et al., 2013) and validated it as a probable tsunami (NGDC/WDS, 2026; Maramai et al., 2019).

Tomassetti Guerra et al. (2021) documented a high-energy marine deposit in the city of Estepona (Málaga), dated by archaeological materials to the last third of the 9th century AD, and directly linked it to this event. In turn, Morales et al. (2008) identified a tsunamigenic layer in the Huelva estuary, dated by radiocarbon to AD 810 ± 89 , which could also correspond to the same tsunami.

Although this earthquake has some historical basis, the sources are very distant in time from the event. The tsunami claim is even more questionable, as it only appears in one much later work that lacks explicit reference to the original source. Therefore, 680 following reliability criteria, the partial score of the contemporary sources is 0, and this event is not included in the catalogue.

6.6 The 5 May 1706

On 5 May 1706, an eruption began in Garachico on Tenerife Island and was classified as VEI 2 (Volcanic Explosivity Index). Early accounts by Viera y Clavijo (1776) describe the event, stating that: "but it was reserved for a volcano to complete the work of its ruin (...) . On 5 May 1706, it burst from the top of the high cliff (...). An arm blocked the port, removing the sea". 685 Further details from Ruiz (1990) and Romero Ruiz and Beltrán Yanes (2015) reference Martínez de Fuentes, author of "History of the Canary Islands' eruptions" from the late 18th century, who mentioned that "these lava flows continued running for several days, receding the sea by about 250 meters". Another contemporary author, Bory de Saint Vincent (1803), reported "On the night of 5 May 1706, a thunderstorm-like noise was heard underground, and the sea receded. (...) The sea, soon returning to its bed, floods the debris of the port that has collapsed".

690 Despite entries in tsunami catalogues by NGDC/WDS (2026) and Maramai et al. (2019) suggesting a probable tsunami, the described sea behavior is likely due to lava flows entering the sea rather than a tsunami. The inclusion of a 1706 tsunami in these catalogues is based on references that do not clearly mention tsunami characteristics. For instance, the oldest reference used by NGDC/WDS (2026) is Berninghausen (1964), who cites "Waves which accompanied the volcanic eruption that overwhelmed the city of Garachico." This information is supposedly from Agostinho (1935), but "Notes on Some Tsunamis of the Azores"



695 does not mention the 1706 event. Thus, we believe the only plausible reference from his list is (Stone, 1889), who cited Bory de Saint Vincent (1803) and Viera y Clavijo (1776), according to the historian González (2022). Therefore, the tsunami information is assigned a partial score of 0, indicating "No tsunami", consistent with the conclusion reached by Galindo et al. (2021), who recommended excluding this event from tsunami catalogues.

6.7 The 24 September 1774

700 The earliest reference to a tsunami occurring on 24 September 1774 comes from *The Annual Register* for the year 1774 (October, 1775), which states: "On the 24th of September, the sea ebbed and flowed, in the harbour of Málaga, in Spain, thrice in the space of an hour, two feet perpendicular, without any apparent cause. The same phenomenon happened the same day, and about the same hour, at Leghorn". Despite being a contemporary source, no mention of an earthquake is made, as Mallet (1854) notes.

705 In this case, different tsunami compilations assign varying levels of reliability to the event. Macías et al. (2013) list this tsunami as valid, NGDC/WDS (2026) assigns a reliability index of 1 (very doubtful tsunami) to the event, while Maramai et al. (2014) dismiss it, citing the reason: No tsunami description. This tsunami is also excluded from the Spanish catalogue, as there is no information about the generating cause, the description of the tsunami is only partially fulfilled (with just one observation), and the contemporary source does not mention its origin —apart from being a London-based publication—
710 resulting in a reliability index of "No tsunami".

