Characterization of the sea storms in the south and southwest of Gran Canaria and Tenerife and their socioeconomic and environmental consequences.

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Curso 2021-2022

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Trabajo fin de titulo para la obtención del Grado en Ciencias del Mar

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Título del TFT:

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INTRODUCTION

Sea storms are an extreme meteorological event in which atmospheric conditions produce an overrising in sea level with an increase in waves height (Ayala et al., 2002; Rodríguez-Báez et al., 2017). The events with these characteristics are usually accompanied with strong wind, responsible of the action on the sea surface that forms waves (Medina et al., 2006).

The work released by Medina et al (2006) in the Canary Islands, in which this kind of processes are studied, shows a change of the sea storms tendency in the north-south zone. This fact is explained by the different waves' generation behave in the north (waves generated in the North Atlantic Ocean with a very extensive generation "fetch"), respect to the south (waves generated in nearer zones of the islands).

The sea storms effect by the wave action is determined by some factors. The meteorological system which generates it and the movement respect to the cost line, as well as physical-geographic characteristics of affected areas, e.g, barometry or sea bottom configuration (Hidalgo et al., 2015). In addition, the nearer to the coast the more waves suffer bottom friction, loose velocity/speed and the energy conservation tendency makes their height rise; this and the lack of stability, make them break hitting the coast. The size and wave strong, with all the conditions said before, are determinant for coast damages.

During sea storms, the coast and all built on it are seriously damaged and modified. This causes large environmental, human and economic losses in strategic areas of the islands. Specifically, docks are the most affected during sea storms, which supposes a totally communication cut between islands. Beaches, natural landscapes quite environmental and touristic interesting, are also a victim of sea storms that leave them extremely damaged.

Since 1960, Canary Island's touristic development, which continues today, has advanced very quickly. Because of weather conditions and cost landscapes, the islands one of the most popular summer destinies. This fact, joined to the progressive migration to the coast by the habitants, produce an accelerating increase of population in these areas.

The Canarian coastline is of great interest, both from a natural point of view and for its potential socio-economic implications (Ferrer y Hernández-Calvento, 2016). For this reason, it is so important to have a thorough knowledge of the marine storms that affect tourist areas, where an important part of the islands' economy is concentrated.

Different investigations have studied sea storms in Canary Islands' coasts, as well as their geographics, environmental and economic consequences. This work, precisely, have been developed with the same methodologies already applied in those investigations. Thus, in this work we have analysed areas in the south and southwest of Gran Canaria and Tenerife, different from the work of Yanes et al. (2021).

The main objective in this final degree project is to know the costal vulnerability of south and south-west Gran Canaria and Tenerife zones during sea storms, zones with very high interest because of their location or amount of population. Inside this investigation, it is look for detecting the wave parameter variation during sea storms episodes, knowing the atmospheric pattern in the different situation and identifying the most affected zones during these episodes.

STUDY AREA

The studied areas correspond to the south and south-west Gran Canaria and Tenerife zones (Canary Islands, Spain), as these are the most economically important in terms of tourism on both islands. This field has been delimited by the following way: The Gran Canaria south zone, from Pasito Blanco beach to Patalavaca beach (Fig. 1d) with 13 km of extension. Gran Canaria southwest from Bufadero (between Tauro beach and Amadores beach) to Puerto de Mogán (Fig. 1c), with 6.5 km of extension. The Tenerife south zone, from Punta de los MejIllones to Punta los Callados (Fig. 1b), with 31.3 km of extension. Finally, southwest zone of this island, from La Enramada beach to Callao Salvaje (Fig. 1a) with 9.7km of extension. The totally extension of all studied zones is 60.5 km with discontinued sections.

Canary Islands are located inside Alisios winds area. This wind regime shows a clear seasonal pattern. During winter season the wind blows with moderate or weak intensity in a NNE component, while in summer season, NE Alisios winds blow with less intensity. Marine conditions in Canary Islands are strongly related to atmospheric conditions, that is why waves are usually quite soft.

The north coast of the island is the most exposed to waves action, being studied areas S-SW the less exposed. Furthermore, waves conditions present a clear seasonal pattern with waves conditions soft from April to October and stronger from November to March. Respect to sea storms, it has observed that extreme waves events also have a significant seasonal behaviour (Guerra-Medina y Rodríguez, 2021).

