



Historical impact records as a complementary source of evidence for coastal flood risk assessment in the Canary Islands

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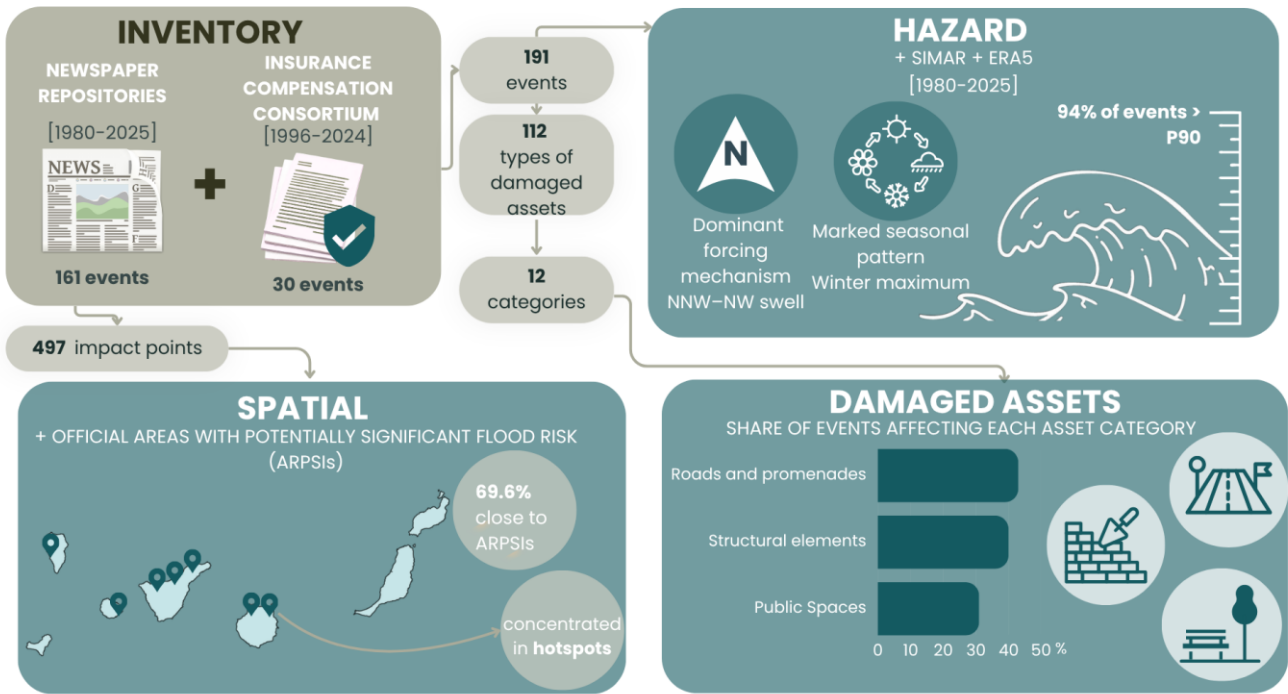
Abstract. Despite major advances in characterizing coastal flood hazards, historical impact datasets remain scarce for many island regions, limiting the assessment of coastal flood risk. This study presents the first archipelago-wide inventory of damaging coastal events in the Canary Islands, integrating historical newspaper archives with insurance compensation records from the Spanish Insurance Compensation Consortium (CCS). The database documents 191 unique wave- and tide-induced events between 1980 and 2025, including their mechanisms, spatial distribution, affected assets, and reported impacts.

More than 94 % of events coincided with offshore wave conditions exceeding the 90th percentile (P90), and 29.5 % were associated with North Atlantic swell. Impacts clustered in recurrent hotspots, with roads and promenades, structural elements, public and recreational spaces, and coastal protection structures among the most frequently affected assets. Comparison with official flood-risk mapping showed that 69.6 % of impact locations fell within 500 m of Areas of Potential Significant Flood Risk (ARPSIs); however, several damaging events predated the formal designation of these areas by decades. Integrating documentary, insurance, and physical hazard information further shows that no single source fully captures damaging coastal flooding: newspaper coverage was more closely related to the number of insurance claims than to aggregate indemnified losses, while insurance records remained constrained by coverage and claim behavior.

The resulting database provides an empirical basis for coastal damage modelling, vulnerability assessment, and adaptation planning. Building on the limitations identified in this study, future work should focus on normalizing hotspot recurrence and developing quantitative damage functions linking wave conditions to asset-level impacts, paving the way for a region-specific



25 coastal damage scale for the Canary Islands.



Keywords: documentary archives; insurance claims; extreme waves; impact hotspots; coastal exposure; risk governance; wave-induced coastal flooding.

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1 Introduction

Coastal areas are among the most productive and socio-economically valuable regions worldwide (Millennium Ecosystem Assessment, 2005; Martínez et al., 2007). They support key ecosystem services, including food provision, water quality regulation, and cultural benefits linked to trade, recreation, and tourism (de Groot et al., 2010; Magalhães Filho et al., 2022).

35 At the same time, coasts concentrate population, infrastructure, and economic activities: around 40 % of the global population lives within coastal zones, and this proportion has increased over recent decades (Cohen et al., 1997; Cosby et al., 2024). This concentration of population, infrastructure, and economic activities increases the potential for impacts of coastal flooding and other climate-related hazards (IPCC, 2019, 2022).

These hazards pose challenges for islands, where limited land availability concentrates people and assets in coastal zones —

40 reaching up to 97 % in some island territories — while strong dependence on tourism and fisheries further increases



socioeconomic vulnerability (Andrew et al., 2019). This combination of high exposure and vulnerability has prompted the study of coastal risks from different perspectives, including sea-level rise modelling (Kopp et al., 2014; Amores et al., 2022), coastal erosion assessment (Luijendijk et al., 2018; Voudoukas et al., 2020), and socio-ecological vulnerability analysis, with the aim of supporting the implementation of disaster risk reduction measures (Shah and Wang, 2024). Within this broader research framework, historical records constitute a key source of evidence for improving the understanding and assessment of coastal flood risk (WMO, 2022). They provide valuable information for identifying flood-prone areas, validating hazard models, estimating return periods, and assessing event severity (Llasat et al., 2009; Needham, 2010; Haigh et al., 2017; Yagoub et al., 2020; Sancho-García et al., 2021). Several initiatives have compiled historical records of coastal impacts in different regions by integrating information from multiple documentary sources (Black and Law, 2004; Souto-Ceccon et al., 2025; Delforge et al., 2025). Despite these efforts, islands often lack the high-resolution data required for robust flood risk assessments (WMO, 2022). The Canary Islands exemplify these challenges, with increasing tourism-driven littoralization and continued need to improve coastal flood risk assessment (Asín and Godenau, 2014; Díaz and Domínguez, 2015).

In the archipelago, drivers of coastal flooding such as marine storms have been identified using buoy records and wave modeling (Yanes Luque et al., 2006; Guerra-Medina and Rodríguez, 2021; Yanes Luque et al., 2021; Megías Dorado, 2024). In combination, extreme sea-level statistics, terrain-based inundation mapping, and hydrodynamic modeling have been used to identify potentially exposed areas across the archipelago (Ministerio de Agricultura, Alimentación y Medio Ambiente, 2014; Gobierno de Canarias, 2022). Likewise, vulnerability assessments have also been developed for specific coastal sectors (e.g., García-Romero et al., 2023). Together, these studies provide valuable information on the hazard, exposure, and vulnerability components of coastal flood risk (UNDRR, 2015). However, considerably less attention has been devoted to the analysis of historical impact records, despite their potential to complement and validate coastal flood risk assessments by documenting the impacts of real events (WMO, 2011). This limited attention is also reflected in the scarce representation of the archipelago in existing historical disaster databases. The Canary Islands are either explicitly excluded from the geographical scope of some datasets, such as iHANZE (Historical Analysis of Natural Hazards in Europe), or lack available records in others, including the European Coastal Flood Awareness System (ECFAS; Souto-Ceccon et al., 2025) and the DesInventar Sendai database (UNDRR, n.d.). While recent work has documented historical coastal impacts in Tenerife (López Saavedra et al., 2025), existing records remain geographically fragmented and do not systematically capture impact-generating flooding events across the entire archipelago.

Coastal flooding can result from several mechanisms, including storm surge, wave-driven run-up and overtopping, tides, sea-level rise, and tsunamis, often acting in combination (WMO, 2011). This study focuses specifically on damaging events driven by anomalous wave conditions and exceptional astronomical tides — hereafter referred to as *wave- and tide-induced coastal flooding events* (Stockdon et al., 2006; Sallenger, 2000) — rather than tsunamis or fluvial and pluvial flooding near the coast. Nonetheless, to address this gap, we develop the first archipelago-wide inventory of damaging coastal flooding events in the Canary Islands by integrating historical press archives and insurance compensation records. The inventory includes information on event occurrence, triggering mechanisms, spatial distribution, affected assets, and reported impacts, providing



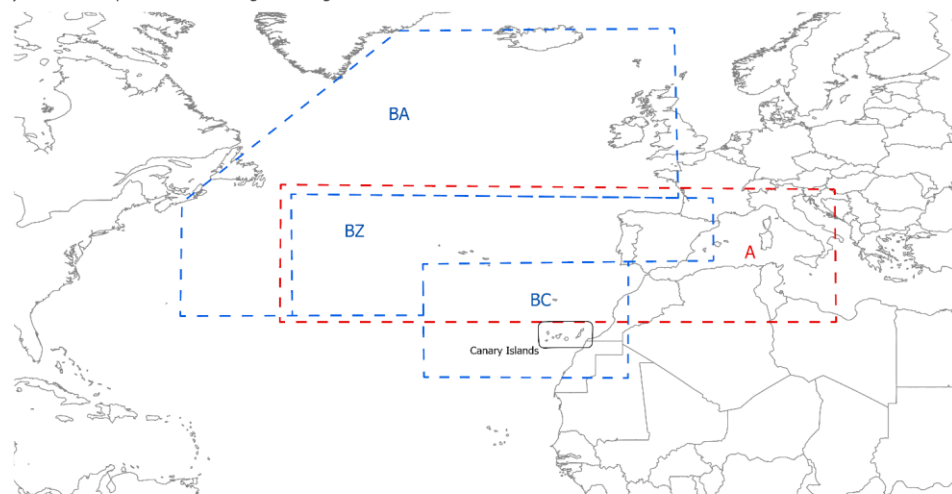
75 an independent basis for comparison with existing coastal flood assessments. Specifically, this study addresses the following research questions: (1) How many damaging coastal flooding events can be reconstructed across the Canary Islands from documentary and insurance records? (2) Which oceanographic forcing mechanisms are most frequently associated with documented impacts? (3) Where are damaging impacts recurrently concentrated, and which types of assets are most frequently affected? (4) To what extent do historical impact locations correspond with officially designated flood-risk areas?

80 **2 Study Area and its maritime climate**

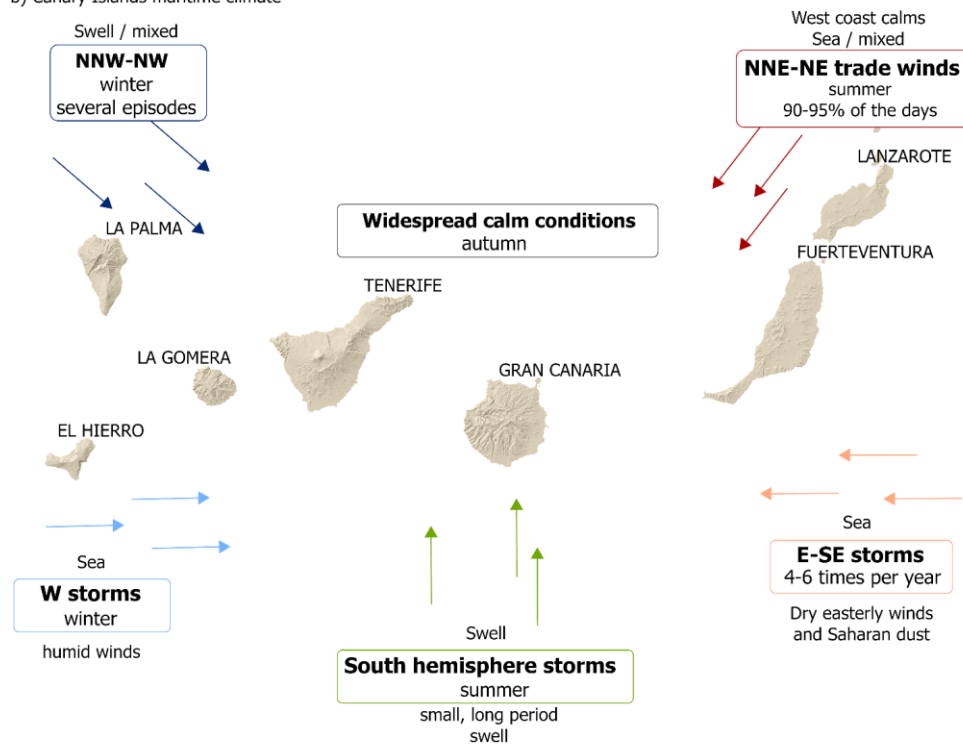
The Canary Islands, an outermost region of Spain, are in the eastern sector of the North Atlantic Ocean, approximately 1 400 km from the European mainland (Iberian Peninsula) and about 100 km from the northwestern African margin (Western Sahara). Within this context, population distribution is highly uneven: more than 80 % of inhabitants are concentrated on the two central islands, Tenerife and Gran Canaria, while Lanzarote and Fuerteventura account for smaller shares, and the western islands (La Palma, La Gomera, and El Hierro) remain the least populated (Santana, 2017). At a finer spatial scale, littoralization drives population concentration along the coastline, producing an increasingly continuous urban strip along much of the archipelago's shoreline (Asín and Godenau, 2014; Díaz and Domínguez, 2015). As a result, the 1 553 km of coastline hosts 242 urban settlements, averaging approximately one settlement every 6 km, which underscores the marked concentration of both population and economic activity in coastal zones (Díaz and Domínguez, 2015). This pattern is reflected in the population distribution, with 10.7 % of residents living within 100 m of the coastline, 25.9 % within 500 m, and more than one-third (36.5 %) within 1 km. (ISTAC, 2025) This pronounced concentration of population and assets along the coast makes the maritime and climatic conditions affecting the archipelago particularly relevant for understanding the occurrence and impacts of coastal flooding (Mosegue, 2007; Rodríguez-Martín, Cruz-Pérez, and Santamarta, 2022; García-Román, 2022; Megías Dorado, 2024). The dominant climatic influences (Fig. 1) are:



a) Location of pressure centres generating marine storms



b) Canary Islands maritime climate



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Figure 1: (a) Types and location of pressure centres generating marine storms in Canary Islands where A is anticyclonic situations; BC low pressures in the areas surrounding the Canary Islands; BZ, low pressures in the Azores-Iberian Peninsula and BA low pressures above 45°N and 40°W. (b) summary of meteorological phenomena influencing Canary Islands maritime climate, adapted from Mosegue (2007) and Yanes Luque et al. (2021)