6.8 The 18 November 1929

On 18 November 1929, a Mw 7.2 earthquake struck along the southern edge of the Grand Banks, triggering a massive submarine slump that ruptured 12 transatlantic cables. It also generated a tsunami that crossed the Atlantic Ocean, recorded by Portuguese tide gauges in Leixoes, Lagos, and Ponta Delgada, where the maximum amplitude reached only 0.14 m (Fine et al.,
715 2005; Baptista and Miranda, 2009). Galindo et al. (2021) suggests that the tsunami likely reached the Canary Islands, though with a low amplitude. However, the only available marigram from Tenerife does not show any tsunami signal, and there are no documentary accounts indicating that the event affected Spain. As a result, this event is excluded from the Catalogue of tsunamis on the Spanish coast.

6.9 The 7 July 1941

720 On 7 July 1941, three large waves approximately 40 m high were reported by the newspaper *La Tarde* in Tenerife (Canary Islands), which described how the waves caused serious damage along the port's coastline. On Avenida de José Antonio, the waves destroyed part of the balustrade and hurled stones against the Palacio Insular. The water flooded the esplanade and entered the Naval Command, reaching 0.5 m high, and caused destruction in the Iberia Company offices, where an employee was slightly injured. The waves swept away vehicles, pedestrians, and a nearby refreshment stand. At the Eastern dock, the
725 water rose 5 m above the surface, destroying transport tracks and dragging away materials stored on the pier. In San Andrés,

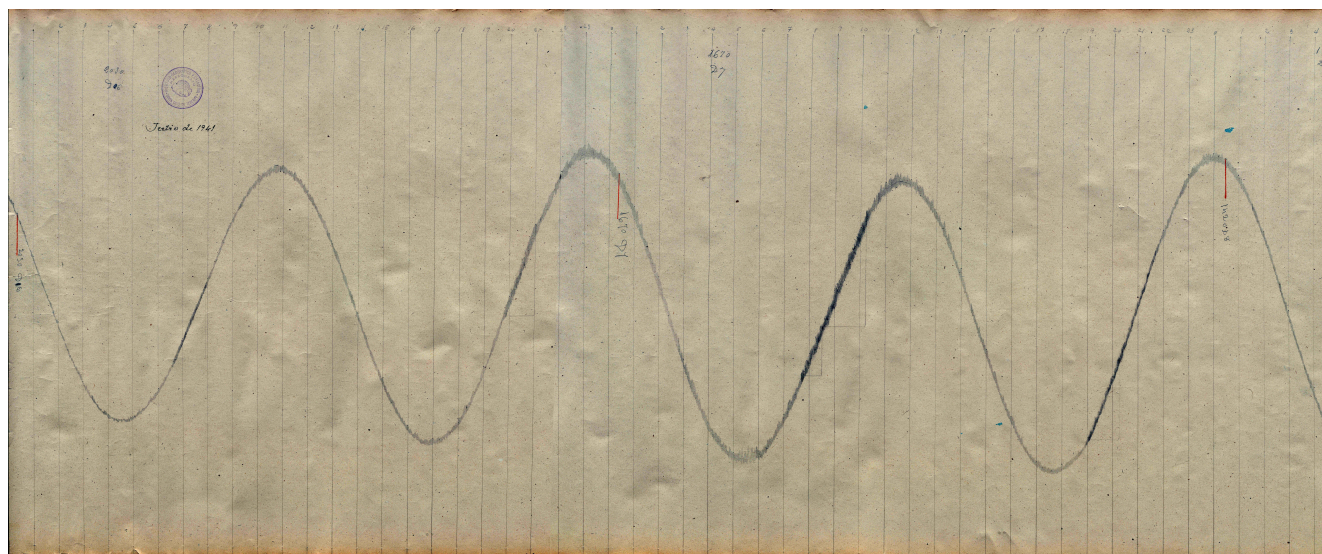


Figure 7. Santa Cruz de Tenerife marigram showing sea-level variations on 7 July 1941. IGN, National Geographic Institute of Spain.

the storm was particularly severe: several fishing boats were smashed against the shore, the water reached the town's church square, telephone communication was cut off, and bus service was suspended due to road damage.

Afonso Mosegue (2011) argues that the event was likely caused by a local gravitational landslide rather than a freak wave, which is not expected along the East Coast, and notes that only journalistic data are available, of limited value in this field. Galindo et al. (2021) agree with this interpretation and catalogue the event as a tsunami. They further suggest that the most likely source of a landslide affecting Santa Cruz would be the 200-meter-high cliffs of the old massif northeast of the city, since the southwestern coast is mostly low and rocky.

