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SEDIMENTARY BUDGET ON LAS CANTERAS BEACH, GRAN CANARIA (CANARY ISLANDS, SPAIN).

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FINAL DEGREE WORK

SEDIMENTARY BUDGET ON LAS CANTERAS BEACH, GRAN CANARIA (CANARY ISLANDS, SPAIN).

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LAS PALMAS DE GRAN CANARIA

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ABSTRACT

This paper deals with sedimentary balances and how the sediments move in function of the waves in a beach with special boundary conditions. For this purpose, the topography of the beach was done with a total station and two prism. Topography data were analyzed with SIG software. Wave data were taken from deepwater buoys. Two parameters were calculated, the Dean’s parameter and Larson’s (1988) parameter, to know the type of the beach. Balances show an accretion of sand on the beach even though in some periods there were big losses of sand on the beach. The parameters calculated are not good to estimate the type of the beach due to the boundary conditions of this particular beach.

INTRODUCTION

Las Canteras beach is located in la Bahía del Confital, in the North shore of Gran Canaria in the Canary Islands. It is a sandy beach of about 3 Km of length (Fig. 1). It borders in the north with the Isleta isthmus and with a breakwater in the south. There are two distinct zones, the first one is the southern sector which is exposed to the waves. The second one is the northern and central sectors that are hidden by the waves because of a natural sandstone bar that determines the breaking of the waves. This sandstone bar emerges in the low tide.

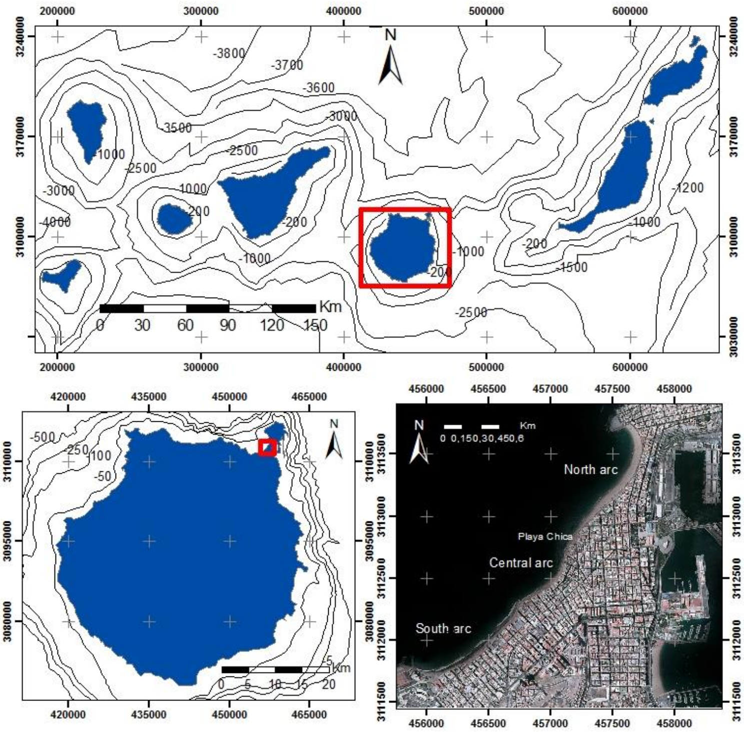

Figure 1: Location of the study area

The mean wave approaching directions are from the North and from the Northwest during the biggest storms (Alonso and Vilas, 1996; Alonso, 2005). The average significant wave height is 1.42 ± 0.6 m and the average spectral peak period is 10.21 ± 2.62 s (Alonso, 1993; Alonso, 1994; Alonso and Vilas, 1994; Alonso and Vilas, 1996). The significant wave height in winter could reach 4 m (Alonso, 2005). The tidal range during the spring tides is greater than 2.5 m and during the neap tides it is approximately of 1 m (Alonso, 1994; Alonso and Vilas, 1994; Alonso and Vilas, 1996). The tide currents are to NE during the high tide and to the SW during the low tide (Alonso, 2005).The predominant wind directions are from NE, NNE and ENE because of the trade winds. The mean wind speed is 7-8 m/s. The water temperature range between 18 and 24 ºC, being higher in summer and lower in winter (Puertos del Estado, 2015). The sand grain size in the northern arc of the beach is 0.27 mm, in the central arc is 0.29 mm and in the southern arc is 0.20 mm (DGC, 2006)

Now how is the sediment mobility at Las Canteras beach, which is a very relevant aspect for coastal management in an urban beach like this (Fig 2). This kind of study should be carried out during at least one year, in order to register both summer and winter conditions. Nevertheless, due to time limitations, this work only covers a 5 months period.