- 100 (a) Sea- and mixed sea–swell conditions from the NNE–NE generated by trade winds. These predominantly easterly winds are associated with subtropical high-pressure systems and blow toward the equatorial low-pressure belt, following a NE–SW direction in the Northern Hemisphere. This regime mainly affects the northern, eastern, and southeastern coasts, while western and southwestern shorelines remain relatively calm due to sheltering. Wave conditions from this sector occur with a frequency of 90–95 % between June and September, decreasing to 45–50 % during the rest of the year.
- 105 (b) Swell from the NNW–NW generated by extratropical cyclones. These systems develop along the North Atlantic storm track at high latitudes, with the most energetic events linked to deep low-pressure centres (central pressure < 990 mb). Several episodes occur annually, primarily between December and March. These swells impact the northern and western coasts, whereas eastern and southeastern coastlines remain sheltered due to the shadowing effect of island topography.
- 110 (c) Mixed sea-swell from the W–NW generated by moderate Atlantic depressions. These conditions occur between November and April and are generally characterized by lower wave energy compared to major storm events. Their influence is mainly observed along western coasts and occasionally in northern sectors, while southern and eastern coastlines remain relatively calm.
- 115 (d) Sea conditions generated by weak regional depressions. These local depressions develop in the vicinity of the Canary Islands and generate locally forced wind waves (sea), rather than swell, owing to the limited fetch available for wave development. Wave direction depends on the position of the low-pressure centre, although the resulting conditions typically affect the eastern and southeastern coasts. When the depression is centred over North Africa, these events are commonly associated with dry easterly winds and Saharan dust transport (*calima*).
- (e) Long-period swell generated by Southern Hemisphere storms. This swell occasionally reaches the Canary Islands and is characterized by low wave heights but very long periods. It primarily affects coastlines exposed to southern wave components.

120 3 Sources and methods

In line with the conceptual disaster risk assessment framework proposed by Van Westen (2013), this study adopts an impact-based perspective in which historical evidence of damaging events contributes to understanding the interaction between coastal hazards, exposure, and vulnerability. Within this framework, documentary archives, insurance compensation records, and oceanographic data are integrated to reconstruct damaging coastal flooding events and their associated impacts across the

125 Canary Islands. This reconstruction process provides an empirical foundation for one of the key components of coastal flood risk assessment: the characterization of hazardous coastal processes through the historical inventory of damaging events and the analysis of observed impacts produced by wave-induced coastal flooding.

Accordingly, the methodological sequence follows several key components of disaster risk assessment frameworks:

1. Disaster inventory analysis: compilation and validation of a database of damaging coastal flooding events derived from
- 130 historical documentary and insurance records.



2. Hazard characterization: analysis of the dominant oceanographic and meteorological forcing mechanisms associated with documented impacts using wave and atmospheric datasets.
 3. Spatial hazard-impact analysis: identification of recurrent impact-reporting hotspots and spatial patterns of damaging coastal flooding across the archipelago.
 - 135 4. Exposure and vulnerability characterization: examination of the most frequently affected assets, infrastructures, and damaged elements associated with coastal flooding events.
 5. Risk assessment comparison and gap identification: evaluation of the extent to which historical impact records support, complement, or reveal limitations in existing coastal flood hazard and risk assessments in the Canary Islands.
- Each of the processes used to develop these key components is described in the following sections.

140 3.1 Disaster inventory analysis

A disaster inventory analysis was conducted to compile and integrate information on damaging coastal flooding events in the Canary Islands. For the purposes of this study, an event refers to an independent episode of coastal flooding, whereas an impact record refers to a specific occurrence of documented damage at a given location. A single event may therefore include multiple impact records, affected locations, newspaper reports, and insurance claims. The inventory was developed using two main
 145 sources: historical press archives from the universities of the Canary Islands and the coastal-impact claims database provided by the Spanish Insurance Compensation Consortium (CCS).

3.1.1 Press archive inventory

A systematic documentary analysis was performed to compile a database of damaging marine events in the Canary Islands. Digital newspaper repositories from the University of Las Palmas de Gran Canaria (JABLE) and the University of La Laguna
 150 (Maresía) were used. The analysis was restricted to the period from 1980 onwards to ensure methodological consistency and temporal comparability. Earlier newspaper archives have lower digital coverage and optical character recognition (OCR) quality, reducing the reliability of systematic keyword-based searches. Moreover, the rapid coastal urbanization associated with the tourism boom of the 1960s and 1970s substantially altered the exposure context, limiting the comparability of pre-1980 records. Therefore, restricting the analysis period is consistent with recommendations for the use of digitized newspaper
 155 databases in historical research (Beach and Hanlon, 2023; Llasat et al., 2009).

A preliminary keyword sensitivity test was conducted using terms such as *temporal marítimo* (maritime storm) and *golpe de mar* (local expression referring to wave overtopping or heavy sea impacts). The candidate keywords were also compared with the list of coastal hazard alerts (2009–2020) issued by the Government of the Canary Islands to identify the terms that most effectively captured wave-induced coastal impacts. This process yielded 2 659 reviewed articles from JABLE and 2 565 from
 160 Maresía, respectively. Inclusion criteria were restricted to events resulting from wave action, exceptional astronomical tides, or their combination — including material damage caused by wave overtopping, run-up, or tide-driven marine flooding — while events attributable exclusively to fluvial or pluvial flooding, and tsunami-generated inundation were excluded. Incidents



involving only human impacts, such as injuries, drownings, or disruptions to services (e.g., transport cancellations or port closures) in the absence of material damage, were also not recorded.

165 3.1.2 Insurance consortium

A database of coastal-impact claims provided by the Consorcio de Compensación de Seguros (CCS) was analyzed. Only records classified as *embate de mar* (marine wave impacts) were considered for the period 1996–2024, corresponding to the years for which data are available. The CCS database contains 138 registered dates linked to compensation claims. However, these dates represent days with reported indemnifications and do not necessarily correspond to independent events, as consecutive dates may belong to the same storm episode. To address this limitation, a temporal and spatial cross-reference between the press archive inventory (PAI) and the CCS database was performed in RStudio. Records were considered temporally coincident when the absolute difference between the PAI event date and the CCS record date was seven days or less and spatially coincident when they shared the same postal code. This criterion was adopted because coastal storm impacts are frequently reported over several consecutive days, while CCS records may reflect the administrative registration of a claim rather than the exact timing of damage occurrence. This temporal tolerance was used to reduce false mismatches associated with reporting delays while remaining short enough to avoid merging independent storm events. Temporal discrepancies between datasets were calculated as the absolute difference between event dates, while spatial coincidence was evaluated at the postal code level whenever possible.

Events included in the CCS database but not initially identified in the PAI inventory were subsequently verified through additional newspaper archive searches using combinations of event date, postal code, and coastal-impact keywords (e.g., waves, sea damage, overtopping). Temporal coincidence alone was not considered sufficient to merge records into a single event. Candidate matches were subsequently reviewed using their spatial location, documentary descriptions, and associated coastal forcing conditions. Consecutive dates associated with the same storm episode were grouped into a single damaging coastal event in order to avoid overcounting prolonged impact episodes. Finally, duplicate records associated with the same date and postal code were removed to avoid counting multiple reports corresponding to a single event.

Each CCS event was classified according to whether it coincided with a PAI-documented event ("with press coverage") or not ("without press coverage"), following the temporal matching criterion described above. Differences between the two groups in total indemnified losses and number of insurance claims were assessed using Wilcoxon rank-sum tests, given the marked right skew of both variables; Welch's t-tests on log-transformed values were additionally run as a robustness check (reported in Supplementary Material S1). Associations between press coverage and categorical episode attributes (affected capital municipalities, number of islands involved) were evaluated using Pearson's chi-squared test. Logistic regression models were subsequently fitted to identify which episode characteristics best predicted the presence of press coverage, with model comparison based on Akaike's Information Criterion (AIC) and McFadden's pseudo- R^2 .



3.2 Hazard characterization. What generates impacts?

195 Understanding the physical processes responsible for documented coastal flooding is a fundamental step in impact-based
disaster risk assessment. Following the reconstruction of the historical event inventory, hazard characterization aims to identify
the oceanographic and meteorological conditions associated with events and to establish their relative importance across the
archipelago. Rather than relying solely on predefined hazard thresholds, the analysis links documented impacts with the
physical conditions under which they occurred, thereby providing an empirical characterization of the hazard component of
200 coastal flood risk. To achieve this, offshore wave conditions associated with each documented event were reconstructed and
classified according to the dominant wave-generation mechanisms affecting the Canary Islands.

3.2.1 Characterization of wave conditions associated with impact events

To characterize the physical conditions of the documented events, wave conditions were extracted from 46 offshore nodes of
the SIMAR hindcast database (Puertos del Estado), providing continuous coverage for the 1980–2025 period. SIMAR is a
205 numerical hindcast of wind and wave conditions derived from the operational wave modelling system of Puertos del Estado,
combining the SIMAR-44 (1958–2005) and WANA (2006–present) datasets. Although the nodes are geographically assigned
to the coastline, the wave parameters are representative of deep-water conditions rather than nearshore processes (Puertos del
Estado, 2026).

Daily maximum significant wave height (H_s) and peak period (T_p) were calculated for each node, and the 90th, 95th, and 99th
210 percentiles were derived from the full daily time series available at each location. Percentile thresholds were used because they
normalize local wave climatology among offshore nodes with different exposure conditions and are widely adopted for
identifying anomalous and extreme wave events in the Canary Islands (Guerra-Medina and Rodríguez, 2021; Rubio Astorga,
2020; Megías Dorado, 2024). Absolute wave-height thresholds were not adopted because identical H_s values may represent
ordinary conditions at exposed locations but extreme conditions at more sheltered sectors of the archipelago. An event was
215 considered associated with a percentile exceedance when at least one node exceeded the corresponding threshold within the
event window. The number of nodes exceeding each percentile level was subsequently computed for every event, providing a
spatial indicator of the extent and severity of anomalous wave conditions.

Based on these data, swell and wind-sea components, as well as wave direction, were used to classify events according to the
typologies proposed by Mosegue (2007) and Megías Dorado (2024). The resulting classification was additionally cross-
220 validated using reanalysis and hindcast datasets from ERA5 single-levels (Hersbach et al., 2020, Copernicus Climate Data
Store) and the Copernicus Marine Service IBI-MULTIYEAR wave product, to assess consistency between the SIMAR-based
characterization and independent wave-climate reconstructions.



3.3 Spatial hazard-impact analysis. Where do impacts occur?

The spatial distribution of historical coastal flooding impacts provides valuable evidence for identifying recurrent impact-prone areas and evaluating their consistency with existing hazard assessments. Within the disaster risk assessment framework, the spatial analysis of documented events contributes to the characterization of hazard occurrence by revealing areas where damaging coastal flooding has repeatedly affected exposed coastal sectors. To achieve this, three complementary analyses were undertaken: (i) the identification of impact-reporting hotspots based on the spatial density of documented events, (ii) the estimation of historical event frequency using the combined event inventory, and (iii) the comparison of documented impact locations with the official flood hazard and risk mapping of the ARPSI framework. Together, these analyses provide an empirical assessment of the spatial distribution, frequency, and consistency of historically documented coastal flooding impacts across the Canary Islands.

3.3.1 High-resolution identification of coastal impact hotspots

Events identified through the press archive inventory were geocoded using toponymic references and manually located in Google My Maps to generate a spatial inventory of events. The georeferenced event database is provided in S1. A hexagonal grid with a diameter of 1 km was subsequently generated in QGIS, and the number of events within each cell was calculated to identify spatial hotspots of coastal damage occurrence. The 1 km hexagonal grid represents a compromise between the spatial precision achievable from documentary georeferencing and the need to identify regional patterns while minimizing artificial fragmentation of event locations. For the aggregation–dispersion analysis, only hexagons intersecting the coastline were retained in order to focus the statistics on the active coastal fringe and avoid inland cells not relevant to coastal processes. Within these selected coastal hexagons, event counts per cell were used to compute measures of spatial concentration, including summary statistics, quantiles, cumulative distribution functions, and the Gini coefficient as an index of inequality in event distribution (Ma and Mostafavi, 2024; Dang et al., 2026)

3.3.2 Postal-code-level distribution of historical coastal impacts

To complement the high-resolution hotspot analysis based on the PAI, historical event frequency was assessed at the postal code level by integrating the PAI and Consorcio de Compensación de Seguros (CCS) records. The two sources provide complementary spatial information: the PAI allows individual impacts to be geographically located at relatively high spatial resolution, whereas CCS records provide complementary observations but spatially aggregated at the postal-code level. CCS records were therefore used to extend the spatial coverage of the impact inventory rather than to refine the location of individual events. Postal codes associated with CCS claims were incorporated when they were not represented by a corresponding PAI event, while PAI events were retained in the frequency calculation. Where records from both sources referred to the same documented event, they were integrated into a single historical event to avoid double counting.