While these interpretations suggest a landslide-induced tsunami, based on the synoptic analysis carried out and the existing knowledge of how southern swell affects this area, it cannot be ruled out that the phenomenon was caused by a southern-origin swell (Peñate de la Rosa and Quintero Plaza, 2025).

Regarding the tide gauge record from Tenerife (Fig. 7), no evidence of a tsunami is observed. Instead, the sea appears agitated from approximately a day before, with the effects most noticeable from the low tide around 6–7 a.m. until the midday high tide, when newspapers report the episode. The fact that the event coincides with the high tide may explain why flooding occurred only when the sea level was at its maximum.

Based on these plausible scenarios, we consider that the cause must have been of meteorological origin. Since the marigram shows no tsunami signal, the assigned score is 0, which classifies the event as "No tsunami".



6.10 The 14 August 1978

On 14 August 1978, a M5 earthquake occurred in the Gulf of Cádiz (IGN, 2026; Table 2). According to the catalogues of Maramai et al. (2019) and NGDC/WDS (2026), this event generated a definite tsunami that was recorded by the IEO tide gauge of Cádiz. This conclusion is based on a digitized marigram from Cádiz published in Campos Romero (1992), which identifies a maximum wave amplitude of 0.12 m. As the original marigram from the IEO could not be located for analysis of the tsunami signal, the curve was compared with that recorded by the IGN Cádiz tide gauge. Despite apparent silting of the instrument's stilling well, the marigram reproduces the record reasonably well until approximately 14:30, shortly after the earthquake at 14:17; however, no tsunami signal is evident, likely as a result of the silting. The available nearby IEO marigrams from Ceuta, Algeciras, and Tarifa were examined, with no clear evidence of a tsunami found in the records.

An earthquake of magnitude 5 is generally unlikely to generate a tsunami and in Portugal no tsunami signals were recorded according to Baptista and Miranda (2009). On the other hand, López Carmona et al. (2026) have reviewed the atmospheric registers to verify the existence of possible gravity waves that could have generated these sea level perturbations. According to their study, the barograph trace from the 14th stands out from the other daily records within the same week due to its pronounced high-frequency oscillations, particularly between 12 UTC and 14 UTC. These were induced by surface pressure waves, likely associated with gravity waves generated by upper-level storms that may have moved across the Gulf of Cádiz, causing disturbances in the air vertical velocities, the marine boundary layer (MBL) thickness and the resulting pressure fluctuations at the surface.

The analyzed information suggests an atmospheric configuration conducive to the development of convection and associated gravity waves affecting the Gulf of Cádiz coast. Such a scenario would be favorable for the generation of surface pressure disturbances propagating from SW to NE, which may have been further amplified by resonance mechanisms, including oscillations in semi-enclosed basins (seiches) in areas such as the Bay of Cádiz or the Guadalquivir estuary. This atmospheric scenario is very similar to the seiche episode in Conil and the MSL elevations observed in several semi-enclosed water bodies on 13 August 2022, which also coincided with high tides associated with spring tides, and whose analysis was presented at the 2024 Scientific Meeting of the Asociación Meteorológica Española (AME) (López Carmona and Izquierdo, 2024).

Therefore, the observed sea level oscillations in the records are most likely of atmospheric origin, while a tsunami origin is considered unlikely; consequently, this event has been excluded from the tsunami catalogue.

6.11 The 27 May 2003

On 27 May 2003, a Mw 5.8 aftershock struck northern Algeria and was felt in Spain. Official sources from the Balearic Islands reported sea oscillations of 0.15-0.20 m in Palma and Maó, however, this signal is not observed in the marigram of Palma. Similarly, no such oscillations were observed in the marigrams from other areas of the Balearic Islands, such as Eivissa or Sant Antoni. Unfortunately, there are no records of sea level for Maó on that date. Moreover, the newspaper *Diario de Menorca* reported on 28 May 2003, that a precautionary deployment was made along the coasts of Maó and Ciutadella, noting that only "oscillations of little importance" were observed from the time of the earthquake until four hours later.