Figure 2: Beach air view with arcs location.

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Beach morphology is controlled by wave energy, tide and boundary conditions (Alonso, 1994; Bernabeu et al, 2003). Swell dominated beaches show an alternation of accretion and erosion on a large temporal scale, normally in relation with the seasons (Quartel et al, 2008). Beach changes occurs in different time scales in relation with the stormy events and wave climate changes. High-energy waves operate in periods of days or even hours producing erosion. While the recovery of the beach occurs during the low energy wave conditions and takes more time than the erosion period (Alonso and Vilas, 1994; Benavente et al, 2000; Quartel et al, 2008; van Rijn et al, 2003).

Sandy coasts are dynamic environments that are changing constantly. To calculate the volume of sediments gain and lost in the beach is a good way to monitor this changes (Farris and List, 2007). Sedimentary balance is a way to estimate the gains and losses of sediment under certain boundary conditions and in certain periods of time. The purpose of sediment budget is to describe the background erosion rates in terms of volume and to determine the transport directions of sediments (Kana, 1995).

This changes in the sedimentary balance of the beach in short periods of time are due to the mean currents, like tide, wave, wind- and density driven currents, which carry the sediment in the main direction flow. Wave induced transport is related to the oscillating and mean current generated by the wave boundary layer. The net onshore transports is generated in non-breaking wave conditions and the net offshore transport in breaking waves conditions (van Rijn, 1997).

Beach profiles help to analyze sedimentary balances. Concave downwards profiles have a net erosion trend with an offshore transport, because of are typical of dissipative beaches. Concave upwards profiles have a net accumulation trend with sediment accumulation on the upper part of the beach. Planar profiles do not show changes in a long term (Alonso, 1994). In profiles we could observe the beach bar behaviour with offshore-onshore cycles. In storm conditions there is an offshore transport that results an erosion in the upper part of the profile and a formation a bar in the breaking point. With favourable conditions there is an onshore migration that results an accretion of sand on the foreshore and a berm formation. This profiles responses are known as bar/berm profiles (Larson, 1988 and van Rijn et al 2003). Onshore-offshore bar migration of individual profile is of the order of 0,2 to 1L, being L cross-shore bar length (van Rijn et al, 2003).

The evaluation of sedimentary balances could be done from the topography of the beach, doing perpendicular profiles to the shoreline. The topography has to be done with high accuracy because little variations could carry big changes in the balance (Pardo Pascual et al, 2005). With geographic information systems (GIS), digital elevation models (DEM) are created from the interpolation of the topographic altitudes. DEMs are used to calculate the sedimentary budget with the GIS tools (Pardo Pascual, 2005 and Mistasova et al, 2005).

The objectives of this work are calculate the sedimentary balances at Las Canteras beach during the winter and spring months to see the sand transport in relation with the waves energy, estimate de sedimentary balances and see the beach profile type and beach type from the wave energy and grain size.

DATA ACQUISITION AND METHODOLOGY

The data measurement methods for this study consisted on beach elevation profiles measured with a Leica T307 Total Station (Leica Geosystems, 2000) and two milestone with a prism (Fig 3).