Because CCS records are aggregated at the postal-code level, postal codes were used as the common spatial unit for the integrated analysis, representing the highest spatial resolution consistently available across the two datasets. Postal-code boundaries were obtained from the 2017 postal-code layer provided by the Centro Nacional de Información Geográfica (CNIG). Coastal segments associated with each postal code were generated using the 2023 coastline dataset from the Instituto Hidrográfico de la Marina (Línea de Costa LC2023, CC-BY 4.0).

For each postal code, historical event frequency was calculated as the total number of unique damaging coastal events documented during the 1980–2025 study period. Each event was counted once within a postal code, irrespective of the number of associated newspaper reports, insurance claims, or individual impact records. The resulting metric therefore represents the cumulative number of documented damaging coastal events affecting each postal code over the study period.

The resulting spatial distribution was used to characterize the historical recurrence and concentration of documented coastal impacts at the postal-code scale and to identify areas where the high-resolution PAI hotspot analysis was complemented by additional events recorded in the CCS database.

3.4 Exposure and vulnerability characterization. What gets damaged?

Following previous impact-based hazard databases developed from press sources, which characterize impacts at the event level (Llasat et al., 2013; Gil-Guirado et al., 2019; Yanes Luque et al., 2021; Johnson et al., 2025; Papagiannaki et al., 2026), we classified the assets reported as affected in each documented coastal damaging event. Thus, the analysis focuses on identifying which types of assets were affected in each event, rather than on quantifying the exact number of damaged assets.

At the data collection stage, reported impacts were recorded at the asset level, preserving the specific element described in the source (e.g., pavement, wall, vehicle, or building). These individual assets were subsequently assigned to broader asset categories according to their functional and structural characteristics. This allowed specific reported elements to be retained while facilitating their aggregation and comparison across events. The predefined classification comprised roads and promenades, structures, public spaces, protection structures, landscape elements, port infrastructure, residential buildings, commercial buildings, street furniture, vehicles, industrial facilities, and other elements.

For each documented event, we recorded the assets reported as affected and their corresponding categories. The occurrence of each asset category was then calculated based on the number of distinct events in which at least one asset within that category was reported as affected, relative to the total number of documented damaging events. Thus, the resulting percentages represent the proportion of damaging events in which each asset category was reported as affected, providing an overview of the types of assets most frequently impacted by coastal damaging events.

3.5 Risk assessment validation and gap identification.

Historical impact records were used as an independent empirical source to evaluate the extent to which existing coastal flood assessments represent locations where damaging events have occurred. The analysis focused on the officially designated Areas of Potential Significant Flood Risk (Áreas con Riesgo Potencial Significativo de Inundación, ARPSIs) included in the second



285 flood-risk management planning cycle. The official ARPSI delineations were obtained from the flood hazard and risk maps of
the second implementation cycle of the EU Floods Directive, made available through the Spanish National Floodplain Mapping
System by the Ministry for the Ecological Transition and the Demographic Challenge (Ministerio para la Transición Ecológica
y el Reto Demográfico, 2025). This cycle was selected because the third-cycle revision remained under consultation at the
time of the analysis.

290 Georeferenced impact locations derived from the press archive inventory were spatially compared with the official ARPSI
delineations. A historical impact point was considered spatially associated with an ARPSI when it was located within the
mapped area or within a 500 m buffer around its boundary. This tolerance was adopted to account for the positional uncertainty
inherent in documentary sources, in which impact locations were frequently reported through place names or coastal landmarks
rather than precise geographic coordinates. The proportion of impact records spatially associated and not associated with the
295 ARPSI network was subsequently calculated. This comparison was interpreted as an empirical evaluation rather than as a
complete validation of the official risk maps. Spatial correspondence was considered evidence that the official assessment
successfully identifies coastal sectors with documented damaging impacts. Conversely, impact locations outside the mapped
ARPSIs were treated as potential assessment gaps requiring further examination, rather than automatically interpreted as
mapping errors, because discrepancies may also reflect georeferencing uncertainty, differences in spatial scale, changes in
300 exposure, or impacts produced by processes not fully represented in the official modelling framework.

A retrospective temporal analysis was also conducted for coastal sectors incorporated into, or proposed for incorporation into,
the ARPSI framework following recent damaging events. For these locations, the historical inventory was examined to
determine whether comparable impacts had already been documented before their formal recognition. This analysis was used
to assess whether historical records could have provided earlier evidence of recurrent coastal risk.

305 Finally, thematic gaps were examined by comparing the types of assets documented as damaged in the historical inventory
with the exposure categories represented in regional coastal flood assessments. Particular attention was given to asset
categories that were recurrently affected in the documentary record but insufficiently differentiated in existing assessments, as
well as categories included in exposure mapping but absent or underrepresented in the press-derived inventory. These
discrepancies were interpreted in light of insurance coverage, spatial resolution, and temporal biases associated with each
310 source.

4 Results

This section presents the main findings obtained from the integration of documentary, insurance, and oceanographic evidence.
The results are organized according to the principal components of the methodological framework: disaster inventory analysis,
hazard characterization, spatial impact patterns, comparison with official risk assessments, and characterization of damaged
315 assets.



4.1 Disaster inventory analysis

The disaster inventory was constructed by integrating the press archive inventory (PAI) and the records provided by the Insurance Consortium (Consortio de Compensación de Seguros; CCS). The following subsections present the results obtained from each source and their integration into a combined database of damaging coastal events for the 1980–2025 period.

320 4.1.1 Press archive inventory (PAI)

The press archive analysis identified 161 coastal damaging events in the Canary Islands during the 1980–2025 period (Supplementary material 1). For five events, the exact occurrence date could not be determined due to ambiguity in the newspaper records (xx/05/1982, xx/02/1994, xx/09/2000, xx/08/2007, xx/09/2007). These cases were retained in the dataset but excluded from the analyses requiring precise event dating.

325 This analysis also led to the geolocation of 497 impact records associated with the events (S1). The spatial extent of individual events varied, as indicated by the number of distinct georeferenced impact points linked to each event ($n = 187$ events with point-level data; median = 1; interquartile range [IQR] = 1–2.5; mean = 2.64). While most events were represented by a single impact point, a few events resulted in a higher number of spatially distinct points, with a maximum of 26 recorded for a multi-island episode in April 2024.

330 The temporal distribution of events shows marked interannual variability (Fig. 2a). The highest annual frequency was recorded in 2018, with nine documented damaging events, whereas no events were recorded in 1980, 1981, or 1988. Excluding these early years affected by probable archive incompleteness, the mean annual frequency for the analyzed years was 3.71 events per year. Monthly event distribution reveals a seasonal pattern, with most damaging events concentrated during the winter months (Fig. 2b).

335 4.1.2 Insurance consortium

For the 1996–2024 period, the CCS database contains 138 different dates with registered coastal claims. These dates correspond to days with reported indemnifications and do not necessarily represent independent coastal events, as consecutive days may belong to the same storm episode. During the same period, the PAI inventory contains 83 unique dated events. The temporal comparison using a 7-day matching window indicates that 105 CCS records coincide temporally with at least one PAI event. Among these, 45 records also coincide spatially at the postal code level. Conversely, 44 of the 83 PAI dates had at least one corresponding CCS record within the defined temporal window, whereas 39 events (approximately 47 % of the PAI inventory for this period) show no CCS counterpart.

340 The CCS temporal series also exhibits substantial interannual variability. The highest number of registered claim dates occurred in 2018, with 14 dates, while several years (1996, 2000, and 2019) recorded only one date. The mean annual frequency for the CCS dataset is 4.93 dates per year. Additional documentary searches were conducted for CCS dates not initially identified in the PAI inventory. Consecutive dates associated with the same storm episode were grouped as single coastal



events to avoid overcounting prolonged impact episodes. Following this revision process, 30 additional damaging events were incorporated into the final inventory. The combined PAI+CCS database comprises a total of 191 unique damaging coastal events for the 1980–2025 period.

350 Episodes with press coverage were associated with substantially higher median indemnified losses (€15,816 vs. €4,855) and a higher median number of claims (2 vs. 1) than episodes without coverage (Wilcoxon rank-sum test, $p = 0.028$ and $p < 0.001$, respectively; consistent results obtained with Welch's t-test on log-transformed values, see S1).

Logistic regression further showed that the number of insurance claims was the strongest predictor of press coverage. The model based on log-transformed claims provided the best fit (AIC = 103.35; McFadden's pseudo- $R^2 = 0.162$) and indicated
355 that each one-unit increase in log-transformed claims was associated with a 7.51-fold increase in the odds of press coverage (OR = 7.51, 95 % CI: 2.39–44.7, $p = 0.006$). The model based on indemnified losses alone showed a weaker fit (AIC = 116.01; McFadden's pseudo- $R^2 = 0.055$). Adding indemnified losses to claims did not improve model performance (AIC = 105.23; McFadden's pseudo- $R^2 = 0.163$), while models incorporating the number of affected municipalities, islands, or whether a regional capital was affected also provided no improvement in fit (AIC = 105.18–108.01; McFadden's pseudo- $R^2 = 0.163$ –
360 0.173). No significant association was found between press coverage and whether an episode affected a regional capital ($\chi^2 = 0.20$, $df = 1$, $p = 0.66$). A significant association was observed with the number of islands affected ($\chi^2 = 11.25$, $df = 4$, $p = 0.024$), although this result should be interpreted cautiously because several categories contained very few observations. Given the moderate sample size ($n = 138$ CCS dates) relative to the number of candidate predictors, these pseudo- R^2 values should be interpreted as indicative rather than as evidence of strong predictive performance, and no cross-validation was performed
365 to confirm out-of-sample fit.

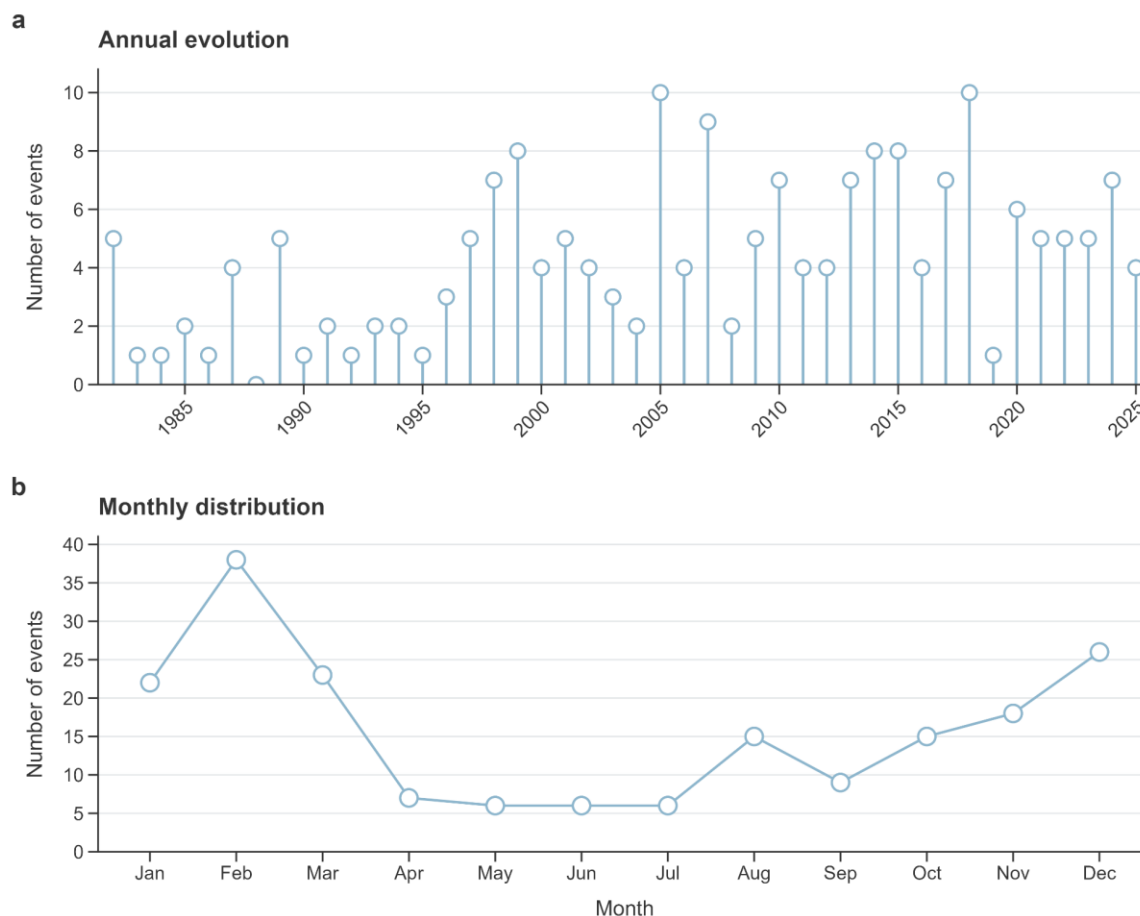


Figure 2: Temporal evolution of damaging coastal events in the Canary Islands derived from the combined PAI+CCS inventory, showing (a) annual frequency of recorded events and (b) monthly distribution of occurrences.

4.2 Hazard characterization. What generates impacts?

Only events with known damage locations and dates were used, resulting in a total of 156 coastal-impact events analyzed using wave conditions extracted from the SIMAR offshore nodes. Of these, 112 events (60.9%) were associated with significant wave heights exceeding the 99th percentile (P99) at least one node within the event window, 50 events (27.2 %) exceeded the 95th percentile but not P99, and 11 events (6.0 %) exceeded the 90th percentile but not P95 or P99. Only 11 events (6.0 %) were not associated with any exceedance of the 90th (P90), 95th (P95), or 99th (P99) percentile thresholds. Overall, the results indicate that 94 % of the documented impact events were associated with anomalous or extreme wave conditions relative to the local climatology represented by the SIMAR hindcast.