775 After considering all available information, this tsunami is classified as No tsunami.

6.12 The 25 January 2016

On 25 January 2016, a Mw 6.4 earthquake occurred in the Alboran Sea (Bufo et al., 2017). According to CEA (2016), a tsunami of very low amplitude was recorded on the tide gauges at Motril and Málaga on the Spanish coast, with maximum peak-to-trough amplitudes ranging from 3 to 4 cm. In the case of Melilla, the tide gauge station did not record any tsunami signal.

Upon analyzing the signals from the Motril and Málaga stations, we were unable to conclusively identify the arrival of a tsunami. The reported amplitudes are comparable to the measurement noise, leading us to exclude this event from the catalogue. In this regard, Masina et al. (2017) reported the following: "oscillations of period 13' and amplitude up to 4 cm were present before the earthquake in records of all stations in the area (...). This event can be classified as just over the tsunami identification threshold".

6.13 The 18 March 2021

On 18 March 2021, a Mw 6.0 earthquake occurred offshore near the Algerian coast. Heinrich et al. (2024) indicates that it triggered a small-amplitude tsunami recorded by several tide gauges in Spain, Italy, and France, where the observed amplitudes are significantly influenced by ambient noise.

Examining the waveforms recorded at the Maó and Alcudia tide gauges, located in the Balearic islands of Menorca and Mallorca respectively, a tsunami arrival around 01:00 could be inferred, with maximum wave heights of only a few centimeters. In the port of Maó, there appears to be a new oscillation with periods in the 5–15 minute range; however, frequent fluctuations in this area make it difficult to distinguish the tsunami signal from the background noise (Begoña Pérez, personal communication). In conclusion, this event is similar to the case of 25 January 2016, with amplitudes comparable to the ambient noise, leading to the event being disregarded.

7 Paleotsunamis

The study of paleotsunamis is beyond the scope of this work; however, we find it relevant to offer a brief summary to complement the historical catalogue.

The geological and archaeological records from the southwestern coast of the Iberian Peninsula provide evidence of Extreme Wave Events (EWEs), such as paleotsunamis and severe storms. Gutiérrez-Rodríguez et al. (2022) and Costa and Andrade (2020) highlight how (^{14}C) radiocarbon dating has contributed to understanding the timing of these events, despite its broad calibration ranges and the marine reservoir effect, which make it difficult to establish precise chronologies. This challenge is further compound in the study of boulder deposits (Costa and Andrade, 2020). Consequently, archaeological remains serve as key input for chronological estimates (Reicherter et al., 2022).



805 According to the review on tsunami deposits from Costa et al. (2022), EWEs have been identified from approximately 7900 cal BP to 1000 cal BP. Some of these events were likely caused by storms or tsunamis, as suggested by sedimentary records showing evidence such as spit barrier breaching, chenier formation, and the deposition of marine materials.

The earliest EWE proposed in this review occurred in the Valdelagrana spit barrier (7900–7600 cal BP), based on evidence such as coarse sediments and marine shell fragments; this was followed by another in the same location (6700–6400 cal BP).
810 In the Doñana marshlands (4880–4560 cal BP), marine deposits were found. Between 4500 and 4100 cal BP, a major event reshaped the Doñana coastline, while another in Barbate-Zahara de los Atunes (ca. 4000 BP(OSL)) left backwash deposits.

During 3900–3000 cal BP, several EWEs were recorded in the southwestern with similar features: input of marine fauna, chenier development and erosive phase in the spit barrier. More tsunami deposits were attributed in Doñana estuary (c.a. 3900–3700, 3500 and 3000 cal BP), Guadalete estuary (3400–3300 cal BP and around 3100 cal BP), Cachón estuary (3125
815 cal BP), and Piedras estuary (around 3000 cal BP). Between 3000 and 2500 cal BP, erosional events impacted the Guadiana, Piedras, Tinto-Odiel, and Guadalquivir estuaries, causing chenier development, marine sediment input and spit barrier breaching.