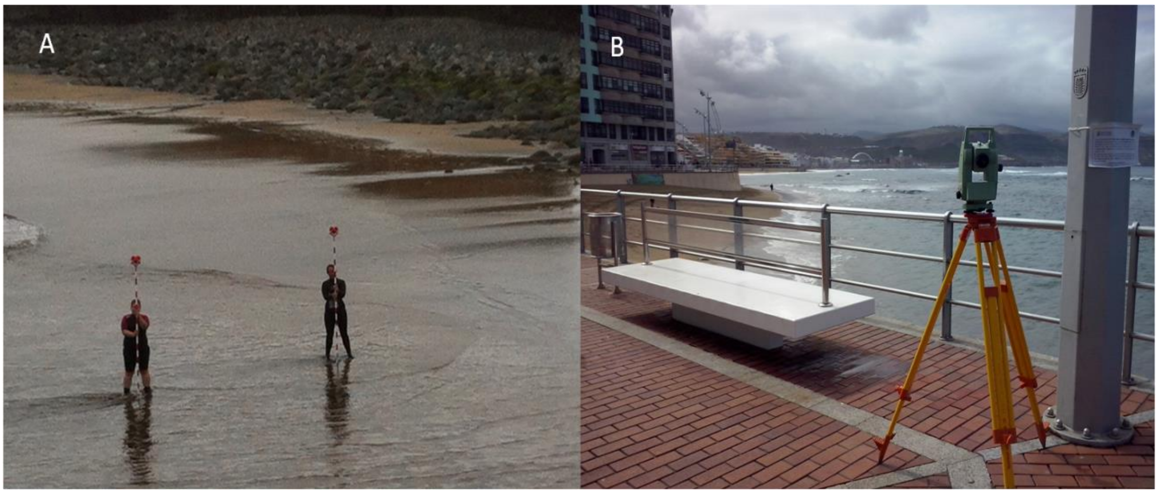

Figure 3: Sampling on the beach. A) Measuring with the milestones and prisms. B) Total station ready to start measuring.

The measurements were done by beach arcs: the Northern arc, the Central arc and the Southern arc. The profiles were measured once a month coinciding with the spring low tide to reach the maximum submerged part of the beach. The heading of the profile is the seafront and the profile ends in the water depending on the wave conditions. The profiles were perpendicular to the shoreline and with a distance between them of 20 m. On one profile, points were taken each 5 m. the average of measured points in each field trip was 1400 (Fig 4). Field trips were done on January 23rd and 24th; 17th, 19th and 20th of February; 24th and 25th of March; 20th and 21st of April and 18th, 19th and 21st of May. Tidal height was 0,2 m in January; 0,4-0,1 in February; 0,4-0,6 in March; 0,2 in April and 0,3-0,5 in May.

Figure 4: Sampling points of January field trip.

The data analysis consisted in transforming the topographic data in digital elevation models (DEM) with geographic information system (GIS) software. To create the DEM first data were filtered in order to remove the wrong ones in the ESRI® ArcGIS 10.1™ software. Then the Kriging method was used to interpolate the data and generate the DEM. The spacing of the model was 2 m for the entire beach and 1 m when the model was done by arcs. Once DEM was done for each field trip, we calculated the sedimentary balance between one field trip and the previous one and from first to last field trips. Finally, the sediment volume gain or loss was computed for each field trip and for the total of the study with the Surfer® 11-Golden software. Beach profiles were made from the DEM with ArcGIS 10.1^{TM} software. Six beach profiles were done in the entire beach. Two in each arc.

There are different criteria to distinguish the bar/berm profiles. In this paper was used the Larson’s (1988) criterion has been used to distinguish beach profile type in each arc. This criterion was selected because it is used deepwater wave height instead of breaking wave height, which it could not be estimated appropriately due to the sandstone bar. This criterion relates the deepwater wave steepness and the dimensionless fall velocity parameters in the following equation:

$$\frac{H_0}{L_0} = 0.00070 \left(\frac{H_0}{wT}\right)^3 \quad (1)$$

Where H_0 is deepwater wave height, L_0 is deepwater wavelength, w is sand fall velocity and T is wave period. There is a bar profile when $H_0/L_0 < 0.00070(H_0/wT)^3$. There is a berm profile when $H_0/L_0 > 0.00070(H_0/wT)^3$.