Following the wave-climate classification described in Sect. 2, wave-driven coastal-impact events were assigned to the corresponding coastal forcing categories. To simplify the analysis, all sea conditions were grouped into a single category

irrespective of the specific wave direction, whereas events primarily associated with exceptional astronomical tides (e.g., equinoctial tides) were considered separately.

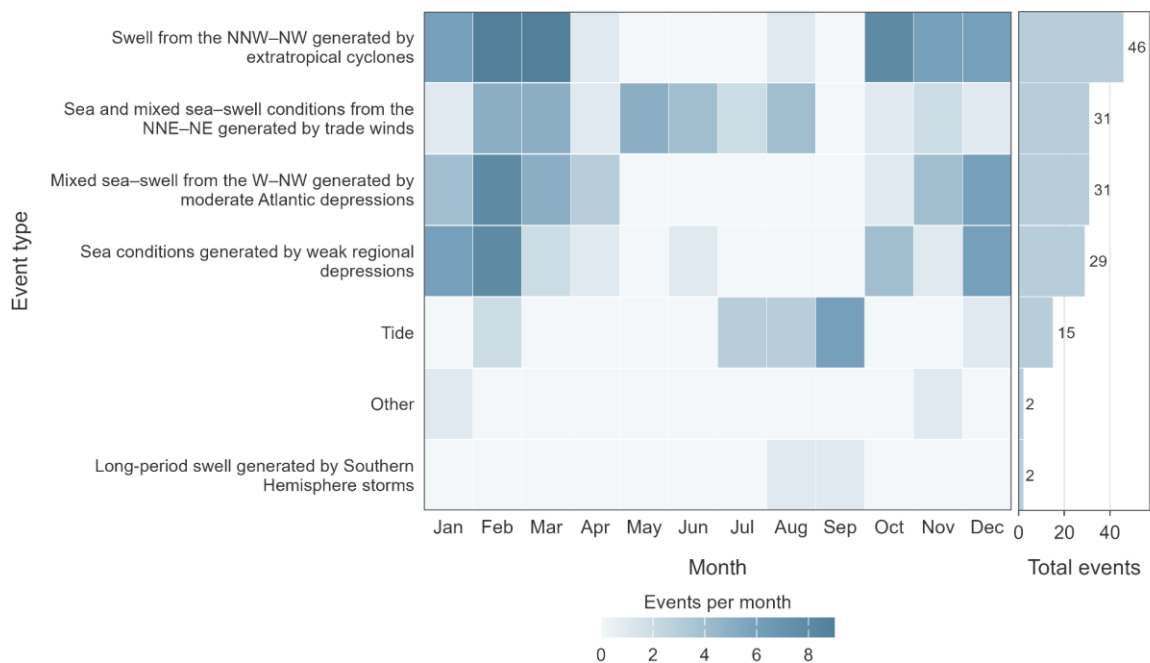


Figure 3: Monthly frequency of coastal forcing event types. The heatmap shows the number of events recorded for each event type and month, with darker shading indicating higher frequencies. The bar chart on the right summarizes the total number of events for each category over the study period.

The monthly and seasonal distribution of events varied among coastal forcing categories (Fig. 3). Swell from the NNW–NW generated by extratropical cyclones was the most frequent event type (29.5 %), with maximum occurrences recorded during winter (December–March), particularly in February and March, and additional events observed during autumn (October–November). Sea and mixed sea–swell conditions from the NNE–NE generated by trade winds (19.9 %) occurred throughout most of the year, spanning winter, spring, and summer, with relatively higher frequencies between February and August. Mixed sea–swell from the W–NW (19.9 %) generated by moderate Atlantic depressions was concentrated mainly during winter (January–March) and early spring (April), with additional occurrences during autumn and early winter (October–December). Sea conditions generated by weak regional depressions (18.6 %) were also recorded predominantly during winter, reaching their highest frequency in February and occurring less frequently in January, March–April, October, and December. Tide-related events (9.62 %) showed a marked concentration during summer (July–September), with the highest frequency observed in September. Long-period swell generated by Southern Hemisphere storms (1.28 %) was restricted to late summer (August–September). Events classified as "Other" (1.28 %) occurred only sporadically.



4.3 Spatial hazard-impact analysis. Where do impacts occur?

The spatial analysis reveals a highly uneven distribution of damaging coastal impacts across the Canary Islands. Most records are concentrated in a limited number of recurrent hotspots, although their spatial extent and recurrence vary considerably among coastal sectors. Moreover, while most documented impact locations coincide with officially identified flood-risk areas, a substantial proportion occurs outside them, revealing potential gaps in existing assessments (Fig. 4).

Postal codes with the highest recurrence of events (>20 records, shown in dark red on the map) are located exclusively in northern Tenerife, coinciding with the municipalities of Puerto de la Cruz (28 events), San Cristóbal de La Laguna (24 events), and Garachico (22 events). The high-intensity category (10–20 events, shown in red) is distributed more broadly along the north and east coast of Tenerife, the northeastern coastline of Gran Canaria, around the urban core of Las Palmas de Gran Canaria (17 events) and Arucas (14 events), and specific points in La Palma (14 events), La Gomera (13 events), and southern Gran Canaria (35100, 13 events). By contrast, Fuerteventura, El Hierro, and almost the entirety of Lanzarote fall within the low-intensity category (<5 events), with the exception of a localized stretch in eastern Lanzarote (5–10 events). This pattern suggests that exposure to coastal damage is not distributed proportionally to the surface area or coastline length of each island but is instead concentrated in highly localized stretches associated with urban centres and the most exposed coastal fronts of the islands with greater relief and coastal development (Tenerife and Gran Canaria), as opposed to a more diffuse, lower-intensity pattern on the smaller or less exposed islands (Fuerteventura, Lanzarote, El Hierro).

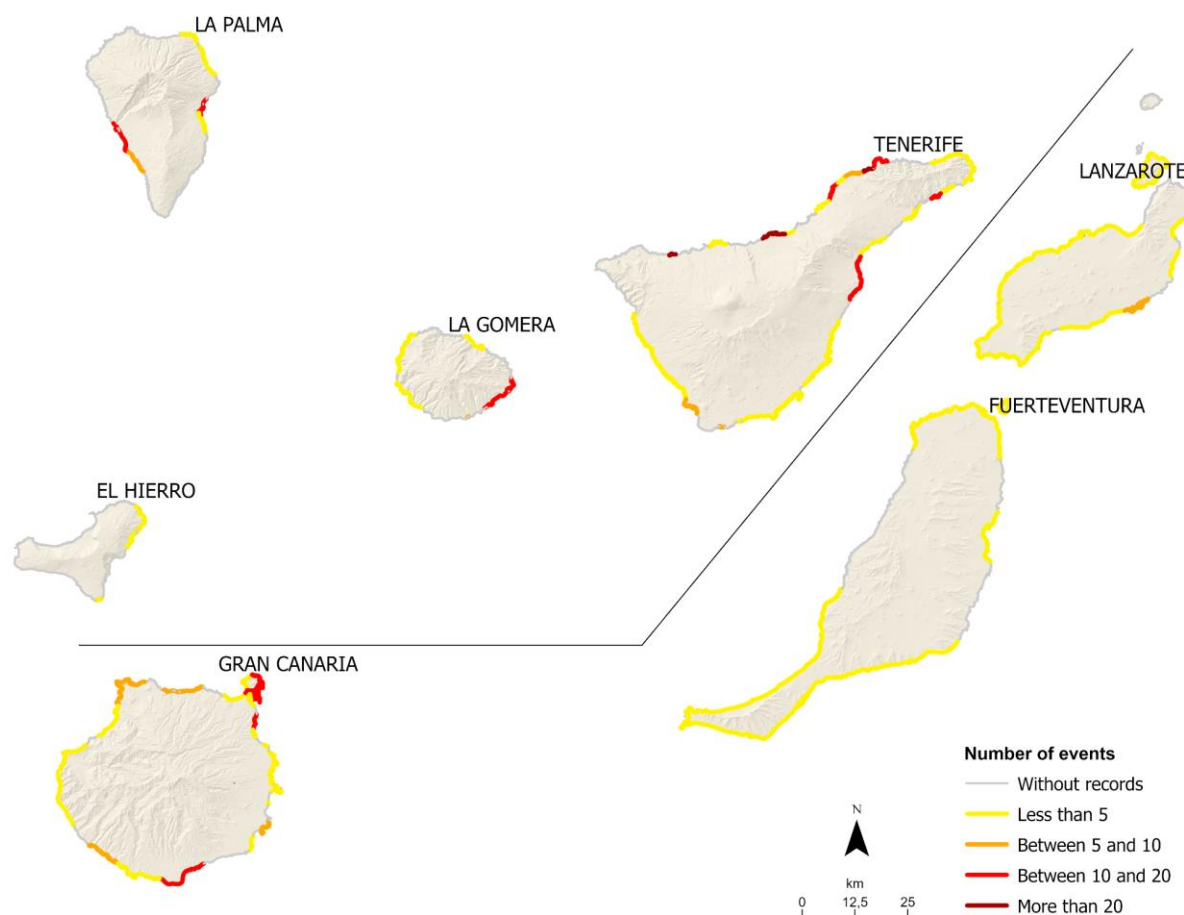


Figure 4: Spatial distribution of events by postal code across the Canary Islands.

415 4.3.1 Hotspots

The spatial distribution of coastal-damaging events across the 1 km coastal hexagonal grid is heterogeneous and highly concentrated. More than half of the hexagons record no events, resulting in a median value of zero and a strongly zero-inflated distribution. The mean number of events per cell is low (0.31), while the standard deviation is relatively high (1.36), and the coefficient of variation ($CV = 4.42$) indicates extreme relative dispersion. Inequality in event distribution is very pronounced, as reflected by a Gini coefficient of 0.939. Cumulative distribution analysis further shows that approximately 80 % of all events are concentrated in only about 5.6 % of coastal hexagons, evidencing a highly localized pattern of coastal impact hotspots dominated by a very small number of high-intensity cells.



4.3.2 Historical event frequency

The comparison between postal codes (CP) and hotspot distribution reveals clear spatial heterogeneity in damage concentration patterns (Fig. 4). Of the coastal postal codes, 40.0 % record no events, 40.0 % record between 1 and <5 events, 12.1 % between 5 and <10 events, 6.3 % between 10 and 20 events, and 1.6 % more than 20 events over the 1980–2025 study period. The concentration of events within a small proportion of postal codes, including those with more than 20 events, indicates that documented coastal impacts are spatially localized. Several postal codes exhibit highly localized impacts, where damage is concentrated in a small number of points. This pattern of high-frequency, spatially clustered events is observed in Bajamar, Garachico, San Andrés, Tazacorte, and Punta del Hidalgo. In contrast, other areas show a broader spatial distribution of high-frequency events extending across several kilometers of coastline. This more diffuse pattern of hotspot occurrence is evident in Puerto de la Cruz, Las Palmas de Gran Canaria, and Candelaria.

4.4 Exposure and vulnerability characterization. What gets damaged?

Detailed records specifying the affected structures were available for 153 of the 191 coastal-impact events (Fig. 5), whereas the remaining press and insurance accounts provided only generic damage descriptions (e.g., sinkholes or scour). Across the detailed records, 112 distinct asset types were identified and classified into the structural categories defined in the methodology. Damage occurrence shows variability across the structural categories identified from the press records. Transport-related infrastructure, particularly roads and promenades, was the most frequently affected category, being reported in 66 events (43.1 %). Structural elements were affected in 62 events (40.5 %), followed by public and recreational spaces, reported in 48 events (31.4 %), and protective structures, affected in 40 events (26.1 %). Residential buildings were reported as affected in 27 events (17.6 %), while commercial buildings and other elements were each reported in 23 events (15.0%) and 22 events (14.4%), respectively. Street furniture was also affected in 22 events (14.4 %), followed by vehicles, reported in 12 events (7.8 %), and industrial facilities, affected in 4 events (2.6 %). Since a single event could affect several asset categories, these percentages are not mutually exclusive and their sum exceeds 100 %. Overall, the results indicate that roads and promenades, structural elements, public spaces, and coastal protection structures were the asset categories most frequently affected across the documented events.

The number of distinct asset categories affected per event was strongly right-skewed (median = 2; IQR = 1–3; range = 1–10), with most events affecting only one or two categories, while a smaller subset of events affected seven or more categories simultaneously. A similar right-skewed pattern was observed for the number of distinct individual assets affected per event (median = 2; IQR = 1–3; range = 1–16). The events impacting the largest number of distinct exposed assets ($n = 16$) were Tropical Storm Delta (November 2005) and the storm event of January 1999.