Between 2200 and 1600 cal BP, according to Costa et al. (2022), there is a wide variety of dates. For instance, around 2200–2000 cal BP, a sandy layer with marine fauna was found between Doñana estuarine deposits, showing a distinct erosional
820 base and high magnetic susceptibility, around 2100 cal BP (Valdelagrana-Guadalete Estuary), there was evidence of spit barrier breaching and reorganization of the back-barrier drainage system, or 2100–1900 cal BP (Río Piedras Estuary), an erosional gap was detected in the spit barrier. Backwash deposits have been described in Carteia (Algeciras) and, using archaeological remains, the tsunami layer was dated to around 1900 cal BP.

This marks the transition into the Common Era, during which several EWEs with spit barrier breaching were identified in
825 the Piedras River estuary (1300–1200 cal BP), Tinto-Odiel estuary (around 1050 cal BP), Doñana spit-Guadalquivir estuary (1700–1600 cal BP and 1250–1000 cal BP), and Valdelagrana spit-Guadalete estuary (ca. 1500–1300 cal BP and 1000 cal BP).

Reicherter et al. (2022) concludes that at the end of the 4th century, in the Bay of Bolonia, tsunami waves flooded the forum area of Baelo Claudia, reaching about 8 meters above the modern mean sea level, and buildings near the sea in the Decumanus Maximus main road area were covered by a "black layer", interpreted as a tsunami deposit.

830 Tsunami deposits can also include cliff-top boulders weighing several tons. Tsunami waves can rip up and transport large blocks, depositing them on rocky coasts. In the Iberian Peninsula, boulder deposits in Cope, Murcia (Lario et al., 2017) and North Castelló, València (Roig-Munar et al., 2018b) have been linked to EWEs, though distinguishing between tsunamis and storms remains challenging, and their age is unknown. Roig-Munar et al. (2023) identified large boulders on the eastern Balearic coast, suggesting a tsunamigenic origin. Radiocarbon and dissolution pan data from Mallorca and Menorca indicate
835 two events: one between 1508–1826 CE and another between 438–565 CE.



8 General discussion and conclusions

This study presents a critical re-evaluation of the Catalogue of tsunamis on the Spanish coast. Building on existing databases and relevant literature, the updated compilation results from a systematic search and thorough consultation of primary sources and original marigrams. This comprehensive approach has enabled a refinement of the reliability of historically reported events, incorporating new information when available and discarding events lacking sufficient evidence.

This catalogue compiles 16 reliable tsunamis since the year 1522. These events are evenly distributed between the Atlantic Ocean and the western Mediterranean Sea, with eight events reported in each basin.

In the western Mediterranean, the most active subregion is northern Algeria, where five tsunamigenic events have been recorded. These include two submarine earthquakes (Mw 6.6 in 1856 and Mw 6.8 in 2003), two onshore earthquakes (Mw 6.7 in 1790 and Mw 7.1 in 1980), and one complex event in 1954, in which a submarine landslide was likely triggered by an Mw 6.7 onshore earthquake. These tsunamis were observed or recorded by tide gauges in various Spanish coastal cities and, in some cases, caused minor to moderate damage to ports and vessels, such as in the Balearic Islands. Additional events in the western Mediterranean include a submarine earthquake in the Alboran Sea in 1804 (Mw 6.1) and two onshore earthquakes in southern Spain: one in Almería in 1522 and another in Málaga in 1680. All three generated local tsunamis that affected nearby coastlines.

In the Atlantic Ocean, five significant submarine earthquakes have been associated with the Azores-Gibraltar fault zone. These include three events of Mw 7.8 (1941, 1969 and 1975) and two of Mw 8.5 (1755 and 1761). The 1755 tsunami was the most devastating, causing extensive damage and casualties on the Spanish coast. Additionally, an event recorded in 1969, with an unknown cause and location, is included, although it is presumed to have originated in the Atlantic. A local tsunami in 2020 was generated by a gravitational landslide in the Canary Islands, and a distant Mw 8.1 submarine earthquake in the South Sandwich Islands in 2021 was recorded by tide gauges in the Canary Islands.