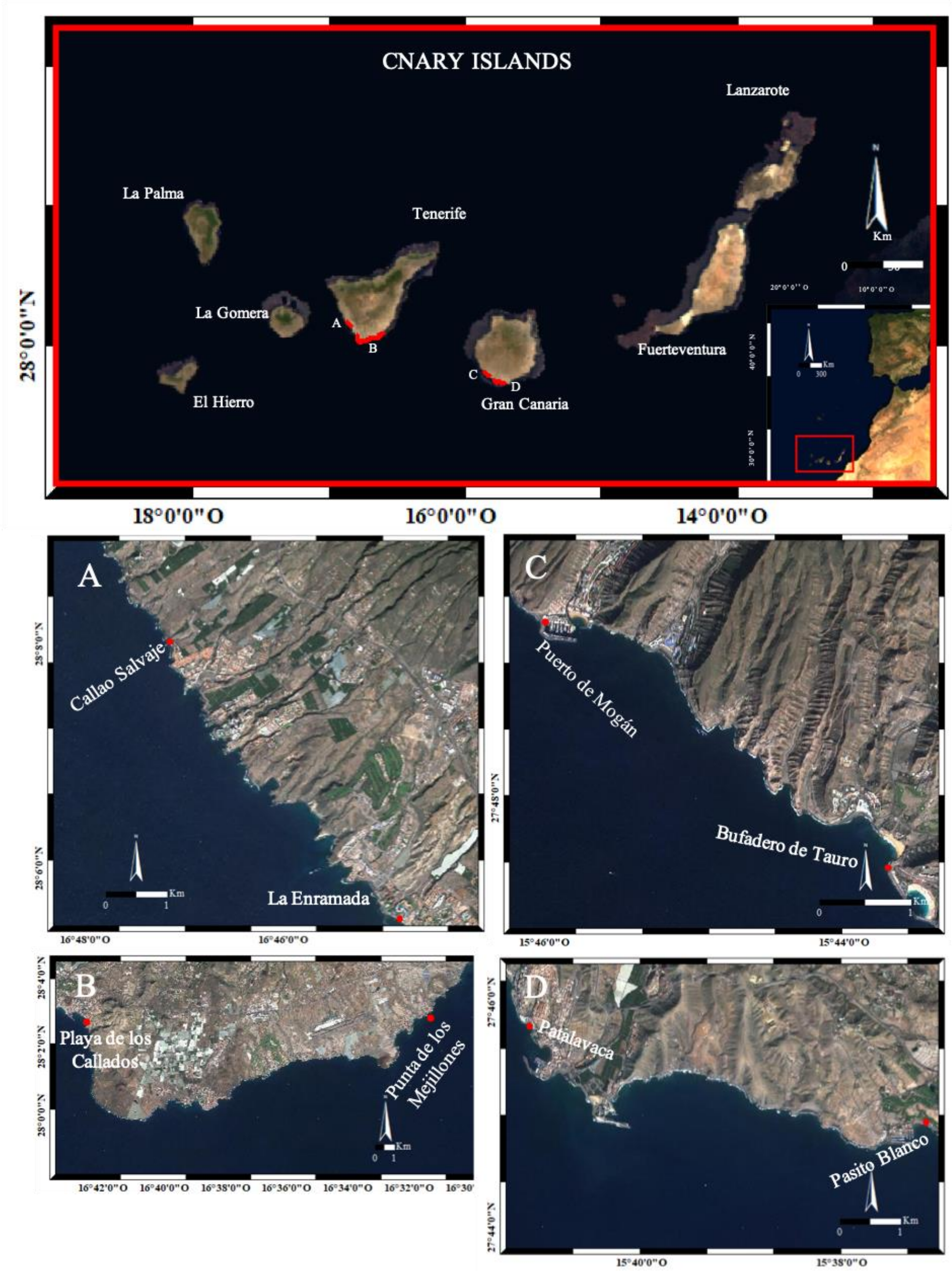

Figure 1. At the top, the Canary Islands with study areas coloured in red and their location in the Atlantic Ocean. A) Study areas in the SW of Tenerife. B) Study areas in the S of Tenerife. C) Study areas in the SW of Gran Canaria. D) Study areas in the S of Gran Canaria.

METHODOLOGY AND REFERENCES

In one hand, studied zone of coastline has been characterized. The coast typology was divided in two types: "natural" groups and "artificial" groups. Inside natural groups, it was identified the followings subgroups: rocky coast, sandy beach, pebble beach, cliffs y ravine mouth. And inside artificial coast classification: artificial beach, hotels, houses, restaurants, promenade, dykes, breakwater, sports port, apartments. As well Geographic Information System "Arcgis" as Canary Islands photographies from "IDECanarias" were used to analyse coastline 100 metres section by 100 metres section. It has been created a data base where each section has a type of coast of those said before. For those section where appear more than one coast type it has given the most representative section classification. After this, it was calculated percent value of each coast type in the different studied zones.

In the other hand, the methodology of this work in focus on two key elements: (i) the wave characterization during sea storms and (ii) their geographic and social consequences. To analyse the first variable, it has used the Oceanographic base data of Puertos del Estado (www.puertos.es). This administration provides directional waves data related to numeral wave generation and propagation models (Rodríguez-Báez et al., 2017). The three SIMAR points with the highest representation for the coastal areas of interest were selected. SIMAR 4033006 for Gran Canaria (Fig. 2B).; SIMAR 4023009 y SIMAR 4021009 for Tenerife (Fig. 2A).

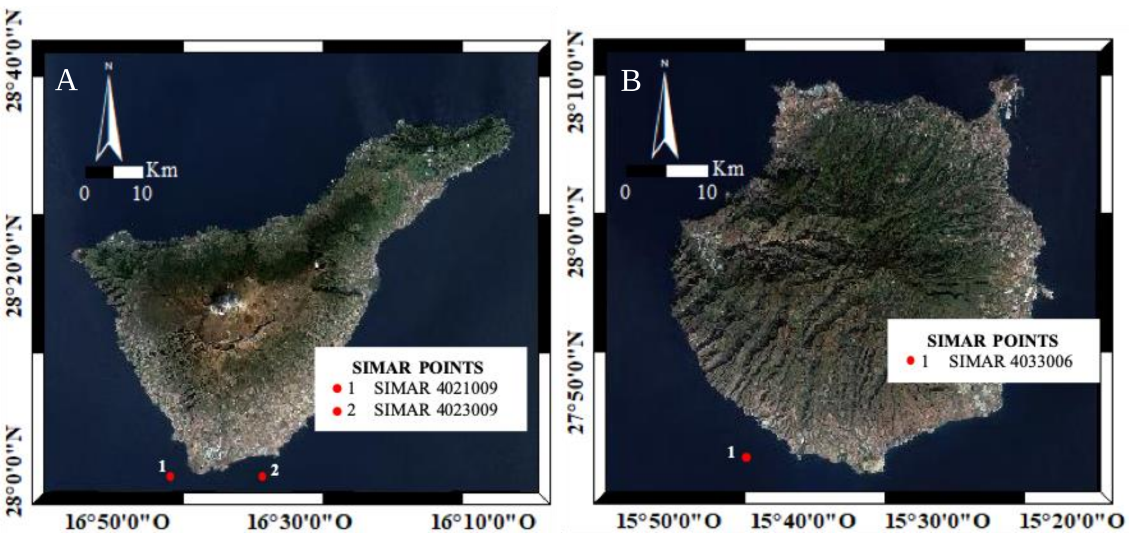

Figure 2. A) SIMAR points chosen for the characterisation of the mean swell in Tenerife. B) SIMAR points chosen for the characterisation of the mean swell in Gran Canaria.

The average swell in these areas was characterized to compare it with the situation in which the parameters take extreme values, associated with seastorm episodes. To define thresholds and recognised these extreme values of significant wave (Hs) it was used the 99th percentile (Yanes, 2007). According to Rodríguez-Báez et al (2017), the 99th percentile shows the 1% of extreme events of statistical series and is estimated to be representative for swell analyses of sea storm episodes.

The atmospheric state during these events was analysed to determinate the conditions where sea storms become violent enough to cause damage to coastal infrastructures. The weather maps available on the website of the German meteorological service (www. Wetterzentrale.de) were consulted in those specified dates. The daily synoptic maps provide information on the barometric situations in which the winds that cause the storms have been generated (Yanes y Marzol., 2009).

The second variable was studied through systematic consultation of the press from 1970 to 2020. The coastal infrastructures that have been damaged and their consequences for tourism and, therefore, for the insular economy, have been assessed. This part has been based on a similar methodology that used by Yanes et al (2009) in an analysis of the consequences of marine storms in Tenerife using the press as the main source of documentation.

In this work, a search by words was carried out in the digital press archive of the ULPGC (Jable). The terms used: storm, waves, south, Gran Canaria and Tenerife. Newspapers as *La Provincia, El Día, Diario de Avisos, El Eco de Canarias and Diario de Las Palmas* were consulted from 1970 to 2020. From the results obtained, were selected those that referred to material damage on the coast due to the action of the waves in the study areas (Fig.1). A database was developed that includes duration of the storm, data from the newspaper that published the news, affected area, environmental and material damage, victims and state of the sea (Table 1).

Table 1. Example of the database compiled with the information obtained from the press search on marine storms in the S and SW of Gran Canaria and Tenerife.

Date of the storm	Date of the news	Newspaper	Page	Island	Affected zone	Demages
04-07/ 12/1991	7/12/91	La Provincia	cover, 17, 18	GC	Arguineguín-Patalavaca-Mogán	Promenade between Arguineguin and Patalavaca fractured. Pool of a complex in Patalavaca busted. Demage to the dyke that connects Taurito with Puerto de Mogan. Damage to Restaurante El Faro (Puerto de Mogán). Value: 100 M pesetas

RESULTS

Coastline characterization

In the results of the coastline characterization (Table 2), we can observe that, despite being tourist areas and mostly artificial with hotels, dikes, ports, breakwaters, etc. (Yanes et al., 2021), the areas resulting from the delimitation, named before, are mainly natural. The percentages of non-anthropized areas are 54.6% in the areas studied in Gran Canaria and 83.3% in those of Tenerife, so that 73.5% of the total coastline analyzed has a natural character. The remaining 26.5% is the percentage of coastline on which it has been built within the study area (Table 2).