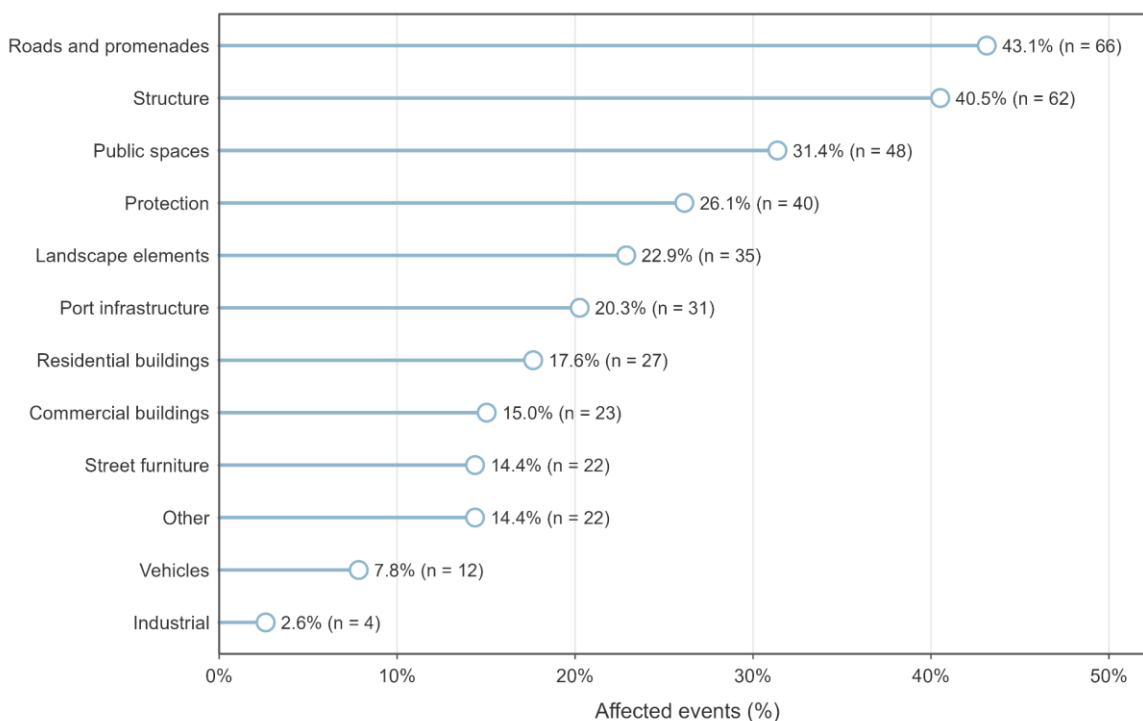


Figure 5: Frequency distribution of coastal events with reported damage across affected asset categories (1980–2025). Bars represent the total number of damaging events recorded for each structure or infrastructure type.

At a more detailed level, the individual elements most frequently reported as damaged include walls ($n = 29$ events, 19.0 %), residential buildings ($n = 26$ events, 17.0 %), swimming pools ($n = 26$ events, 17.0 %), beaches ($n = 22$ events, 14.4 %), urban roads ($n = 21$ events, 13.7 %), and promenades ($n = 20$ events, 13.1 %). These figures reflect the number of events in which each element type was affected, rather than counts of individual damaged structures, and are distributed across both built and coastal environments.

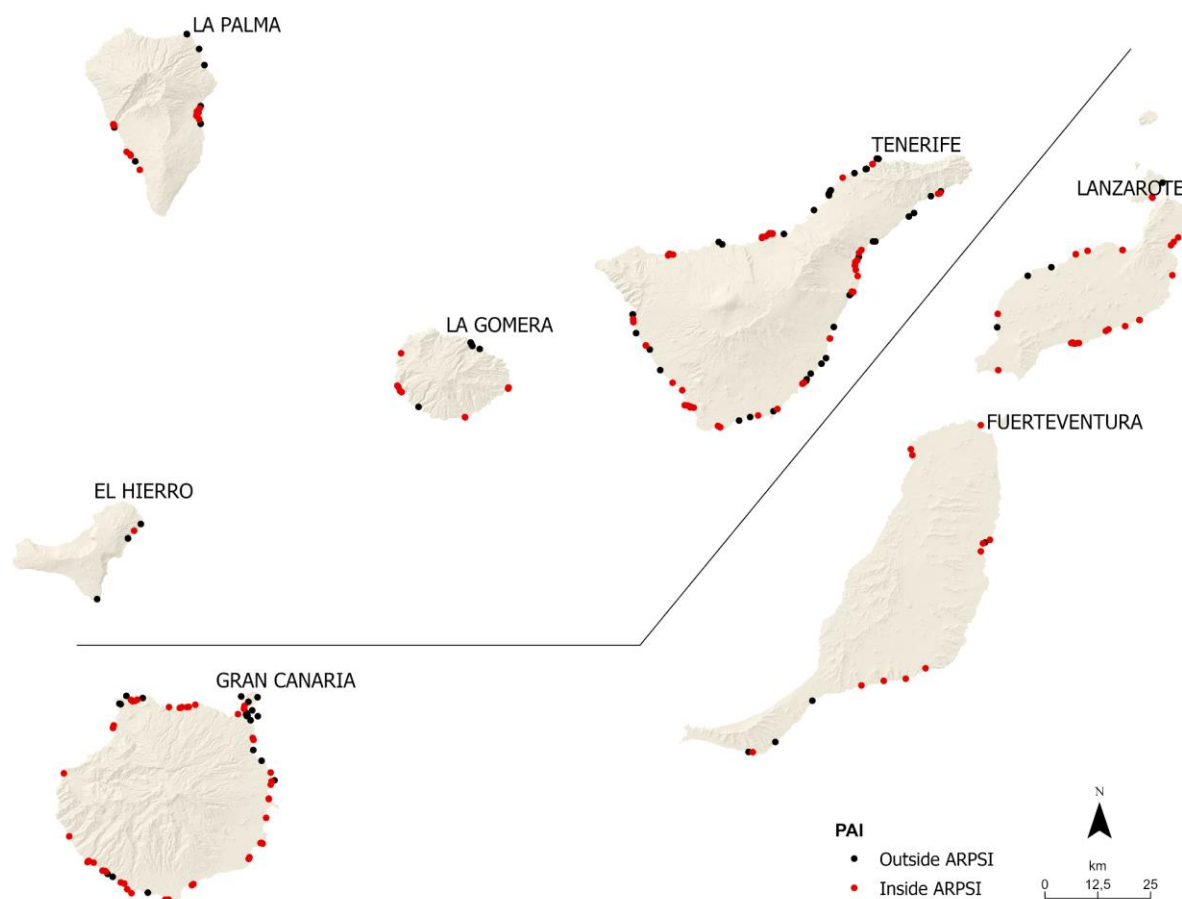
4.5 Comparison with official flood-risk areas and identification of potential gaps

Of the 497 impact records, 346 (69.6 %) were located within an ARPSI or within the 500 m buffer defined around these areas (Fig. 6). The remaining 151 points (30.4 %) were located outside the mapped areas. These results indicate a substantial spatial correspondence between the historical record of coastal impacts and the official flood-risk mapping. A particularly noteworthy finding is that almost one-third of the documented locations were not associated with any ARPSI area.

The historical analysis also identified coastal sectors where damaging floods had occurred recurrently before their formal recognition as Areas of Potential Significant Flood Risk. For example, 14 events were documented in Bajamar prior to 2018, with records corresponding to 1982, 1999, 2003, 2010, 2011, 2013, 2014, 2015, 2016, and 2017. A similar pattern was observed in Mesa del Mar–El Pris, where at least eight damaging events were recorded before 2018, with the earliest documented event dating back to 1985.



470 Differences were also observed when comparing the damaged assets recorded in the press-based inventory with the exposure categories used in regional coastal flood assessments. Transport infrastructure, basic supply networks, public and recreational spaces, and coastal protection structures appeared repeatedly in the historical record. In contrast, agricultural infrastructure was not identified in the press-based inventory, although it is included in the regional assessment of assets and land uses exposed to coastal flooding developed within the framework of the PIMA Adapta Costas de Canarias program.



475 **Figure 6: Spatial distribution of damage points documented in the Press Archive Inventory (PAI) across the Canary Islands. The map highlights the spatial concentration of documented coastal impacts and their distribution within and outside areas identified as having significant potential flood risk (ARPSIs).**

5 Discussion

480 The findings demonstrate the value of historical impact records as a complementary source of evidence for coastal flood -risk assessment in the Canary Islands. Their interpretation nevertheless requires consideration of the completeness and biases of



the underlying sources, the diversity of impact-generating mechanisms, and the interaction between hazard, exposure, and vulnerability that shapes the observed spatial and thematic patterns.

5.1 Reliability and completeness of historical impact records.

485 The reliability of the reconstructed inventory depends on the characteristics and limitations of the documentary and insurance sources from which it was derived. Assessing their respective coverage, biases, and degree of correspondence is therefore essential for determining the extent to which the combined database represents the actual occurrence and consequences of damaging coastal flooding. Indeed, this study presents the first archipelago-wide inventory of damaging coastal flooding events in the Canary Islands based on systematic analysis of historical press archives and insurance records. The identification of 191
490 damaging events between 1980 and 2025 indicates that coastal flooding impacts constitute a recurrent component of the archipelago's coastal hazard landscape (Yanes Luque, 2017). Beyond its value for historical reconstruction, the resulting database provides a foundation for future coastal risk assessments, vulnerability analyses, adaptation planning, flood-risk management strategies, and the development of impact-based coastal hazard research in the Canary Islands.

The incorporation of CCS records resulted in the identification of additional damaging events that were not detected through
495 the initial press archive search. At the same time, nearly half of the press-derived events lacked a corresponding insurance record. Newspaper archives tend to emphasize socially visible impacts affecting public infrastructure, community activities, and highly exposed coastal areas, whereas insurance databases are inherently filtered by insurance coverage, asset ownership, claim behavior, and compensation criteria (Gall et al., 2009). The absence of a matching CCS record does not necessarily indicate that the newspaper-derived event was incorrectly identified. Damage may have affected uninsured assets, public
500 infrastructure, recreational spaces, or properties for which no compensation claim was submitted. Conversely, CCS-only events may have generated dispersed private losses without reaching the level of social visibility required to attract newspaper coverage. In the Canary Islands, the comparison between events with and without newspaper records further suggests that the presence of newspaper coverage is more closely associated with the number of insurance losses generated by an event than with the total economic losses recorded by the CCS. This pattern is consistent with the interpretation that newspaper coverage
505 reflects the social visibility of an event — approximated here by the number of distinct insurance claims and thus by the spatial extent of reported damage — rather than its aggregate economic magnitude. An episode generating many small, dispersed claims across a coastal sector appears more likely to attract press attention than one producing a single large, spatially confined loss. This distinction is relevant when using either source in isolation to characterize event severity and reinforces the need for the multi-source approach adopted in this study. In contrast, no clear differences were found according to whether the affected
510 areas included the regional capitals or different islands. Similar discrepancies between documentary and insurance-based records have been reported in other coastal flood inventories, demonstrating that no single data source can fully represent the spectrum of historical coastal impacts (Ruocco et al., 2011; Haigh et al., 2017). The additional biases identified here further reinforce the need for multi-source approaches, which improve event detection and reduce the limitations inherent to individual documentary datasets (Kellermann et al., 2020; Mazhin et al., 2021).



515 A further pattern worth noting is that most events affected only one or two impact points and one or two asset categories (See Fig. 4.1 and 4.4). This pattern likely reflects the combined effects of threshold-dependent wave overtopping and run-up, the discontinuous distribution of exposed assets, and the reporting characteristics of the documentary sources. Along an otherwise exposed coastline, overtopping may occur only where local defense heights or promenade elevations fall below critical levels, while damage can only be documented where exposed assets are present. Moreover, press and insurance records tend to capture discrete, identifiable damage rather than systematically documenting the full affected coastline. Nevertheless, the occurrence of more extensive events, such as Tropical Storm Delta (2005) and the January 1999 storm, which each affected 16 types of assets, and the April 2024 episode, which was georeferenced at 26 points across several islands, indicates that the inventory is not inherently limited to one or two locations. The predominance of low-extent events therefore likely reflects, at least partly, the localized nature of the documented impacts, although the contribution of reporting and exposure patterns cannot be fully separated with the available data.

The increase in recorded events during recent decades may partly reflect an increase in hazard events or growing exposure in coastal hazard-prone areas, as observed globally (Lincke et al., 2022). However, it is also likely influenced by improvements in media coverage, digitization of newspaper archives, reporting practices, the influence of the internet, and the progressive availability of complementary information sources such as insurance records (Visser et al., 2026). Consequently, the temporal evolution of the number of documented events should be interpreted with caution, as it may reflect both actual changes in coastal flood impacts and variations in data availability and reporting capacity. Despite these limitations, the identification of historical impact events presented here provides a basis for the future incorporation of the Canary Islands into regional and continental-scale impact databases from which the archipelago has so far been largely absent (Paprotny et al., 2024; Souto-Ceccon et al., 2025; UNDRR, n.d.)

535 5.2 Physical drivers of damaging events

The strong concentration of impacts under P95–P99 wave conditions indicate that damaging coastal flooding in the Canary Islands is predominantly associated with extreme sea states. However, documented impacts occurring without P90 exceedances highlight the limitations of wave-threshold-based approaches, which would have overlooked these damaging events (Merz et al., 2014; Rodríguez-Báez et al., 2017). These findings further suggest that damaging events may be underrepresented in hazard assessments and databases that rely exclusively on predefined physical thresholds. The occurrence of damage below the highest wave percentiles also highlights the multivariate nature of coastal flooding. Impact generation depends not only on significant wave height but also on wave period and direction, tidal level, storm surge, coastal orientation, local morphology, and the presence and vulnerability of exposed assets. Consequently, univariate wave thresholds may be insufficient to represent the range of conditions under which damaging coastal flooding occurs. Overall, the SIMAR hindcast tends to underestimate extreme wind speeds and wave heights during severe storm conditions and may perform less reliably in the southern Canary Islands due to boundary effects in the model domain that limit the accurate representation of southwest swell conditions (Puertos del Estado, 2026). The identification and characterization of these historical impact events constitute a first step



towards an impact-based understanding of coastal flooding; however, future work should develop vulnerability and damage curves to quantify the relationship between wave conditions and the resulting impacts on exposed coastal assets and communities (Prahl et al., 2018).

Beyond limitations related to exposure and vulnerability, some impacts may also arise from physical processes that are not adequately represented by conventional wave statistics. Newspaper sources from the Canary Islands contain more than a dozen reports describing "monstrous", "gigantic", or otherwise unusually large waves causing localized coastal damage and hazardous marine conditions. Several of these accounts explicitly mention the arrival of "three unusually large waves" in succession, a feature potentially consistent with wave-grouping processes associated with extreme sea states. Although these accounts do not constitute direct evidence of rogue waves, they point to the possible occurrence of rogue-wave-like events in the Canary Islands, a potentially important but overlooked coastal hazard in the region (Mosegue, 2007, 2011; Didenkulova et al., 2023). Future work could assess these episodes quantitatively using instrumental observations and hindcast wave data, together with statistical indicators of wave dynamics (Peñate de la Rosa and Quintero Plaza, 2025).