Among the events listed above, the following have been added compared to the previous Catalogue of tsunamis on the Spanish coast by the IGN (Carreño et al., 1999): 1522, 1761, November 1941, July 1969, 2003, 2020 and 2021.

The list of discarded tsunamis includes 13 events that were previously considered reliable in different tsunami compilations. Their exclusion is based on the assigned reliability index, following the criteria established by Tinti et al. (2004). In most cases, a reliability index of 0 is attributed to factors such as the lack of coeval documentary accounts or clear tsunami evidence. In comparison with the previously published catalogue, 5 events have been removed: 60 B.C., 1706, 16 November 1755, 1978, and 27 May 2003. The latter two are the most noteworthy, as they had previously been considered definite tsunamis.

Figure 8 shows the timeline of the Catalogue of tsunamis on the Spanish coast, illustrating the temporal distribution of events by reliability index and including the discarded tsunami events.

Our analysis provides new insights through the incorporation of previously unreported marigrams for the studied events of 18 November 1929, 7 July 1941, 28 February 1969, 17 July 1969, 26 May 1975, 14 August 1978, 10 October 1980, 21 May 2003, and 18 March 2021. Regarding the historical accounts, efforts have been made to reconstruct the chronology of the writings

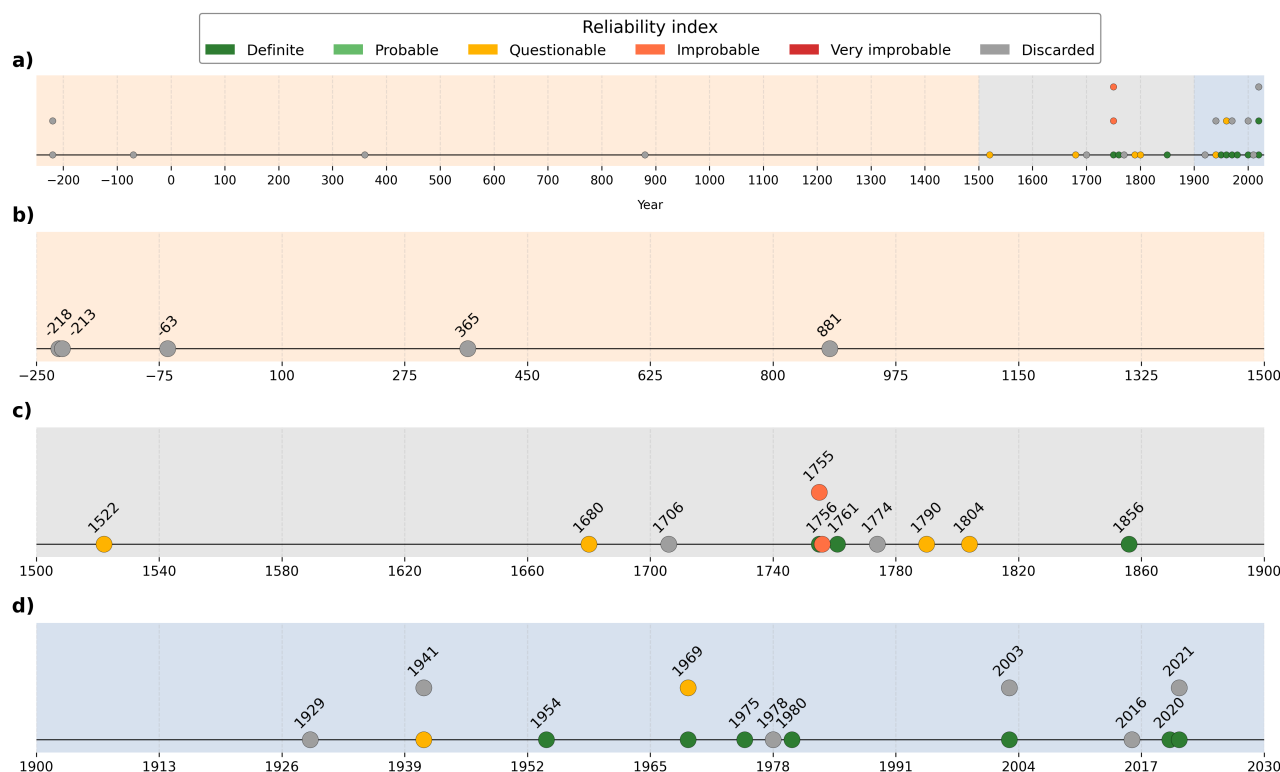


Figure 8. Timeline of the Catalogue of tsunamis on the Spanish coast, illustrating the temporal distribution of events classified by reliability index, including discarded tsunami events.(a) Complete temporal timeline of the catalogue. (b) Zoom for the period from -250 to 1500 CE. (c) Zoom for the period from 1500 to 1900 CE. (d) Zoom for the period from 1900 CE to the present.

with the support of historians' research. Whenever possible, original sources have been consulted to avoid unquestioningly
870 relying on transcriptions from secondary works; when this was not feasible, it has been clearly indicated.

Should further evidence become available, the reliability indices of these events may be subject to revision and refinement. Nonetheless, as highlighted by Udías (2015), the lack of contemporary sources makes it especially challenging to verify events prior to the Arabic period, thereby rendering their inclusion in early catalogues highly uncertain and, together with the poor identification of small tsunamis before the instrumental period (O'Loughlin and Lander, 2013), this significantly limits the
875 overall completeness of the catalogue.