Table 2. Percentages of the characterisation of the coastline studied in Gran Canaria and Tenerife (IDECanarias orthophoto, adapted from Yanes et al, 2021, own elaboration).

Area		Gran Canaria S	Gran Canaria SW	Tenerife S	Tenerife SW
Natural (%)	Rocky coast	54,5	41,3	51,9	26,5
	Sandy beach	12,5	7,9	1,1	29,9
	Pebble beach	25,0	6,3	12,2	12,0
	Cliffs	4,5	38,1	34,2	31,6
	Ravine mouth	3,4	6,3	0,5	0,0
Artificial (%)	Aritficial beach	0,0	15,8	0,0	0,0
	Hotel	0,0	5,3	6,7	13,8
	Houses	0,0	0,0	0,0	24,1
	Restaurants	0,0	0,0	2,7	17,2
	Promenade	0,0	0,0	12,0	17,2
	Dykes	35,7	26,3	12,0	3,4
	Breakwater	23,8	13,2	14,7	0,0
	Sports port	40,5	39,5	52,0	0,0
	Apartments	0,0	0,0	0,0	24,1

Average swell

Table 3 shows the average values of significant wave (Hs), maximum wave (Hmax), peak period (Tp), wave direction, speed and wind direction. These parameters define the annual average wave values on the S and SW coasts of Tenerife and SW of Gran Canaria. The average regime in the study areas is characterized by a swell of the ENE in the S of Tenerife, NW in the SW and NW in the SW of Gran Canaria. This swell is linked to NE-ENE winds in Tenerife and NNE in Gran Canaria with an average annual speed of 15.7 km/h. It is defined as moderate swell because it has a significant wave (Hs) averaging one meter high (measure a little lower in Gran Canaria) and a peak period (Tp) of 10 seconds. The waves behaviour in the study areas presents seasonal characteristics. During winter, the storms season, the significant average height is practically the same except in the SW of Tenerife, where it increases from 0.9 to 1.3 meters. At specific times, the wave height has reached 4.8 meters in the SW of Gran Canaria and 3.5 m on the island of Tenerife.

Table 3. Characterization of the average swell (Puertos del estado, adapted from Yanes and Mrazol, 2009, own elaboration).

Parameters	S Tnf			SW Tnf			SW GC		
	Annual	Winter	Summer	A	W	S	A	W	S
Hs (m)	0.9	0.9	0.7	0.9	1.3	0.8	0.6	0.6	0.5
Hmax (m)	2.6	3.3	2.2	2.7	3.4	1.5	3	4.8	1.4
Tp (s)	8.0	8.4	7.6	11.5	13.1	10.2	10.6	12.1	8.5
Swell direction	ENE	ENE	ENE	NW	NNW	NW	NNW	NNW	NNW
Wind intensity (km/h)	16	15.3	16.6	13.4	14.1	13.4	17.7	16.3	19
Wind direction	NE	NE	NNE	ENE	ENE	ENE	NNE	NNE	NNE

Sea storm characterization

The search for episodes of marine storms is carried out in the study area through statistical analysis of the waves and wind. In order to identify situations in which the waves behavior is notably different from the annual average regime, the 99th percentile is studied (Yanes, 2007) (Table 4). The hourly record of the significant wave height (State Ports) was analyzed using these thresholds from 1970 to 2020, ignoring the results in which the storm lasts less than 12 hours. The result was 106 episodes for the island of Tenerife and 67 for Gran Canaria (Annex 1). From this set of data, we can determine that 78% of the storms occur during the autumn and winter months, while the other 22% are distributed among the other seasons. Of the 163 storms, only 19% coincide simultaneously in Tenerife and Gran Canaria.

Table 4. 99th percentile values for significant wave height (own elaboration, Puertos del Estado)

p99 Hs (m)						
		Annual	Winter	Spring	Summer	Auttum
TNF SW	4021009	2.5	1.6	1.4	1.7	1.2
TNF S	4023009	1.6	1.8	1.5	1.4	1.3
GC SW	4033006	1.8	2.2	1.6	0.9	1.5

Sea storm atmospheric state

Through the analysis of the synoptic maps during the 163 storm episodes, 5 situations were observed in which the atmospheric configuration causes the waves to exceed their usual levels. The most common situation, observed during 41.8% of the storms, is the presence of a low pressure to the northwest of the archipelago (Fig. 3) reaching the center of pressure on the islands on some occasions. Between November and March, the Azores Anticyclone heads to the North Atlantic, giving way to storms in the north-western of Canary Islands. The storm of 16-21 / 01/1979, that of 28-29 / 12/1970 or that of 14-19 / 02/2010 are some examples of this situation. In these two storm episodes the waves reached 4.5 meters.

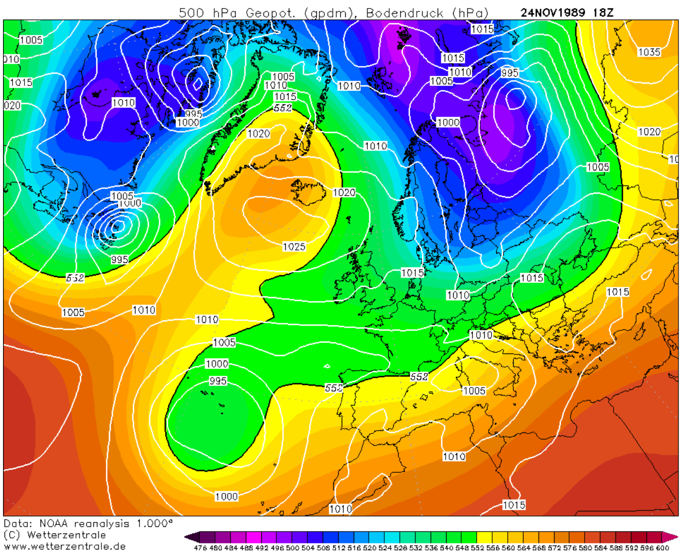

Figure 3. Atmospheric configuration of low pressure to the northwest of the Canary archipelago (Wetterzentrale).

The next most representative situation in the study is the anticyclone located to the north of the islands, very close to them (fig. 4). This phenomenon is the cause of the swell in 19.6% of the cases. Of the areas studied, it mainly affects the south coast of Tenerife, with practically no effect on the areas studied in Gran Canaria. The weather of 04-06/02/2012 is an example of this atmospheric configuration.