The meteorological characterization of the identified coastal forcing mechanisms is consistent with the seasonal maritime climate of the Canary Islands described by Mosegue (2007) and with more recent regional wave-climate assessments Rodríguez-Martín et al., 2022; Megías Dorado, 2024). Overall, the identified impact-generating mechanisms reflect the combined influence of North Atlantic winter storms, the persistent northeast trade-wind regime, regional depressions, tidal modulation, and occasional long-period swell from remote sources. However, the results also indicate that not all forcing mechanisms contribute equally to coastal risk. High-energy North Atlantic swell events emerge as the most frequent damaging-impact events across the archipelago. This interpretation is also consistent with the spatial patterns of coastal storm impacts reported by Yanes Luque et al. (2021). Although less frequent, the recurrent occurrence of impacts during equinoctial tides is particularly noteworthy. While the timing and astronomical component of these tides are highly predictable, the occurrence and severity of impacts depend on their interaction with wave conditions, meteorological surge, local coastal morphology, and exposure. Their recurrence nevertheless points to persistent exposure and potential planning deficiencies in low-lying coastal areas rather than exceptional hazard conditions (Mosegue, 2011)

Additionally, these results have implications for future climate-change impact assessments. Previous studies have often evaluated future coastal flooding by combining present-day extreme water levels or historical return-period events with projected sea-level rise (Gobierno de Canarias, 2022). However, return periods derived from buoy observations are based on probabilistic analyses and rarely account for the specific meteorological and oceanographic mechanisms responsible for damaging coastal impacts (Merz et al., 2014; Ministerio de Agricultura, Alimentación y Medio Ambiente, 2014; Gobierno de Canarias, 2022; Rodríguez-Martín et al., 2022). The present analysis shows that damaging coastal flooding in the Canary Islands arises from diverse oceanographic drivers, including North Atlantic winter storms, the northeast trade-wind regime, regional depressions, and tidal amplification. Recent studies suggest that wave storms in the North Atlantic may become less frequent but more intense (D'Agostini et al., 2022), while changes in cyclone activity and seasonality could alter the timing and characteristics of storm-generated swell reaching the archipelago (Li et al., 2026). Consequently, considerable uncertainty



remains regarding the future evolution of the maritime climate affecting the Canary Islands, highlighting the need for further research and for coastal risk assessments that consider not only sea-level rise but also potential changes in the frequency, intensity, seasonality, and trajectories of impact-generating meteorological systems.

585 5.3 Spatial patterns of coastal flood impacts

The spatial heterogeneity identified in both the impact-reporting hotspot analysis reflects the combined influence of three interacting controls: (i) the spatial variability of coastal hazard, driven by the regional wave climate and the sheltering effect of the islands; (ii) the uneven distribution of exposed infrastructure along the coastline of the Canary Islands; and (iii) spatial and societal reporting biases inherent to documentary records.

590 First, the observed impact pattern reflects the spatial variability of marine forcing across the archipelago (Mosegue, 2007; Megías Dorado, 2024). However, hazard alone cannot explain the spatial concentration of documented impacts. Historical geodemographic processes have concentrated population, infrastructure, and economic activity within coastal urban belts typically comprising the island capitals and the principal tourist resorts (Martel and Armengol, 1994; Santana, 2017). Ports and harbor facilities also emerge as recurrent impact locations because they combine direct exposure to wave action with high
 595 socioeconomic importance. Consequently, the highest frequencies of documented damage occur where energetic marine conditions coincide with high levels of exposure, rather than where hazard is greatest alone.

Despite the relatively short observational record, several recurrent impact-reporting hotspots emerge consistently. Importantly, these hotspots generally represent localized coastal sectors rather than entire postal-code areas. This spatial concentration indicates that local controls, including coastal morphology, harbor configuration, infrastructure layout, and shoreline
 600 orientation, strongly influence where damaging wave impacts occur within broader administrative units. For example, although a given postal code may appear highly affected, impacts are often concentrated within small stretches of coastline, such as the area surrounding the port of San Sebastián de La Gomera. In contrast, other sectors, such as the coast of Gáldar, exhibit a more dispersed distribution of impacts extending across larger portions of the coastline. This suggests that postal-code units provide a useful regional overview, but finer spatial analyses are required to accurately identify impact-prone sectors and understand
 605 the processes controlling their recurrence.

In addition to the physical controls described above, documentary databases are inherently affected by reporting biases. Events affecting urban or tourist areas are more likely to be reported than those occurring in sparsely populated or remote coastal sectors, while events causing little or no visible damage may be entirely absent from the documentary record (Yanes Luque et al., 2021). A clear example is provided by one of the few documented wave-impact events on the northern coast of Lanzarote.
 610 In April 2005, newspapers reported severe wave conditions that caused damage along the island's northwestern coast. The event coincided with the spring equinoctial tide and the Easter holiday period, when numerous campers were present in the area. Their presence likely increased the visibility and reporting of the event; had the coastline been unoccupied, the episode might have remained undocumented despite the occurrence of hazardous marine conditions. Although this individual case



cannot demonstrate the magnitude of reporting bias, it illustrates how temporary variations in human presence and social visibility may influence whether a hazardous coastal event enters the documentary record.

Overall, the identified impact-reporting hotspot should be interpreted as locations where hazard, exposure, and reporting probability converge rather than as a direct representation of the spatial distribution of coastal hazard alone. Consequently, historical impact databases provide valuable information on areas of recurrent societal impact, but they should be interpreted alongside independent hazard assessments when evaluating coastal flood risk.

A further caveat concerns the interpretation of event-level variability in spatial extent and asset diversity (Sect. 4.4). The predominance of events affecting only one or two impact points and one or two asset categories may reflect several, non-exclusive processes: localized hazard variability, spatially uneven exposure, asset-specific vulnerability thresholds, or a form of survivorship bias inherent to impact documentation, whereby a single damaged structure is inherently more likely to occur — and to be reported — than simultaneous damage across many locations or asset types. Distinguishing between these explanations is not possible with the present dataset, as doing so would require asset- and location-specific damage functions relating wave forcing to the probability and severity of impact (Prahl et al., 2018). The development of such damage curves, informed by the present inventory together with future higher-resolution hazard reconstructions, represents a necessary next step for disentangling the relative contribution of hazard, exposure, and vulnerability to the observed patterns of event extent and damage co-occurrence.

5.4 Comparison with risk governance (ARPSI)

Although nearly 70 % of our impact points spatially coincide with officially designated ARPSIs, an important limitation emerges from the temporal dynamics of hazard recognition. ARPSIs in the Canary Islands were originally delineated through hydrodynamic modelling approaches, whereas several additional ARPSIs were only proposed after recent severe storm events caused significant damage (Consejo Insular de Aguas de Tenerife, 2019). Notably, some of these newly proposed ARPSIs already had a well-documented history of coastal flooding long before the storm events that prompted their inclusion. For example, the coastal sectors of Bajamar and Mesa del Mar–El Pris (Tenerife) were proposed as new ARPSIs following the extreme storm of 2018. However, our database reveals a long record of damaging marine inundation in both locations well before that event.

For Bajamar, we identified 14 distinct events prior to 2018, including events recorded in 1982, 1999, 2003, 2010, 2011, 2013, 2014, 2015, 2016, and 2017. Similarly, Mesa del Mar–El Pris experienced at least eight documented inundation events before 2018, with impacts dating back to 1985. These findings demonstrate that the hazardous nature of these coastal sectors had been evident for decades before their incorporation into the official flood-risk framework. The approximately 30 % of impact points located outside currently designated ARPSIs also warrants further examination. Some may represent isolated impacts or spatial mismatches associated with the resolution of the datasets, whereas others may indicate recurrently affected locations that are not yet represented within the official framework. Distinguishing between these situations would help evaluate the contribution of historical impact records to future ARPSI revisions.



Conversely, our analysis also identifies locations where historical flood impacts have diminished or disappeared as a result of changes in exposure rather than reductions in hazard. A representative example is La Rajita (La Gomera), where a severe marine flooding event in February 1987 inundated homes and the local school, forcing the evacuation of residents. At that time, the settlement was closely associated with industrial activity linked to a local factory. Following the closure of the facility, the resident population largely disappeared, and reports of wave-induced damage became uncommon. Nevertheless, recent tourism development proposals, including the planned construction of a hotel complex, could substantially increase future exposure and re-establish significant coastal flood risk.

Overall, these findings demonstrate that historical impact records can provide an early-warning indicator of recurrent coastal-risk hotspots, complement hazard-based assessments and supporting the identification of flood-prone areas before their formal recognition within risk-management frameworks. Under projected sea-level rise and potentially increasing coastal-storm impact, sites with documented histories of marine inundation should be prioritized for detailed risk assessment, adaptation planning, and preparedness measures.

5.5 Damage typologies and vulnerability patterns

The damaged structures identified in the press records are consistent with previous studies conducted in the Canary Islands, although the classification schemes used in these studies are not directly comparable. Similar newspaper-based analyses in southern Gran Canaria and Tenerife reported a predominance of impacts affecting beaches, port facilities, coastal protection structures, and urban infrastructure (Yanes Luque et al., 2021). However, the higher representation of beach-related impacts reported by Yanes Luque et al. (2021) likely reflects differences in exposed assets associated with tourism-dominated coastlines rather than differences in coastal hazard. Beaches, promenades, and recreational infrastructure comprise a much larger share of the exposed environment in their study area than in the archipelago-wide dataset analyzed here.

Accordingly, our results are more closely aligned with archipelago-scale coastal flood exposure assessments (Gobierno de Canarias, 2022). Although based on different methodologies, both datasets indicate that transport, infrastructure, residential, and service-related assets are affected more frequently than industrial or agricultural categories (Gobierno de Canarias, 2022). Likewise, the predominance of damage to promenades, beaches, ports, and public infrastructure in our inventory suggests that these asset types are among the most frequently affected components of the present-day coastal system. Their recurrent appearance throughout the documentary record reflects not only their high exposure but also their relatively low tolerance to wave overtopping, erosion, and marine inundation.

It is also noteworthy that, in contrast to those exposure assessments, agricultural assets are absent from the press-derived inventory despite being included in regional exposure analyses (Gobierno de Canarias, 2022). This discrepancy likely reflects inherent biases in newspaper reporting, which tends to prioritize impacts affecting urban areas, public infrastructure, and economically visible assets, leading to the underrepresentation of damage to agricultural land and facilities.

The damage typology identified in the documentary inventory is not spatially random but closely mirrors the hotspot pattern described in Sect. 5.3, reinforcing the interpretation that recurrent impacts arise where specific exposed asset types coincide



680 with locally energetic wave conditions. Natural rock pools (*piscinas naturales*), for instance, show a concentration of recorded damage along the low-lying, north-facing coastline of Bajamar and Punta del Hidalgo (Tenerife), which together account for the majority of all pool-related damage records in the archipelago; damage to this asset type recurs there more frequently than elsewhere, consistent with the low elevation and direct exposure of these structures to north Atlantic swell, and coinciding with the same municipal belt (La Laguna–Takoronte) that emerges as one of the principal impact-reporting hotspots in the postal-code analysis.

685 A comparable pattern is observed for port and harbour-related facilities, where damage records recur across islands with contrasting exposure regimes — Puerto de Los Mármoles and Puerto de Mogán in Gran Canaria, Puerto de Tazacorte in La Palma, Muelle de Sardina in Gáldar — indicating that harbour infrastructure constitutes a transversal vulnerability class rather than a damage pattern specific to any single island. This class extends to fishing-related assets more broadly, including *cofradía* buildings, fish refuges (*refugios pesqueros*) and moored vessels, which recur as damaged elements at several of the same locations independently of the port infrastructure itself.

690 Seafront promenades and maritime avenues, by contrast, show recurrent damage concentrated in island capitals and consolidated urban fronts (Santa Cruz de La Palma, Santa Cruz de Tenerife, Garachico, Las Galletas), directly reflecting the urban exposure belts discussed above. Garachico stands out within this typology as a compound case, where the same storm events repeatedly damage several asset classes simultaneously — the maritime avenue, the municipal pool, the port and the municipal football field — illustrating how the coincidence of multiple exposed infrastructures within a compact urban node can amplify the recurrence of documented impact at a single location.

Finally, direct damage to first-line residential dwellings recurs at a smaller, geographically dispersed set of points across the archipelago, including established fishing quarters such as San Andrés (recorded independently in both Santa Cruz de Tenerife and Arucas), San Felipe and El Altillo (Santa María de Guía), El Confital (Las Palmas de Gran Canaria) and El Pris and Mesa del Mar (Takoronte), as well as smaller or historically informal coastal settlements such as El Remo and La Bombilla (Tazacorte), Giniginámar (Tuineje), Punta Brava (Puerto de la Cruz), La Mareta (Arico), Alojera (Vallehermoso) and La Santa (Tinajo). The recurrence of residential damage at these specific points, several of which are explicitly described in the source material as older or informally built fishing settlements, suggests that a distinct layer of social and structural vulnerability compounds the physical exposure described above. Together, these typology-specific spatial signatures help explain the pronounced concentration of impacts identified in the hotspot analysis (Sect. 4.3.1): rather than reflecting a uniform level of hazard, the recurrence of impacts at particular postal codes arises from repeated damage to the same locally dominant assets. The regional specificity of the observed damage patterns raises broader questions regarding impact classification. Although several international references exist for impact classification, such as tsunami intensity scales proposed by Sieberg (1927) and later refined by Ambraseys (1962), no widely adopted standardized framework currently exists for wave-induced coastal flooding and overtopping. Existing approaches developed in other regions, including the United States (Needham and Keim, 2011), Chile (Campos Caba, 2016), and the United Kingdom (Haigh et al., 2017), are not directly transferable to the Canary Islands, as they do not adequately represent recurrent local impact typologies or the region's specific exposure and vulnerability



conditions. This highlights the need for a region-specific coastal damage scale tailored to the archipelago, which would improve the consistency and comparability of impact assessments and support more robust quantification of coastal storm damages. The compiled inventory of damaged structures and associated loss information provides a potential empirical basis for developing such a framework and for deriving damage functions linked to physical forcing variables.