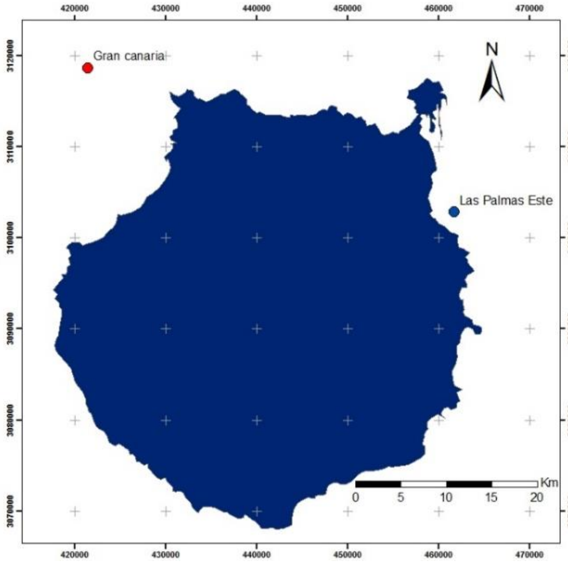

Figure 5: Wave buoys location

Wave data were collected from two buoys (Fig 5). One of them, the Gran Canaria buoy, belongs to the deep-sea network of buoys of Puertos del Estado. This is a Wavescan buoy anchored to 780 m depth which measures wave and atmospheric parameters (Puertos del Estado, 2012a). The other one is Las Palmas Este buoy, situated near Las Palmas port and anchored within less than 100 m. This is a Waverider scalar buoy that serves to complement the deep data buoys (Puertos del Estado, 2012b). We obtained data of peak period (T_p), maximum wave height (H_{max}), waves approaching direction (m_{dir}), mean period (T_m) and significant wave height (H_s), one data each hour except when de sensors didn't work for some hours.

The wave data were used to classify the beach into dissipative, intermediate or reflective modes with Dean's parameter (Dean, 1973).

$$\Omega = \frac{H_b}{WT} \qquad (2)$$

where H_b is the breaking wave height, W is de fall velocity of sediment particles and T is the wave period. To estimate the fall velocity of sediment particles for calculate the Dean's parameter was used the Ponce (1989) formula:

$$w = \left[\frac{4}{3}\frac{g d_s}{C_D}\frac{\gamma_s - \gamma}{\gamma}\right]^{1/2} \qquad (3)$$

where g is the gravitational acceleration, ds is the particle diameter, C_D is the drag coefficient (dimensionless), γ_s is the specific weight of sediment particles and γ is the specific weight of the water. The fall velocity of sediment particles was calculated from the interface provided at http://onlinecalc.sdsu.edu/onlinefallvelocity.php.

Wave propagation was not done with wave data, so breaking wave height was estimated from deepwater wave height (H_0) using Komar and Gaughan's, (1972) expression:

$$H_b = 0.39 g^{1/5} (T H_0^2)^{2/5} \quad (4)$$

where g is the gravitational acceleration, T is the medium period and H_0 is the significant wave height in deep water.

As the sandstone bar protects the beach against the waves, Alonso, (1993) had estimated the wave energy received in each arc. He obtained that only a 30% of the incident energy reaches the North arc, 50% the Central arc and 95% the South arc. With this average energy and the formula of the average energy per unit surface area (Sorensen, 1997), we recalculated the wave height to obtain a better Dean's parameter value. This wave energy formula is:

$$E = \frac{1}{8} \rho g \mathrm{H}_0^2 \quad (5)$$

Where ρ is the seawater density in Kg/m^3, g is the gravitational acceleration and H_0 the wave height in deep water.

Values of Ω less than 2 were associated with reflective beaches, values between 2 and 5 were associated with intermediate beaches and values greater than 5 were typically related with dissipative beaches (Masselink and Short, 1993). This classification was done for each arc of the beach as each arc have different wave conditions because of the sandstone bar and the boundary conditions as well as because the sediment size is also different.

The wave data were used to observe the effect of wave characteristics on the sediment transport. For this, we plotted the peak period was plotted against time and the significant wave height against time and also was done a wave rose with the waves approaching direction. All this plots were done for the 10 days before de data measurement in each month. Wave data of Annex II are the mean of this 10 days plotted in each month. The time in the plots appears as the days of the duration of the experiment, corresponding the first day with the first day we had collected wave data from the buoy. Day one corresponds with January 15th, 2015; the second day corresponds with January 16th, 2015 and so on. Data from Gran Canaria buoy starts on the 25th day of the data collection because it did not work the previous days.