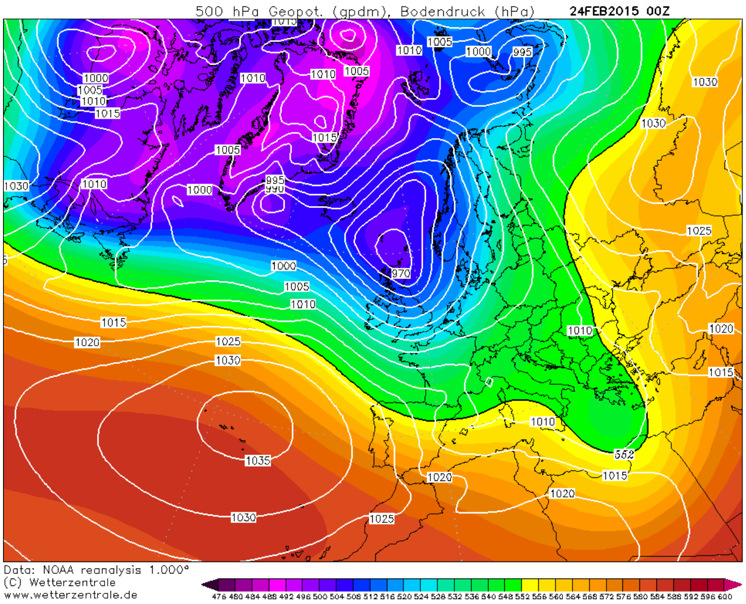

Figure 4. Atmospheric configuration of high pressure to the northwest of the Canary archipelago (wetterzentrale).

In 15.2% of the storm episodes, Canary Islands are seen in the middle of an anticyclone in the west and a storm in the east (28-29 / 11/2014; 13-15 / 04/2003). With the same percentage, the following situation is an anticyclone in the west of the islands (01-03 / 01/2001). Finally, the least frequent situation, but which has caused waves of considerable height in a 8.9%, is the presence of a storm in the North Atlantic, west of Ireland.

Coastal Impacts

Newspapers only reported 11% of the 163 storm episodes obtained through statistical analysis. There are 15 storms that the press talks about on the island of Gran Canaria and 3 on Tenerife (Annex 2). The press refers mainly to the damage suffered in tourist areas or areas of social-commercial interest such as docks, apartments and beaches (fig. 5). Damage to ports or sport docks is mentioned in 10 occasions. There is talk of damage in walk paths on 3 occasions. The rest of the damages such as beaches, apartments or roads, are named twice.

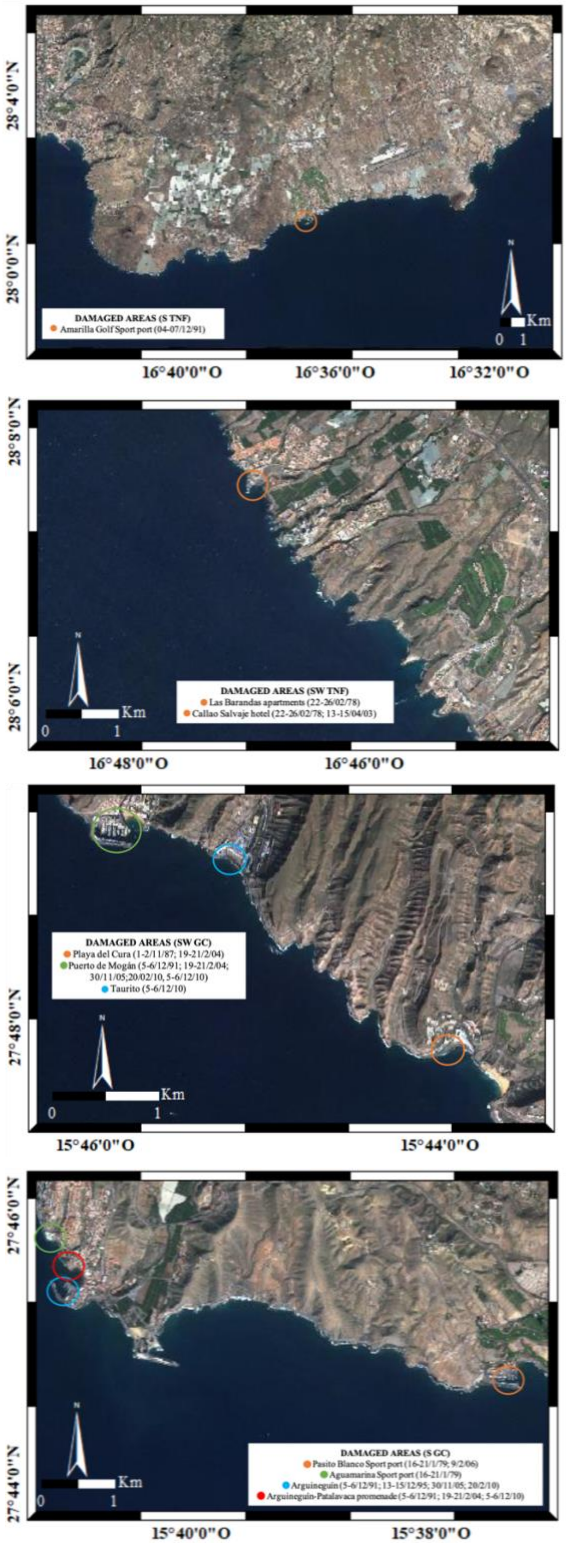

Figure 5. Damage mapping in the south and south-west of Gran Canaria and Tenerife . The damaged areas published in the press and the storms that have affected the same areas are indicated.

The events with the most repercussion in the press for having caused the greatest damage are three: 16-21 / 01/1979, 04-07 / 12/1991 and 19-21 / 02/2004. The first of the events coincides with the first news obtained from the press about storms and damage in the study areas. The storm that took place from January 16 to 21, 1979 had great consequences for the S and SW areas of Gran Canaria. As published by the newspapers "*Diario de Las Palmas*" and "*La Provincia*", the storm had important consequences in the Pasito Blanco sports port, south of Gran Canaria, and the Aguamarina port, in the southwest (Img. 1). Both were greatly affected by the swell, with waves exceeding 3 meters for several days, reaching a maximum height of 4.4 meters.

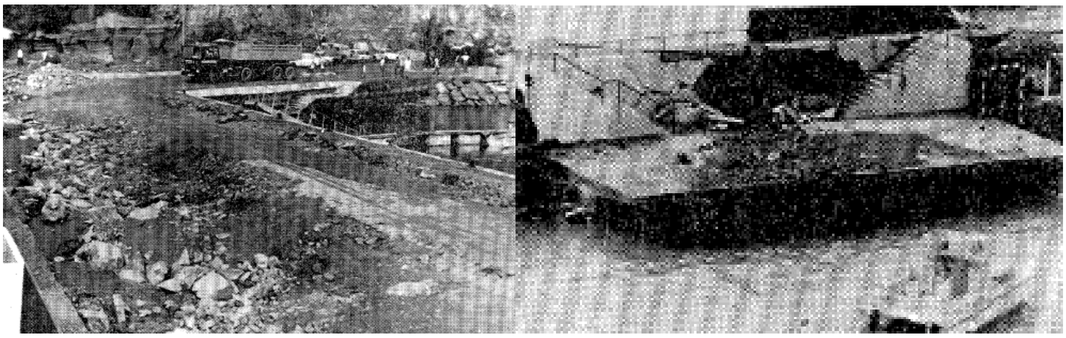

Image 1. Pasito Blanco sports port and Aguamarina jetty (images from "La Provincia").