6 Conclusions

This study addressed four research questions on damaging coastal flooding in the Canary Islands. First, integrating historical press archives (PAI) with Insurance Compensation Consortium (CCS) records allowed the reconstruction of 191 unique damaging coastal events for the period 1980–2025 — the first archipelago-wide inventory of its kind, filling a gap left by existing European and global disaster databases, which either exclude the archipelago or lack coverage for it. Second, the great majority of documented events (94 %) coincided with offshore wave conditions above the 90th percentile, with North Atlantic swell from extratropical cyclones being the single most frequent forcing mechanism (29.5 %). Third, impacts are spatially concentrated in a small number of recurrent hotspots — largely confined to specific stretches of coastline in northern Tenerife, eastern Gran Canaria, and isolated points on the remaining islands — where roads and promenades, structural elements, public and recreational spaces, and protection structures are the asset categories most frequently affected. Fourth, comparison with the official ARPSI flood-risk mapping showed substantial spatial correspondence (69.6 % of impact points within or near designated areas), while also identifying locations, such as Bajamar and Mesa del Mar–El Pris, where recurrent damaging events had been documented for decades before their formal recognition as flood-risk areas.

Taken together, these results show that no single source — press, insurance, or offshore wave records — captures the full picture of damaging coastal flooding on its own: newspaper coverage tracked the number of insurance claims more closely than the aggregate economic loss, insurance records remained constrained by coverage and claim behavior, and wave statistics alone missed a subset of documented events. This reinforces the case for combining documentary and instrumental sources when reconstructing historical coastal hazard impacts in island and other data-limited settings, and the resulting inventory offers a transferable framework for doing so elsewhere.

Building on the limitations discussed in Sect. 5, future work should prioritize normalizing hotspot recurrence and developing quantitative damage functions linking wave conditions to the asset-level impacts documented in this inventory — a step toward a region-specific coastal damage scale for the Canary Islands.

Data availability

The dataset generated and analysed in this study will be made publicly available in a FAIR-aligned repository (Zenodo) following acceptance of the manuscript and before final publication. The dataset and associated metadata will be assigned a DOI and will include the data required to reproduce the analyses and figures presented in this study. During the review process,



the underlying data can be made available to the reviewers upon request or through the Copernicus review system with access limited to reviewers.

The data provided by the Consorcio de Compensación de Seguros (CCS) are not publicly distributable and therefore cannot be included in the Zenodo repository. This data are subject to third-party access restrictions and must be requested directly from the CCS, in accordance with their data access conditions.

The SIMAR wave data used in this study were obtained from Puertos del Estado. Although the SIMAR service is publicly accessible, the data are subject to conditions of use that prohibit their transfer to third parties. Therefore, the original SIMAR data are not included in the Zenodo repository. Readers requiring this data should obtain them directly from Puertos del Estado, in accordance with the applicable access and use conditions. Puertos del Estado is duly acknowledged as the source of the SIMAR data used in this study.

Author contribution

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Competing interests

The authors declare that they have no conflict of interest.

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References

- Ambraseys, N. N.: Data for the investigation of the seismic sea -waves in the Eastern Mediterranean, *Bull. Seismol. Soc. Am.*,
 775 52, 895–913, <https://pubs.geoscienceworld.org/ssa/bssa/article-abstract/52/4/895/116131/Data-for-the-investigation-of-the-seismic-sea>, 1962.
- Amores, A., Marcos, M., Le Cozannet, G., and Hinkel, J.: Coastal flooding and mean sea -level rise allowances in a toll island, *Sci. Rep.*, 12, 1281, <https://doi.org/10.1038/s41598-022-05329-1>, 2022.
- Andrew, N. L., Bright, P., De La Rua, L., Teoh, S. J., and Vickers, M.: Coastal proximity of populations in 22 Pacific Island
 780 Countries and Territories, *PLoS One*, 14, e0223249, <https://doi.org/10.1371/journal.pone.0223249>, 2019.
- Asín Cabrera, M. A. and Godenau, D.: Movilidad migratoria y estrategia 2020 en la región ultraperiférica de Canarias, in: *Movilidad y gran vecindad en las regiones ultraperiféricas de la Unión Europea*, by: Asín Cabrera, M. A., Godenau, D., and Portugués Carrillo, C., Cabildo Insular de Tenerife, <https://dialnet.unirioja.es/servlet/libro?codigo=908333>, 2014.
- Beach, B. and Hanlon, W. W.: Historical newspaper data: A researcher's guide, *Explor. Econ. Hist.*, 90, 101541,
 785 <https://doi.org/10.1016/j.eeh.2023.101541>, 2023.
- Black, A. R. and Law, F. M.: Development and utilization of a national web-based chronology of hydrological events, *Hydrolog. Sci. J.*, 49, 237–246, <https://doi.org/10.1623/hysj.49.2.237.34835>, 2004.
- Campos Caba, R.: Análisis de marejadas históricas y recientes en las costas de Chile, Undergraduate thesis, Universidad de Valparaíso, <https://repositoriobibliotecas.uv.cl/handle/uvsc/12753>, 2016.
- 790 Centro Nacional de Información Geográfica: Cartografía digital de códigos postales, CartoCiudad [data set], <https://datos.gob.es/es/solicitud-de-datos/cartografia-digital-de-codigos-postales>, 2017.
- Cohen, J. E., Small, C., Mellinger, A., Gallup, J., and Sachs, J.: Estimates of coastal populations, *Science*, 278, 1209–1213, <https://doi.org/10.1126/science.278.5341.1209>, 1997.
- Consejo Insular de Aguas de Tenerife: Esquema provisional de temas importantes (EpTI) del tercer ciclo de planificación:
 795 2021–2027, Cabildo Insular de Tenerife, https://www.aguastenerife.org/images/pdf/PHT3erCiclo/EPTI_pht-3_%20TF%20-%20Revisi%C3%B3n%20CIATF_%20firM_JULIO%202019.pdf, 2019.
- Copernicus Marine Service: Atlantic-Iberian Biscay Irish-Ocean Wave Reanalysis (IBI_MULTIYEAR_WAV_005_006), NOW Systems, Météo-France and CESGA [data set], <https://doi.org/10.48670/moi-00030>, last access: 20 October 2026.
- Cosby, A. G., Lebakula, V., Smith, C. N., Wanik, D. W., Bergene, K., Rose, A. N., Swanson, D., and Bloom, D. E.:
 800 Accelerating growth of human coastal populations at the global and continent levels: 2000–2018, *Sci. Rep.*, 14, 22489, <https://doi.org/10.1038/s41598-024-73287-x>, 2024.



- D'Agostini, A., Bernardino, M., and Guedes Soares, C.: Projected wave storm conditions under the RCP8.5 climate change scenario in the North Atlantic Ocean, *Ocean Eng.*, 266, 112874, <https://doi.org/10.1016/j.oceaneng.2022.112874>, 2022.
- Dang, H. A. H., Hallegatte, S., Nguyen, M. C., and Trinh, T. A.: Impacts of global warming on subnational poverty and inequality, *Nat. Clim. Change*, 16, 207–213, <https://doi.org/10.1038/s41558-025-02516-6>, 2026.
- de Groot, R., Fisher, B., Christie, M., Aronson, J., Braat, L., Haines-Young, R., Gowdy, J., Maltby, E., Neuville, A., Polasky, S., Portela, R., and Ring, I.: Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation, in: *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*, edited by: Kumar, P., Earthscan, London, 9–40, <https://doi.org/10.4324/9781849775489>, 2010
- Delforge, D., Wathelet, V., Below, R., Lanfredi Sofia, C., Tonnelier, M., van Loenhout, J. A. F., and Speybroeck, N.: EM-DAT: the Emergency Events Database, *Int. J. Disaster Risk Reduct.*, 124, 105509, <https://doi.org/10.1016/j.ijdrr.2025.105509>, 2025.
- Díaz Hernández, R. and Domínguez Mujica, J.: La población de Canarias en el horizonte de 2020, Informe científico, <https://accedacris.ulpgc.es/handle/10553/16693>, 2015.
- Didenkulova, E., Didenkulova, I., and Medvedev, I.: Freak wave events in 2005–2021: Statistics and analysis of favourable wave and wind conditions, *Nat. Hazards Earth Syst. Sci.*, 23, 1653–1663, <https://doi.org/10.5194/nhess-23-1653-2023>, 2023.
- Gall, M., Borden, K. A., and Cutter, S. L.: When do losses count? Six fallacies of natural hazards loss data, *Bull. Am. Meteorol. Soc.*, 90, 799–810, <https://doi.org/10.1175/2008BAMS2721.1>, 2009.
- García-Román, M.: Breve descripción del clima marítimo y la costa canaria, in: *Fundamentos de los aprovechamientos de la energía hidráulica y marina*, Curso 2022–23, Máster Energías Renovables, Universidad de La Laguna, La Laguna, Islas Canarias, Spain, course slides, 2022.
- García-Romero, L., Carreira-Galbán, T., Rodríguez-Báez, J. Á., Máyer-Suárez, P., Hernández-Calvento, L., and Yanes-Luque, A.: Mapping environmental impacts on coastal tourist areas of oceanic islands (Gran Canaria, Canary Islands): A current and future scenarios assessment, *Remote Sens.*, 15, 1586, <https://doi.org/10.3390/rs15061586>, 2023.
- Gil-Guirado, S., Pérez-Morales, A., and López-Martínez, F.: SMC-Flood database: a high-resolution press database on flood cases for the Spanish Mediterranean coast (1960–2015), *Nat. Hazards Earth Syst. Sci.*, 19, 1955–1971, <https://doi.org/10.5194/nhess-19-1955-2019>, 2019.
- Gobierno de Canarias: PIMA Adapta Costas: Evaluación del riesgo frente al cambio climático en las costas de Canarias, <https://pimacostas.grafcan.es/>, last access: [1 September 2025], 2022.
- Guerra-Medina, D. and Rodríguez, G.: Spatiotemporal variability of extreme wave storms in a beach tourism destination area, *Geosciences*, 11, 237, <https://doi.org/10.3390/geosciences11060237>, 2021.
- Haigh, I. D., Ozsoy, O., Wadley, M. P., Nicholls, R. J., Gallop, S. L., Wahl, T., and Brown, J. M.: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, *Sci. Data*, 4, 170100, <https://doi.org/10.1038/sdata.2017.100>, 2017.



- 835 Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., Nicolas, J., Peubey, C., Radu, R., Schepers, D., Simmons, A., Soci, C., Abdalla, S., Abellan, X., Balsamo, G., Bechtold, P., Biavati, G., Bidlot, J., Bonavita, M., De Chiara, G., Dahlgren, P., Dee, D., Diamantakis, M., Dragani, R., Flemming, J., Forbes, R., Fuentes, M., Geer, A., Haimberger, L., Healy, S., Hogan, R. J., Hólm, E., Janisková, M., Keeley, S., Laloyaux, P., Lopez, P., Lupu, C., Radnoti, G., de Rosnay, P., Rozum, I., Vamborg, F., Villaume, S., and Thépaut, J.-N.: The ERA5 global reanalysis, *Q. J. Roy. Meteorol. Soc.*, 146, 1999–
- 840 2049, <https://doi.org/10.1002/qj.3803>, 2020.
- Instituto Hidrográfico de la Marina: Línea de Costa LC2023, Armada Española, Ministerio de Defensa [data set], distributed by Centro Nacional de Información Geográfica (CNIG), <https://centrodedescargas.cnig.es/CentroDescargas/linea-costas>, last access: 20 October 2025, 2023.
- IPCC: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate, edited by: Pörtner, H.-O., Roberts, D. C.,
- 845 Masson-Delmotte, V., Zhai, P., Tignor, M., Poloczanska, E., Mintenbeck, K., Alegría, A., Nicolai, M., Okem, A., Petzold, J., Rama, B., and Weyer, N. M., Cambridge University Press, Cambridge, UK and New York, NY, USA, 755 pp., <https://doi.org/10.1017/9781009157964>, 2019.
- IPCC: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, edited by: Pörtner, H.-O., Roberts, D. C., Tignor, M.,
- 850 Poloczanska, E. S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., Okem, A., and Rama, B., Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., <https://doi.org/10.1017/9781009325844>, 2022.
- Johnson, R. M., Pandey, B. W., Chand, K., Davies, C. L., Edwards, D., Edwards, E., Jeffers, J., King, K., Kuniyal, J. C., Mishra, H., Phillips, V., Roy, N., Seviour, J., Sharma, D. D., Sharma, P., Singh, H., and Singh, R. B.: 'HiFlo-DAT': A flood
- 855 hazard event-disaster database for the Kullu District, Himachal Pradesh, Indian Himalaya, *Int. J. Disaster Risk Reduct.*, 120, 105336, <https://doi.org/10.1016/j.ijdr.2025.105336>, 2025.
- Kellermann, P., Schröter, K., Thieken, A. H., Haubrock, S. N., and Kreibich, H.: The object-specific flood damage database HOWAS 21, *Nat. Hazards Earth Syst. Sci.*, 20, 2503–2519, <https://doi.org/10.5194/nhess-20-2503-2020>, 2020.
- Kopp, R. E., Horton, R. M., Little, C. M., Mitrovica, J. X., Oppenheimer, M., Rasmussen, D. J., Strauss, B. H., and Tebaldi,
- 860 C.: Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites, *Earth's Future*, 2, 383–406, <https://doi.org/10.1002/2014EF000239>, 2014.
- Li, Z.-B., Heuzé, C., Song, J.-N., Crawford, A., Lai, H.-W., and Chen, D.: All-season analysis of extratropical and arctic cyclones over the Northern Hemisphere oceans during 1940–2024, *J. Geophys. Res.-Atmos.*, 131, e2025JD044894, <https://doi.org/10.1029/2025JD044894>, 2026.
- 865 Lincke, D., Hinkel, J., Mengel, M., and Nicholls, R. J.: Understanding the drivers of coastal flood exposure and risk from 1860 to 2100, *Earth's Future*, 10, e2021EF002584, <https://doi.org/10.1029/2021EF002584>, 2022.
- Llasat, M. C., Llasat-Botija, M., and López, L.: A press database on natural risks and its application in the study of floods in Northeastern Spain, *Nat. Hazards Earth Syst. Sci.*, 9, 2049–2061, <https://doi.org/10.5194/nhess-9-2049-2009>, 2009.