RESULTS

Digital Elevation Models and Sedimentary balances

The digital elevation models generated from the topographic data measured on the beach topography shows that the highest sand accumulation takes place in the northern sector of the beach, where beach cusps are present during all the sampling months (Fig 6). In the central sector the DEMs only reach -1m due to the presence of the rocky substrate in the lower part of the beach profile, which was not measured in February, March and April. In the southern sector it is clearly noticeable the differences between the different models in the lower part of the beach, since in February and May we measured down to -2m while in March and April there are few data lower than -1m. These differences are related to the tidal height and the incident waves during the survey.

Table I shows the calculated volumes from the balances. In all periods there was a gain of sand except between March-February. North and South arcs shows the same behaviour, so that when there was a gain or loss of sand it happens simultaneously in both arcs. The only exception in this pattern took place between April and May, when the northern arc was eroded 2.400 m^3 and the southern one accreted by 7.760 m3. Volume changes in the central arc are much smaller compared to the adjacent sectors. Considering the whole study period, there is a net final balance of 20.000 m^3 produced mainly in the South arc (Fig 7).

February - January	North arc	Central arc	South arc	Entire beach
Accretion (m3)	16.550	1.870	12.581	31.001
Erosion (m3)	2.632	3.144	6.732	12.508
Total (m3)	13.918	-1.274	5.849	18.493
March - February				
Accretion (m3)	3.220	3.079	9.682	15.981
Erosion (m3)	16.981	2.481	13.555	33.017
Total (m3)	-13.761	598	-3.873	-17.036
April - March				
Accretion (m3)	8.562	3.513	11.331	23.406
Erosion (m3)	5.288	3.878	3.529	12.695
Total (m3)	3.274	-365	7.802	10.711
May - April				
Accretion (m3)	4.600	2.496	14.292	21.388
Erosion (m3)	6.980	2561	4.081	13.622
Total (m3)	-2.380	-65	10.211	7.766
May - January				
Accretion (m3)	7.955	2.827	23.684	34.466
Erosion (m3)	6.904	3.932	3.696	14.532
Total (m3)	1.051	-1.105	19.988	19.934