In December 1991 (from 4 to 7) the islands were again affected by a strong storm. The waves washed away the sport dock and fishing port of Mogán and the walk path that connects Arguineguín with Patalavaca (Img. 2). Several tourist areas such as Sunwing and Green Beach (Arguineguín) were damaged by the waves that overflowed the retaining walls, flooding the pool, gardens, disco and ground floor areas (Canarias 7, 12/08/91).

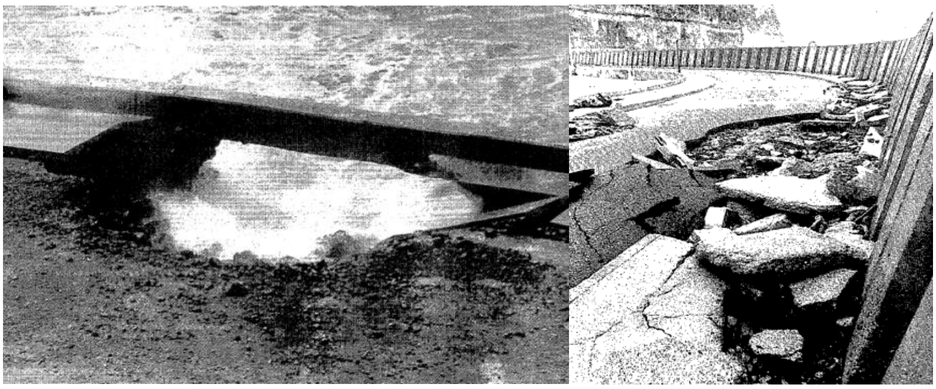

Image 2. Damage on the promenade between Arguineguín and Patalavaca and on the Puerto de Mogan sport port (images from "Canarias 7").

The storm of February 2004 (19-21) caused losses more than 6 million euros (La Provincia, 02/22/2004), the storm over the islands caused waves of more than four and a half meters. “The strong waves lifted several sections of the highway from the port of Mogán (Img. 3) and left part of the breakwater in view, broke pipes and devices in the fishermen's association, flooded a restaurant and a petrol station in Puerto Rico, broke the walk path of playa del Cura, and Patalavaca, flooded the ground floor of hotel shops in Patalavaca and restaurants on Amadores beach, and the shacks of some families in Arguineguín ”(La Provincia, 02/22/2004).

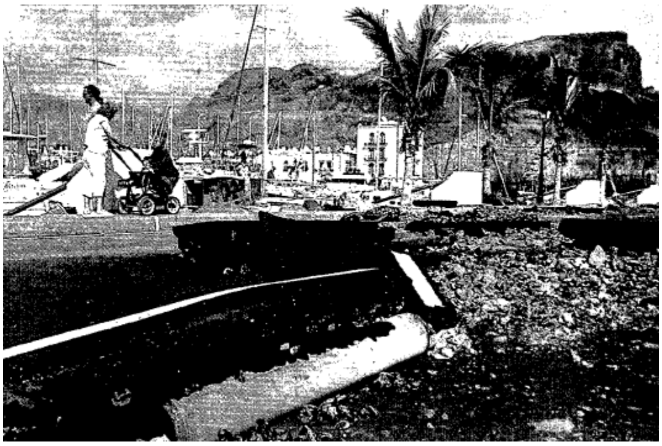

Image 3. Damage on the Puerto de Mogan road (images from "La Provincia").

DISCUSSION

The results presented on the characterization of the coast in the previous section can be confusing because, in the studied areas of both islands (Figure 2), the natural part predominates over the population, even though the reason for selecting these areas is high level of population due to its tourist occupation. The expected result in the study "Marine storms in coastal tourist areas of the Canary Islands” where the populated zone occupies 69% of the section studied (Yanes et al., 2021). This is because the areas analyzed in this work are the "excluded" from the study mentioned before and cover a large percentage of cliffs, rocky coast or non-buildable areas.

The swell regime in this area is characterized by being moderate except in the episodes of storm, where, although the wind in the study area is weak, it is not in the “fetch” in which this swell has formed (Guerra-Medina y Rodríguez, 2021). The statistical analysis on the mean swell shows that, during the sea storm episodes, the swell increases its significant wave height by one meter on average, reaching an increase of three meters. The parameters studied reach higher values in the southwest of Tenerife, this is because it is more exposed to Atlantic storms because it is further west and north than Gran Canaria (Yanes et al, 2021).

The most important sea storms come from the N-NW affecting mainly the west and north of the islands. Although the southern area is protected by own island, the presence of channels between islands allows the propagation of NW-NE wave fields to the south of the islands (Guerra-Medina y Rodríguez, 2021).

In this work, five development patterns of sea storms were established, unlike Yanes et al (2021) which reduces it to four atmospheric situations. Unifying anticyclone situations independently of where the centre of pressure is and avoiding situations in which the islands are in the middle of a storm and an anticyclone. On the other hand, they make a differentiation between the storm located near the Canary Islands and the one located near the Azores.

The validity of the press in this type of study is perhaps the most questionable debate. There is no doubt that the newspaper library constitutes an important source of socioeconomic and environmental information necessary for this type of study. They are important to have an idea of the intensity and damage of sea storm events and other types of risk. News in the press covers a very low percentage of all events. In addition, in most cases, the news gives more importance to rain and windstorms (Yanes, 2009). Despite this, within that percentage dedicated to sea storms, tourist areas such as Maspalomas, Anfi del Mar-Patalavaca and Puerto Rico-Amadores have a greater role (Yanes et al., 2021). Still, it has to deal with the limitations of the press; the impossibility of quantifying the effects of storms or the sensationalism with which this type of information is treated leads to subjective evaluations without scientific rigor (Máyer, 1999). These aspects show that the press is not the way to identify episodes of sea storms. The study of storms is more solid when it is based on the analysis of swell data and statistical calculations and uses the press only to reinforce the data obtained (Yanes, 2009).

Finally, it is important to comment on the impossibility of assessing the economic consequences due to the lack of public information on this aspect, despite the interest involved. Only on three occasions did the press refer to the economic loss caused by these storms. In all three cases, *La Provincia* gives the figure of "hundreds of millions of pesetas" in the storm of 16-21 January 1979, "losses exceeding 6 million €" in the storm of 19-21 February 2004 and "losses of more than 30,000€" in the storm of 5-6 December 2010.The approximate information that we can obtain are the damaged areas, knowing that the highest economic cost corresponds to break of dikes and breakwaters, promenade damages, docks and protections of tourist zones (Yanes et al., 2021). For these cases, it would be interesting to have data from the Insurance Compensation Consortium, where claims (compensation) for damages associated with sea storms to private properties are quantified

CONCLUSIONS

This work has once again demonstrated the vulnerability of the south and southwest coast of Gran Canaria and Tenerife during sea storms in areas anthropized by high tourist occupation. The waves in these areas of the islands are usually not dangerous, but the atmospheric conditions in certain situations, the location of the islands and poor urban planning pose a risk to tourism and, therefore, to the economy of the archipelago. With the data obtained we can conclude that the sea is unpredictable but that its effects can be foreseen, and the damage minimized. In this work, five patterns of development of marine storms have been established. The presence of a low pressure to the northwest of the archipelago, an anticyclone to the north of the islands, the archipelago in the channel between an anticyclone and a squall, the anticyclone to the west of the islands and the squall in the North Atlantic (west of Ireland).