- Llasat, M. C., Llasat-Botija, M., Petrucci, O., Pasqua, A. A., Rosselló, J., Vinet, F., and Boissier, L.: Towards a database on societal impact of Mediterranean floods within the framework of the HYMEX project, *Nat. Hazards Earth Syst. Sci.*, 13, 1337–1350, <https://doi.org/10.5194/nhess-13-1337-2013>, 2013.
- López Saavedra, M., Martí Molist, J., and Martínez Sepúlveda, M.: Historical record of non-extreme events occurring on the Island of Tenerife (Canary Islands) in the period 1494–2020, *DIGITAL.CSIC* [data set], <https://doi.org/10.20350/DIGITALCSIC/17088>, 2025.
- Luijendijk, A., Hagenaars, G., Ranasinghe, R., Baart, F., Donchyts, G., and Aarninkhof, S.: The state of the world's beaches, *Sci. Rep.*, 8, 6641, <https://doi.org/10.1038/s41598-018-24630-6>, 2018.
- Ma, J. and Mostafavi, A.: Urban form and structure explain variability in spatial inequality of property flood risk among US counties, *Commun. Earth Environ.*, 5, 172, <https://doi.org/10.1038/s43247-024-01337-3>, 2024.
- Magalhães Filho, L., Roebeling, P., Villasante, S., and Bastos, M. I.: Ecosystem services values and changes across the Atlantic coastal zone: Considerations and implications, *Mar. Policy*, 145, 105265, <https://doi.org/10.1016/j.marpol.2022.105265>, 2022.
- Martel Alayón, I. and Armengol Martín, M. T.: Distribución espacial de la población en Canarias: una propuesta de ordenación territorial, in: *X Coloquio de Historia Canario-Americana*, Vol. 2, Mancomunidad de Cabildos, 133–148, <https://hdl.handle.net/20.500.12285/coloquios/708>, 1994.
- Martínez, M. L., Intralawan, A., Vázquez, G., Pérez-Maqueo, O., Sutton, P., and Landgrave, R.: The coasts of our world: Ecological, economic and social importance, *Ecol. Econ.*, 63, 254–272, <https://doi.org/10.1016/j.ecolecon.2006.10.022>, 2007.
- Mazhin, S. A., Farrokhi, M., Noroozi, M., Roudini, J., Hosseini, S. A., Motlagh, M. E., Kolivand, P., and Khankeh, H.: Worldwide disaster loss and damage databases: A systematic review, *J. Educ. Health Promot.*, 10, 329, https://doi.org/10.4103/jehp.jehp_1525_20, 2021.
- Megías Dorado, E. J.: Estudio del comportamiento de los swells provenientes del hemisferio sur en las costas de las Islas Canarias, PhD thesis, Universidad de La Laguna, <https://riull.ull.es/xmlui/handle/915/37734>, 2024.
- Merz, B., Aerts, J. C. J. H., Arnbjerg-Nielsen, K., Baldi, M., Becker, A., Bichet, A., Blöschl, G., Bouwer, L. M., Brauer, A., Cioffi, F., Delgado, J. M., Gocht, M., Guzzetti, F., Harrigan, S., Hirschboeck, K., Kilsby, C., Kron, W., Kwon, H.-H., Lall, U., Merz, R., Nissen, K., Salvatti, P., Swierczynski, T., Ulbrich, U., Viglione, A., Ward, P. J., Weiler, M., Wilhelm, B., and Nied, M.: Floods and climate: emerging perspectives for flood risk assessment and management, *Nat. Hazards Earth Syst. Sci.*, 14, 1921–1942, <https://doi.org/10.5194/nhess-14-1921-2014>, 2014.
- Millennium Ecosystem Assessment: Ecosystems and human well-being: Synthesis, Island Press, Washington, DC, ISBN 1-59726-040-1, <https://www.wri.org/research/millennium-ecosystem-assessment-ecosystems-and-human-well-being>, 2005.
- Ministerio de Agricultura, Alimentación y Medio Ambiente: Elaboración de los mapas de peligrosidad y riesgo requeridos por el Real Decreto 903/2010 en la costa española, Gobierno de España, <https://www.miteco.gob.es/es/agua/temas/gestion-de-los-riesgos-de-inundacion/mapa-peligrosidad-riesgo-inundacion.html>



- Ministerio para la Transición Ecológica y el Reto Demográfico: Áreas de Riesgo Potencial Significativo de Inundación (ARPSI), Sistema Nacional de Cartografía de Zonas Inundables, <https://www.miteco.gob.es/es/cartografia-y-sig/ide/descargas/agua/arpsi.html>, last access: 1 September 2025.
- Mosegue, J. A.: El clima marítimo de Canarias, oleajes, temporales y su predicción, *Nautis et Incolis: Revista de la Real Sociedad Económica de Amigos del País de Tenerife*, 4, 261–312, <https://dialnet.unirioja.es/servlet/articulo?codigo=9639867>, 2007.
- Mosegue, J. A. A.: Canarias y los eventos extremos en el mar, *Boletín de la Real Sociedad Económica de Amigos del País de Tenerife*, 1, 63–112, <https://dialnet.unirioja.es/servlet/articulo?codigo=3900459>, 2011.
- Needham, H.: Identifying historic storm surges and calculating storm surge return periods for the Gulf of Mexico coast, PhD thesis, Louisiana State University and Agricultural and Mechanical College, https://doi.org/10.31390/gradschool_theses.3341, 2010.
- Needham, H. and Keim, B. D.: Storm surge: Physical processes and an impact scale, in: Recent hurricane research – climate, dynamics, and societal impacts, IntechOpen, Croatia, 385–406, <https://doi.org/10.5772/15925>, 2011.
- Papagiannaki, K., Kotroni, V., and Lagouvardos, K.: Impact-based analysis of weather-related hazards in Greece (2000–2025): Insights from the High-Impact Weather Events Database (HIWE-DB), *Climate*, 14, 105, <https://doi.org/10.3390/cli14050105>, 2026.
- Paprotny, D., Terefenko, P., and Ślędziowski, J.: HANZE v2.1: an improved database of flood impacts in Europe from 1870 to 2020, *Earth Syst. Sci. Data*, 16, 5145–5170, <https://doi.org/10.5194/essd-16-5145-2024>, 2024.
- Peñate de la Rosa, I. and Quintero Plaza, D.: Breve análisis de la situación de oleaje intenso del 7 de julio de 1941, Agencia Estatal de Meteorología (España), Delegación Territorial en Canarias, <https://hdl.handle.net/20.500.11765/16882>, 2025.
- Prahl, B. F., Boettler, M., Costa, L., Kropp, J. P., and Rybski, D.: Damage and protection cost curves for coastal floods with in the 600 largest European cities, *Sci. Data*, 5, 180034, <https://doi.org/10.1038/sdata.2018.34>, 2018.
- Puertos del Estado: Conjunto de datos SIMAR, Informe técnico INT_8, https://bancodatos.puertos.es/BD/informes/INT_8.pdf, 2026.
- Rodríguez-Báez, J. Á., Yanes Luque, A., and Dorta Antequera, P.: Determinación y caracterización de situaciones de temporal marino e inundación costera por rebase del oleaje en San Andrés, NE de Tenerife (1984–2014), *Investigaciones Geográficas*, 68, 95–114, <https://doi.org/10.14198/INGEO2017.68.06>, 2017.
- Rodríguez-Martín, J., Cruz-Pérez, N., and Santamarta, J. C.: Maritime climate in the Canary Islands and its implications for the construction of coastal infrastructures, *Civil Eng. J.*, 8, 24–32, <https://doi.org/10.28991/CEJ-2022-08-01-02>, 2022.
- Rubio Astorga, I.: Wave evolution in the Canary Islands, Master's thesis, Universidad de Las Palmas de Gran Canaria, Universidad de Vigo, and Universidad de Cádiz, <https://acceda.ris.ulpgc.es/handle/10553/74340>, 2020.
- Ruocco, A. C., Nicholls, R. J., Haigh, I. D., and Wadey, M. P.: Reconstructing coastal flood occurrence combining sea level and media sources: a case study of the Solent, UK since 1935, *Nat. Hazards*, 59, 1773–1796, <https://doi.org/10.1007/s11069-011-9868-7>, 2011.



- 935 Sancho-García, A., Guillén, J., Gracia, V., Rodríguez-Gómez, A. C., and Rubio-Nicolás, B.: The use of news information published in newspapers to estimate the impact of coastal storms at a regional scale, *J. Mar. Sci. Eng.*, 9, 497, <https://doi.org/10.3390/jmse9050497>, 2021.
- Santana, J. S. L.: Demografía y cambio social en Canarias, *Atlántida. Revista Canaria de Ciencias Sociales*, 8, 25–71, <https://www.ull.es/revistas/index.php/atlantida/article/view/1056>, 2017.
- 940 Shah, M. A. R. and Wang, X.: Assessing social-ecological vulnerability and risk to coastal flooding: A case study for Prince Edward Island, Canada, *Int. J. Disaster Risk Reduct.*, 106, 104450, <https://doi.org/10.1016/j.ijdr.2024.104450>, 2024.
- Sieberg, A.: Zurückgehende Wellen [Receding waves], in: *Handbuch der Geophysik [Handbook of geophysics]*, edited by: Gutenberg, B., Vol. 4, Gebrüder Borntraeger, 570–571, 1927.
- Souto-Ceccon, P. E., Montes, J., Duo, E., Ciavola, P., Fernández-Montblanc, T., and Armaroli, C.: A European database of resources on coastal storm impacts, *Earth Syst. Sci. Data*, 17, 1041–1054, <https://doi.org/10.5194/essd-17-1041-2025>, 2025.
- 945 Stockdon, H. F., Holman, R. A., Howd, P. A., and Sallenger, A. H.: Empirical parameterization of setup, swash, and runup, *Coast. Eng.*, 53, 573–588, <https://doi.org/10.1016/j.coastaleng.2005.12.005>, 2006.
- UNDRR: Sendai Framework for Disaster Risk Reduction 2015–2030, UNDRR, Geneva, <https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030>, 2015.
- 950 UNDRR: DesInventar Sendai: Disaster Information Management System [data set], <https://www.desinventar.net/>
- UNISDR: Global assessment report on disaster risk reduction 2015, United Nations, <https://doi.org/10.18356/919076d9-en>, 2015.
- Van Westen, C. J.: Remote sensing and GIS for natural hazards assessment and disaster risk management, in: *Treatise on Geomorphology*, Vol. 3, Elsevier, 259–298, <https://doi.org/10.1016/B978-0-12-374739-6.00051-8>, 2013.
- 955 Visser, H., de Bruin, S. P., Bouwer, L. M., and Petersen, A. C.: Temporal characteristics of disaster data: how to avoid misconceptions, misinterpretation, or misuse, *Int. J. Disaster Risk Reduct.*, 142, 106188, <https://doi.org/10.1016/j.ijdr.2026.106188>, 2026.
- Vousdoukas, M. I., Ranasinghe, R., Mentaschi, L., Plomaritis, T. A., Athanasiou, P., Luijendijk, A., and Feyen, L.: Sandy coastlines under threat of erosion, *Nat. Clim. Change*, 10, 260–263, <https://doi.org/10.1038/s41558-020-0697-0>, 2020.
- 960 WMO: Manual on flood forecasting and warning, WMO-No. 1072, World Meteorological Organization, <https://library.wmo.int/idurl/4/35881>, 2011.
- WMO: Guidelines on implementation of a coastal inundation forecasting–early warning system, WMO-No. 1293, World Meteorological Organization, <https://www.preventionweb.net/media/84362>, 2022.
- Yagoub, M. M., Alsereidi, A. A., Mohamed, E. A., Periyasamy, P., Alameri, R., Aldarmaki, S., and Alhashmi, Y.: Newspapers as a validation proxy for GIS modeling in Fujairah, United Arab Emirates: identifying flood-prone areas, *Nat. Hazards*, 104, 111–141, <https://doi.org/10.1007/s11069-020-04161-y>, 2020.
- 965 Yanes Luque, A.: Desastres naturales en Canarias. La costa como espacio de riesgo en Tenerife, *Sémata: Ciencias Sociales e Humanidades*, 29, 67–89, <https://doi.org/10.15304/s.29.4150>, 2017.



970 Yanes Luque, A., Marzol, M. V., and Romero, C.: Characterization of sea storms along the coast of Tenerife, the Canary Islands, J. Coast. Res., SI 48, 124–128, 2006.

Yanes Luque, A., Rodríguez-Báez, J. A., Máyer Suárez, P., Dorta Antequera, P., López-Díez, A., Díaz-Pacheco, J., and Pérez-Chacón, E.: Marine storms in coastal tourist areas of the Canary Islands, Nat. Hazards, 109, 1297–1325, <https://doi.org/10.1007/s11069-021-04879-3>, 2021.