Moreover, compiling a reliable catalogue requires a critical evaluation of primary sources (Ambraseys and Costas, 2010). However, the task is complicated by the subjective nature of the available information and, as Tinti et al. (2004) note, by the additional subjectivity introduced by experts' judgment, which can effectively be mitigated through clear and consistent criteria. This challenge is particularly evident in the estimation of tsunami wave heights, a critical parameter for characterizing events.
880 Older accounts often report wave heights without specifying the type of measurement—whether it refers to the maximum inundation or runup height, or the elevation relative to sea level at the time of arrival. Furthermore, eyewitness observations are



affected by the observer's location and memory, adding another layer of uncertainty. These factors make it difficult to interpret and compare tsunami wave heights across different events.

Overall, this catalogue represents a valuable step forward in the understanding and documentation of past tsunami activity on the Spanish coast. Future work should include a systematic analysis of detided, digitized marigrams to refine wave height measurements, as well as efforts to improve the understanding of paleotsunami events, with the objective of distinguishing them from other extreme wave events.

Data availability. The tables of the Catalogue of tsunamis on the Spanish coast are publicly available at <https://doi.org/10.7419/162.04.2023>.

Author contributions. JVC conceptualized the study, established the methodology, and reviewed and edited the manuscript. ERB drafted the original manuscript and created the figures. Both authors collected data, reviewed the bibliography and discussed the final version of the manuscript.

Competing interests. The authors declare that they have no conflict of interest.

Acknowledgements. We thank Javier Fernández Fraile and Jose Manuel Martínez Solares for their generous assistance in providing original sources used in this study. We gratefully acknowledge Carlos González, María Ángeles Fraile Torrecilla and Sergio Cantón Mudarra from the IGN for valuable discussions and the provision of original marigrams, as well as Elena Tel and Ignacio Bermejo from the IEO, Cristina Domingues from the University of Lisboa, Begoña Pérez Gómez from the PdE, and Sebastià Monserrat from the UIB for supplying marigram data essential to this study. Special thanks go to Marina López Muga, José Manuel Tordesillas García-Lillo and Mario Lancha Ávila for their assistance in scanning marigrams. We also thank Maria Ana Baptista, Fatima Kaabouben, Anna Lemoine, Agathe Roullé, and Roser Hoste-Colomer for helpful discussions regarding some of their published tsunami data, and César Andrade and Maria da Conceição Freitas for providing access to an original study, as well as the Biblioteca Municipal Central of Santa Cruz de Tenerife. Finally, we thank Francisco J. Escámez Mañas, Tatiana Goded, Bernat Puyol, Beatriz Gaite and Ana Justicia for valuable clarifications.



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