Thanks to the characterization of atmospheric patterns, possible storm episodes can be anticipated, thus avoiding casualties on beaches and minimizing economic losses. The need for the creation of an office to register the damage, both qualitative and quantitative, caused by natural disasters is highlighted. A synergy between experts, public administration and construction companies to enhance urban planning. This would provide information on the limits that maritime constructions should not exceed, for example, and would increase the competitiveness of tourism on the islands due to the savings that would result from the correct construction of this type of public works.

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ANEXO 1

Fechas de temporales obtenidas aplicando el percentil 99 a la altura de ola significativa.

GC SW	Hsmax	TNF SW	Hsmax	TNF S	Hsmax
02-06/01/1970	3.4	31/12/1969-05/01/1970	3.2	31/12/1969-05/01/1970	2.7
28-29/12/1970	4.5	28-29/12/1970	4.3	28-29/12/1970	2.5
05-06/02/1972	2.5	17-19/01/1972	3.3	6/2/73	1.9
21-22/02/1972	2.5	22-24/02/1972	5.2	07-09/12/1976	1.9
01-02/01/1973	2.3	20-25/12/1973	4.0	16-18/01/1979	3.4
27/3/74	2.2	06-07/01/1974	3.7	05-07/02/1982	2.1
04-05/02/1976	2.9	31/01-02/02/1974	3.1	28-30/03/1982	2.1
16-21/01/1979	4.4	24-27/03/1974	2.9	10-11/12/1984	1.8
23-28/01/1979	4.1	15-17/01/1975	2.7	23-25/1/1987	2.1
14-16/02/1981	2.5	27/02-2/03/19975	2.8	11-13/04/1987	2.0
06-08/02/1982	2.6	07-09/12/1976	3.1	25-26/11/1989	2.8
28-30/03/1982	3.5	22-24/02/1977	3.4	30-31/03/1990	2.9
20/3/84	2.2	23/2/78	3.6	04-07/12/1991	3.0
15/12/84	2.1	30-31/03/1978	2.9	7-8/01/1993	1.9
01-02/11/1987	2.7	16-18/01/1979	3.7	15-18/03/1993	2.4
04-06/11/1988	2.2	24-28/01/1979	3.4	29/10/93	2.2
24-27/11/1989	3.9	10-11/02/1979	3.4	02-04/04/1994	1.9
30-31/03/1990	3.4	14-15/02/1981	3.7	13-14/12/1995	2.4
07-08/03/1991	2.4	29-31/12/1981-01-01-1982	3.6	05-06/03/1996	2.0
04-07/12/1991	3.9	12-13/01/1982	3.9	23-24/03/1996	2.1
16-18/03/1993	2.3	05-07/02/1982	3.4	07-09/01/1999	2.5
29-31/10/1993	2.9	16/2/82	2.9	03-04/02/1999	2.1
13-15/12/1995	3.3	28-30/03/1982	3.2	16-18/12/1999	2.0
21-22/01/1996	2.4	07-09/11/1982	3.5	12-13/12/2002	2.9
05-07/03/1996	2.9	15-22/12/1983	3.4	19-21/02/2004	3.4
23-25/03/1996	2.8	01-03/12/1984	3.4	27-28/02/2005	1.9
21-22/12/1996	2.7	17-19/02/1986	3.0	06-07/03/2006	2.0
13-14/01/1997	2.3	28/2/86	3.0	08-10/03/2007	2.1
27/01-03/02/1998	2.4	27-30/03/1986	2.9	31/03-01/04/2008	2.1
21-22/12/2000	2.3	14-16/11/1986	3.4	17-18/02/2010	2.2
22-24/12/2001	2.0	13-14/01/1987	3.7	28-30/11/2010	2.0
31/12/2001-01/01/2002	1.9	03-04/12/1987	3.0	4-6/02/2012	2.6
10-11/04/2002	2.5	15-16/01/1988	3.1	18-19/03/2012	2.2

12-14/12/2002	3.4	09-10/04/1989	4.0	17-19/04/2012	1.9
16-18/12/2002	2.2	19-21/11/1989	3.6	03-10/03/2013	2.8
19-21/02/2004	5.6	25-26/11/1989	2.9	09-14/12/2013	2.1
12-14/12/2004	2.3	18-19/12/1989	3.4	20-21/12/2013	2.0
24-28/02/2005	2.9	26-30/12-1989	5.2	23-26/01/2014	2.7
03-04/03/2005	2.3	30/01/1990-02/02/1990	4.1	26-28/02/2014	1.9
28-29/11/2005	3.5	05-09/03/1991	4.7	04-06/3/2014	1.9
08-10/02/2006	3.2	04-07/12/1991	3.5	24-26/3/2014	2.0
28/02-01/03/2006	3.2	24/11/1993	3.6	09-10/05/2014	2.0
18-20/12/2007	2.0	07-11/01/1994	3.2	17-18/02/2015	2.3
16-17/02/2008	2.4	10-12/03/1995	3.5	24-27/02/2015	2.9
08-10/04/2008	2.1	07-17/01/1996	3.8	15-16/02/2016	2.3
21-25/12/2009	2.6	13-14/11/1996	2.9	12-14/03/2016	2.5
2/2/10	2.5	12-13/12/1996	2.8	26-28/01/2018	2.5
14-19/02/2010	4.7	20-23/12/1996	4.4	25/02-01/03-2018	3.6
14/4/10	2.1	21/1/1997	3.1	02-03/02/2019	2.3
29-30/11-01/12/2010	3.5	23-25/11/1997	3.4	08-12/11/2019	2.7
05-06/12/2010	2.4	18-20/12/1997	4.4	18-19/02/2020	2.3
25-26/01/2011	2.7	29-31/12/1998	4.5	06-07/03/2020	2.5
30/10-01/11/2012	3.0	12-13/01/1999	4.5	02-04/07/2020	2.3
26-27/11/2012	2.2	18-19/01/1999	3.5		
03-06/03/2013	4.7	22-27/10/1999	4.0		
02-04/04/2013	2.6	19-24/12/2000	3.2		
09-16/12/2013	2.1	01-03/01/2001	3.5		
15-16/02/2014	2.3	26-27/01/2001	3.1		
09-11/03/2014	2.5	07-08/02/2001	3.7		
01-02/04/2014	2.5	14-15/03/2002	3.1		
28-29/11/2014	3.8	14-16/11/2002	2.9		
16-17/10/2015	2.6	22-25/11/2002	3.3		
03-04/12/2016	2.1	13-15/04/2003	3.8		
11-12/02/2017	3.9	01-02/11/2003	2.9		
25/02-03/03/2018	3.8	19-21/02/2004	3.9		
16/12/19	2.0	28/02-01/03/2006	3.1		
23/3/20	2.3	04-05/01/2008	3.2		
		01-06/02/2009	3.3		
		16-18/02/2010	3.4		
		04-06/03/2013	3.7		
		06-08/01/2014	3.1		
		17-19/01/2014	3.0		
		15-17-02/2014	3.3		
		28-30/11/2014	4.8		
		24-25/10/2016	3.0		
		25/02-01/03/2018	3.4		
		17-20/11/2018	4.0		
		18-19/02/2019	2.8		
		20-22/11/2019	3.0		
		16-17/12/2019	4.2		
		22-23/12/2019	3.0		
		18-19/02/2020	2.9		

	22-23/03/2020	3.4	
	29-30/10/2020	2.8	
	26-27/11/2020	3.2	
	30/11-1/12/2020	3.6	
	19-20/12/2020	2.9	

ANEXO 2

Base de datos con información sobre daños obtenida en prensa.