Table I: Sedimentary balances by arcs and for the entire beach

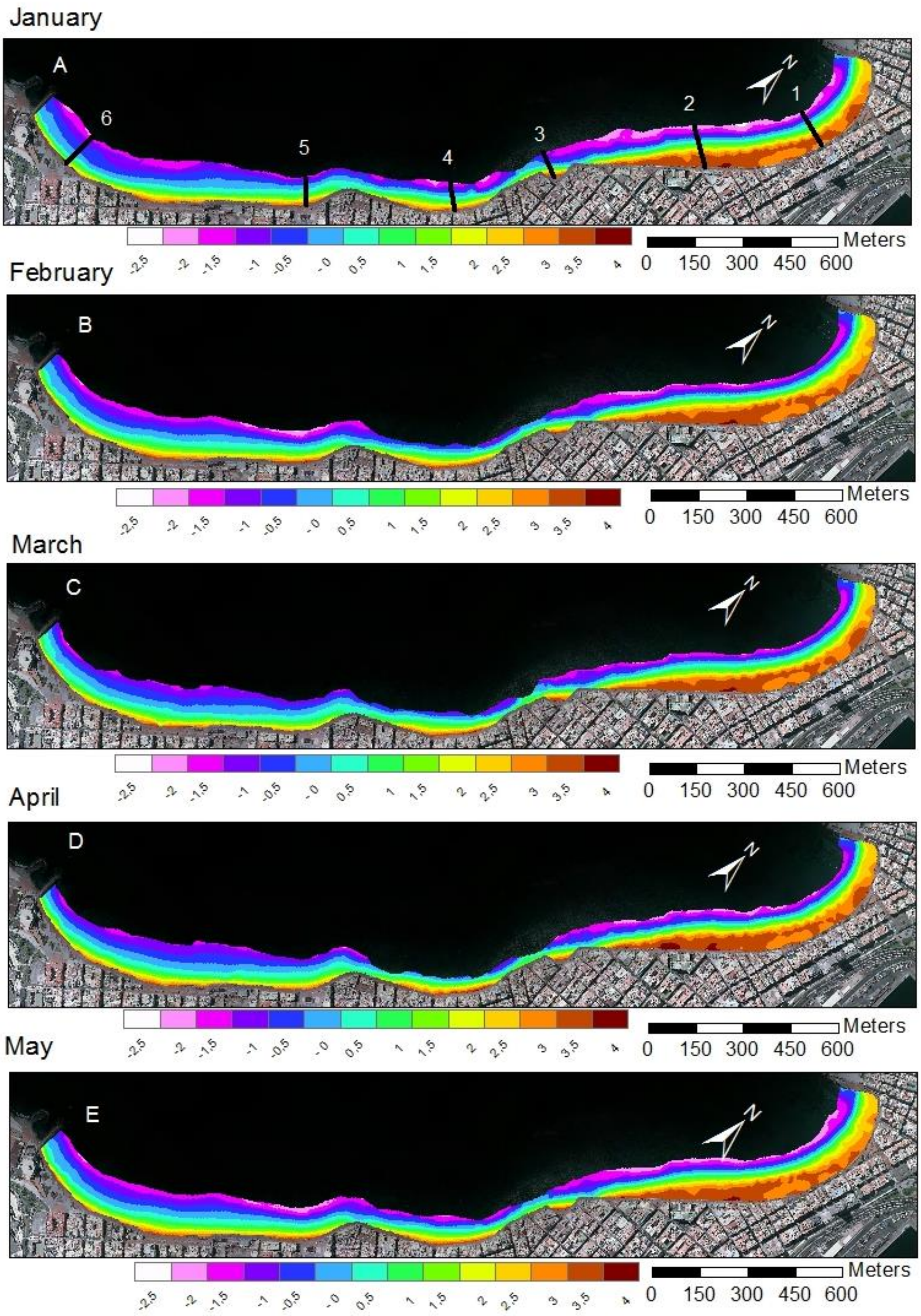

Figure 6: Digital elevation models generated from the topographic data measured on the beach during the study period. A) January data with the location of the 6 beach profiles. B) February data. C) March data. D) April Data. E) May data

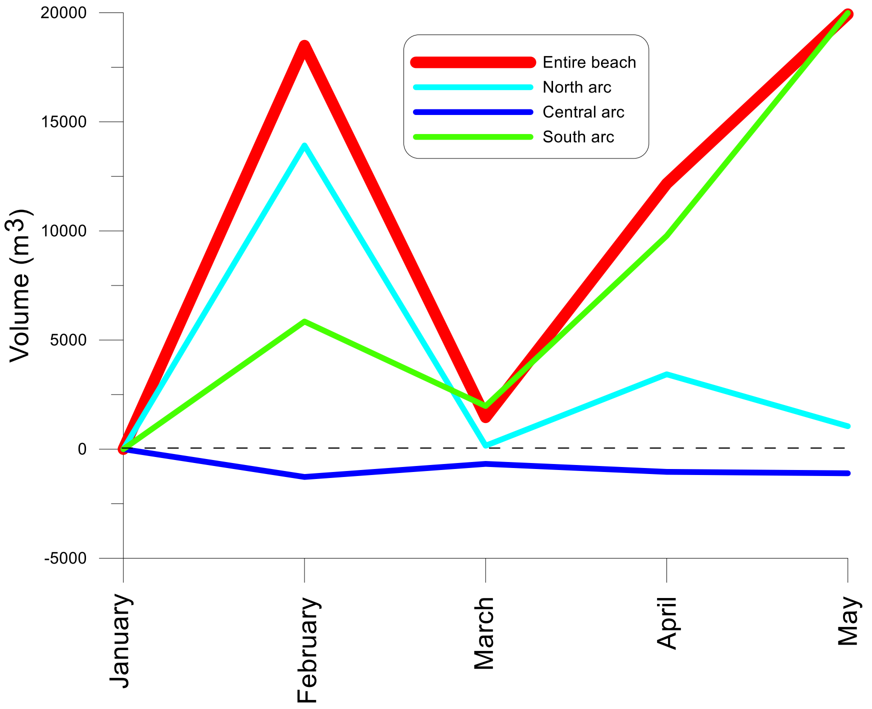

Figure 7: Evolution of volume of sand on the beach from January to May.