Date of the storm	Date of the news	Newspaper	Page	Island	Affected zone	Demages
16-21/01/1979	17/1/79	Diario de Las Palmas	última	GC	Pasito Blanco	El temporal que se ha abatido sobre las islas ha tenido serias consecuencias en el muelle deportivo de Pasito Blanco, al sur de Gran Canaria, que ha quedado muy afectado por el intenso oleaje, con olas de considerable altura
		la Provincia	40	GC	Aguas Mrina y Puerto Rico	los muelles de Aguas Marinas y Puerto Rico quedaron parcialmente destruidos.
	20/1/79	La Provincia	12	GC	Pasito Blanco	Importantes daños en el puerto deportivo de Pasito Blanco
23/2/78	24/2/78	Díario de Avisos	1 y 32	TNF	Callao Salvaje	5 apartamentos destrozados en las barandas (Adeje) daños menores en el hotel Callao Salvaje (rotura de cristales y tabiques), el agua llegó hasta un cuarto piso (20-25m)
01-02/11/1987	3/11/87	Canarias7	3	GC	Playa del Cura	En la playa del Cura, los embates dañaron la carretera que une la planta depuradora, no pudiéndose arreglar ayer por la persistecia del oleaje.
04-07/12/1991	5/12/91	Canarias7	4	GC	Arguineguin	En él caso concreto de Arguineguín, al cierre de esta edición efectivos de la Policía vigilaban con atención el estado dé la escollera, que temblaba literalmente al estallar unas olas que superaban los cinco metros de altura del muro exterior de contención.

	5/12/91	Diario de Las Palmas	10	GC	Puerto de Mogán	Según Protección Civil, en el Puerto de Mogán cinco embarcaciones de pesca fueron arrastradas y hundidas por el fuerte oleaje. En Puerto Rico la violencia del mar hundió también cinco embarcaciones de recreo y arrastró un vehículo aparcado cerca de la costa precipitándolo al mar.
	6/12/91	La Provincia	16	GC	Puerto de Mogán	Tal es el caso del muelle deportivo y pesquero de Mogán que resultó seriamente afectado, así como la Cofradía de Pescadores. /En Puerto Rico se hundieron cinco embarcaciones de recreo y un vehículo estacionado cerca de la costa fue arrastrado por las olas.
	6/12/91	Diario de Avisos	78	TNF	Amarila Golf	Varias embarcaciones arrastradas por el oleaje en Amarilla Golf. 4 barcos pesqueros dañados en Los Cristianos, problemas con amarres sueltos, algunas embarcaciones tragadas por el mar, otras varadas en la playa.
	7/12/91	La Provincia	1	GC	Mogán y Arguineguín	El fuerte oleaje arrasó los puertos deportivos moganeros y el paseo marítimo que une Arguineguín y Patalavaca
	8/12/91	Canarias7	33	GC	Arguineguin	También los daños alcanza ron a por té menos dos comple jos turísticos, como son el Sun wing y el Green Beach, ambos situados en Arguineguín, y que resultaron perjudicados por las aguas del mar que desbordaron los muros de contención inun dando las áreas de piscina, jardines, discoteca y planta baja
13-15/12/1995	14/12/95	Canarias7	3	GC	Pasito Blanco y Arguineguin	En Pasito Blanco se observaba un fuerte oleaje, que se creía superaba los dos metros de altura, Lo mismo ocurria en Arguineguín y Puerto Rico
13-15/04/2003	14/4/03	Diario de Avisos	37 y 38	TNF	Playa Praíso	Desperfectos en el dique de Playa Paraíso y 5 familias desalojadas. El fuerte oleaje provocó el derrumbe de los techos de tres apartamentos en Callao Salvaje (Adeje), tras sufrir el golpe de las olas.

19-21/02/2004	21/2/04	la Provincia	12	GC	Arguineguin	En Arguineguín, los establecimientos Dorado Beach, Puerto Atlántico, Sunwing y Green Beach -donde hubo que evacuar a 40 turistas de las plantas bajas—,también entraron en zafarrancho por inundaciones.
	22/2/04	La Provincia	11	GC	Puerto de Mogán	El fuerte oleaje levantó variós tramos de la carretera del puerto de Mogán y dejó en el aire parte de la escollera, rompió tuberías y aparatos en la cofradía de pesca dores, inundó un restaurante y una gasolinera de Puerto Rico, rompió el paseo de la Playa del Cura, y de Patalavaca, anegó la planta baja de stablecimientos hoteleros de Patalavaca y de restauración de la playa de Amadores, y las chabolas de varias familias en Arguineguín
	27/2/05	Canarias7	21	GC	Taurito y Playa del Cura	Taurito y El Cura, casi no hemos quedado sin arena». Respecto a la playa de Amadores, reveló que ha sufrido bastante las consecuencias del mal tiempo. Inundación de la planta baja de establecimientos hoteleros de Patalavaca y de restauración de la playa de Amadores. En la playa de Amadores, a pesar de su protección, llegó el agua de mar a la línea de los locales comerciales, llegando a entrar en alguno de ellos.
	30/11/05	Canarias7	10	GC	Arguineguin	En el Sur, el oleaje hundió tres barcos en el puerto de Arguineguín, entre ellos El Alegranza, una embarcación de ma dera destrozada al ser lanzada contra la esóollera, mientras que en el Puerto de Mogán resulta ron afectados varios vehículos. Por contra, la playa del inglés y la de Maspalomas no tuvieron mayores incidencia
	9/2/06	La Provincia	13	GC	Pasito Blanco	Un yatete fue arrastrado a tierra por la fuerza del oleaje en la playa de Pasito Blanco.
	20/2/10	La Provincia	3	GC	Puerto de Mogán y Arguineguin	Mongán, Arguineguín, Sardina

	19/2/10	Canarias7	6	GC	Puerto de Mogán	El puerto de Mogán se resiente
05-06/12/2010	7/12/10	La Provincia	7	GC	Taurito, Patalavaca, Amadores y Las Marañuelas	La subida del mar tras el paso de la borrasca causa destrozos en Taurito, Patalavaca, Amadores y Las Marañuelas I La empresa del servicio de mantenimiento cifra las pérdidas en más de 30.000 euros
	7/12/10	La Provincia	1	GC	Taurito, Patalavaca, Amadores y Las Marañuelas	Un repentino oleaje vapuleó la madrugada de ayer la costa de Mogán y causó destrozos en varias playas, en especial en Taurito -en la imagen-, que han perdido arena, hamacas, sombrillas y pasarelas. Cuando los empresarios se disponían a recuperarse de las malas noticias tras las alarmas por mal tiempo o el bloqueo de los aeropuertos, la inesperada subida del mar dejó las playas semidesiertas
	7/12/10	la Provincia	7	GC	Taurito, Patalavaca, Amadores y Las Marañuelas	Taurito o Patalavaca tardarán un mínimo de "tres o cuatro meses" en recuperar de forma natural la arena que perdieron ayer, siempre que no haya más temporales durante el invierno. Tras los destrozos en la Charca y en la playa de Maspalomas, cada vez más frágiles, ahora son las playas de Mogán las que sucumben ante la fuerza del mar, lo que agrava la situación de los pequeños negocios a pie de playa
11-12/02/2017	14/2/17	La Provincia	15	GC	Tauro	Barranco de la playa de Tauro, inundado el pasado domingo, tras la subida de las olas del mar

ANEXO 3

Actividades desarrolladas durante la realización del TFT

En primer lugar, con ayuda del tutor, definimos la zona de estudio y los objetivos. El litoral canario es de gran interés, tanto desde el punto de vista natural, como por sus potenciales implicaciones socioeconómicas, por esta razón, son tan importantes los temporales marinos que afectan a las zonas turísticas, donde se concentra la economía de las islas. Escogimos las costas sur y suroeste de Gran Canaria y Tenerife (Figura 1), por ser estas las más turísticas de las islas.

Se hizo una caracterización del oleaje medio para poder detectar los episodios extremos. Elabore una tabla con datos obtenidos del Banco de Datos Oceanográficos de Puertos del Estado (www.puertos.es). En la tabla se recogen los valores de ola significante, ola máxima, periódico pico, dirección del oleaje y dirección del viento. Estos parámetros definen los valores medios anuales y de invierno del oleaje en las costas S y SW de las dos islas. Se eligieron los puntos SIMAR que mejor representaban las zonas de la costa de interés.

Teniendo el oleaje medio caracterizado, se calculó el percentil 99 de la altura de ola significativa para detectar el umbral de riesgo. Analicé los episodios que superaban esta medida de condiciones extremas durante los últimos 50 años. Solo se escogieron los casos en los que el oleaje supera el umbral durante mas de 12 horas.

Para conocer cuáles son las condiciones en las que los temporales se vuelven lo suficientemente violentos como para causar daños en las infraestructuras costeras, se ha consultado la información meteorológica de la Agencia Estatal de Meteorología (AEMET) durante las fechas señaladas. Los boletines meteorológicos diarios contienen las situaciones sinópticas en las que se han generado los vientos causantes de los temporales. Otra de las páginas consultadas es *Wetterzentrale,* dónde se analizaron mapas sinópticos a 300 y 500 hPa.

Para estimar los daños en temporales se hizo una búsqueda en diferentes periódicos. Con la zona seleccionada, se realizó una búsqueda por palabras en el archivo de prensa digital de la ULPGC (Jable). Los términos empleados fueron: temporal, oleaje, sur, Gran Canaria y Tenerife. Se consultaron ejemplares desde 1970 hasta 2019, de los periódicos *La*

Provincia, El Día, Diario de Avisos, El Eco de Canarias o Diario de Las Palmas. De los resultados obtenidos, se seleccionaron aquellos que hacían referencia a daños en infraestructuras costeras o edificaciones turísticas por la acción del oleaje.

El siguiente paso fue hacer lo mismo, pero buscando directamente en los días en los que los puntos SIMAR detectaron condiciones extremas de oleaje.

Con el conjunto de fechas en las que se registraron incidencias por temporales en la prensa, se elaboró una base de datos en la que se incluyen duración del temporal, fecha y datos del periódico que publicó la noticia, isla, municipio, zona afectada, daños ambientales y materiales, víctimas, estado del mar y situación atmosférica.

En esta tarea fue en la que más tiempo invertí, se trata de un trabajo sencillo pero muy repetitivo. Puede no ser el más interesante, pero es fundamental considerar la información que se refleja en prensa.

Por último, elaboré en Arcgis los diferentes mapas necesarios para apoyar el documento escrito.

La metodología seguida ha sido usada anteriormente por numerosos investigadores en otras zonas. Junto con la investigación, llevé a cabo una revisión bibliográfica sobre investigaciones similares para poder analizar los resultados obtenidos. Algunos de estos artículos son:

- Characterization of storm events along the Gulf of Cadiz (eastern central Atlantic Ocean) (Anfuso et al., 2016).

- Storm-induced damages along the Catalan coast (NW Mediterranean) during the period 1958–2008 (Jiménez et al., 2010).

- Flood Disaster, Impacts and the Tourism Providers' Responses: The Kota Tinggi Experience (Hamzah et al., 2012)

Formación recibida

Para el desarrollo de mi trabajo de fin de título no necesité ninguna formación específica. Mi tutor se encargó de enseñarme a utilizar los programas que necesitaría para el desarrollo de estas (Jable, Wetterzentrale, Puertos Del Estado, ArcGis. Durante los primeros días resolvió todas mis dudas y me enseño la metodología necesaria para esta investigación.

Integración en el grupo de investigación

Mi relación con la empresa ha sido escasa. Dentro del grupo, formado por cuatro investigadores, tuve contacto solo con dos, Pablo y Luis. Además, por las circunstancias (COVID-19) y porque me incorporé tarde, tuve poco contacto con ellos. Durante las horas presenciales que llegué a realizar, se me cedió el laboratorio de SIG del edificio de Geografía en el que trabajaba sola, pero con atención en el despacho las veces que necesitaba.

Aspectos positivos y negativos

Entre los aspectos positivos de las prácticas, señalaría la suerte que he tenido de poder desarrollarlas desde casa sin problemas por falta de laboratorio. Son unas prácticas sencillas pero entretenidas en las que ves cómo funciona el mundo de la investigación. Otro de los aspectos positivos es que dentro del grupo de investigación he sido tratada como un miembro más y no se me han encargado únicamente tareas sobrantes.

Como aspectos negativos podría poner que las tareas que he desarrollado son poca, pero de muchas horas, y eso retrasa el aprendizaje del estudiante. Aun así, entiendo que son las tareas necesarias para este tipo de investigación.

Valoración personal

Con la realización de este trabajo he podido poner de manifiesto los conocimientos adquiridos en numerosas asignaturas. Siempre es necesario repasar algunos conceptos, pero con eso, y con la ayuda de profesores del grado que han contestado a mis correos sin ningún problema, he podido llevar a cabo las tareas asignadas.

Desde que entramos al grado nos hablan de interdisciplinaridad, y es en proyectos así, donde se pone de manifiesto este concepto. He juntado conocimientos de diferentes asignaturas para desarrollar un mismo objetivo.