These differences in the volumes could be observed looking at the sedimentary balances. In the north arc (Fig 8) during the February-January period there was a gain of sand in the lower part of the beach, where the beach cups were. In the March-February balance there was an erosion in the lower part and small accretion in the upper part of the beach. In the balance of April-March there was a loss in the lower beach and accumulation of sand in the middle part. In the May-April balance there was accretion in the northern and the southernmost parts of this arc, with erosion in the central area. In the net balance (May-January) it is observed a net accumulation in the beach cusps zone and a loss in the lower part of the beach, but the net balance shows net accumulation of 1.000 m^3 (Table I)

In the central arc there were smaller changes in the volume of sand, but quite significant at certain locations, such as around Playa Chica and the southern area of this arc (Fig 9). In February-January balance there was a gain of sand in Playa Chica and loss in the south part of Playa Chica. In addition, there was accretion in the northernmost part of the Central arc and erosion in the southernmost part of this arc. During the March-February period there was accumulation in Playa Chica and erosion in the Southern Central arc. In the balance of April-March there was a loss of sand in Playa Chica and gain of sand in the upper part of Central arc. Finally, in the May-April balance Playa Chica was more or less like the previous balance. However, there was erosion in the upper zone northernmost part of the Central arc and a little accumulation in the middle and lower part of the rest of the arc. The net balance shows a net erosion of -1.100 m^3 which is mostly concentrated at los Lisos area (south of Playa Chica).

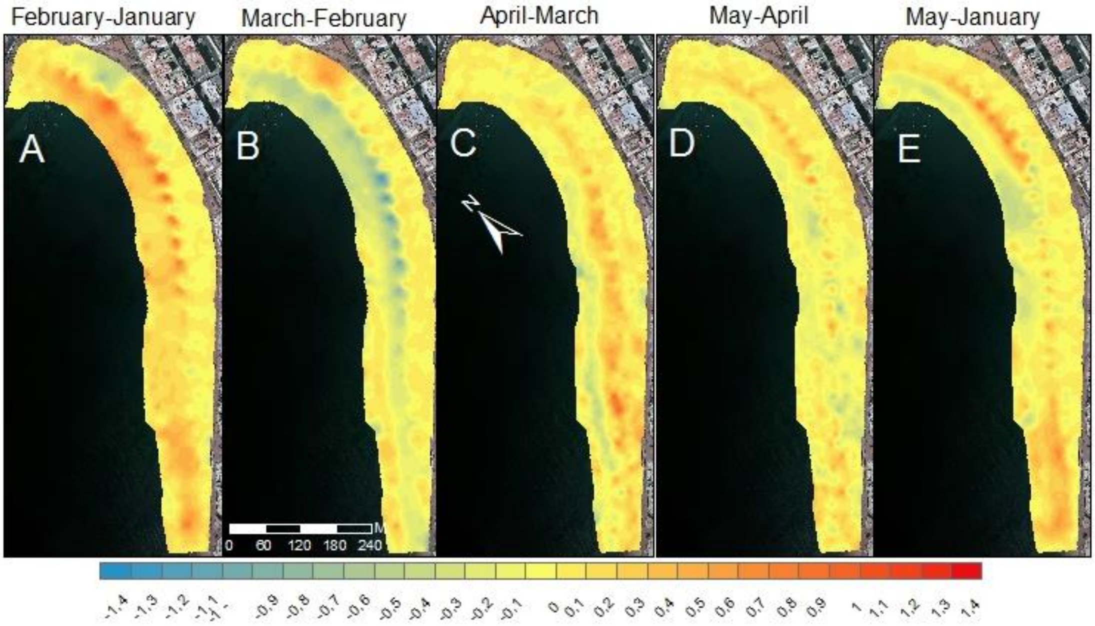

Figure 8: Sedimentary balances for the North arc, red colours corresponds with accretion, the blue ones with erosion and yellow with no changes. A) February-January. B) March-February. C) April-March. D) May-April. E) Net balance May-January

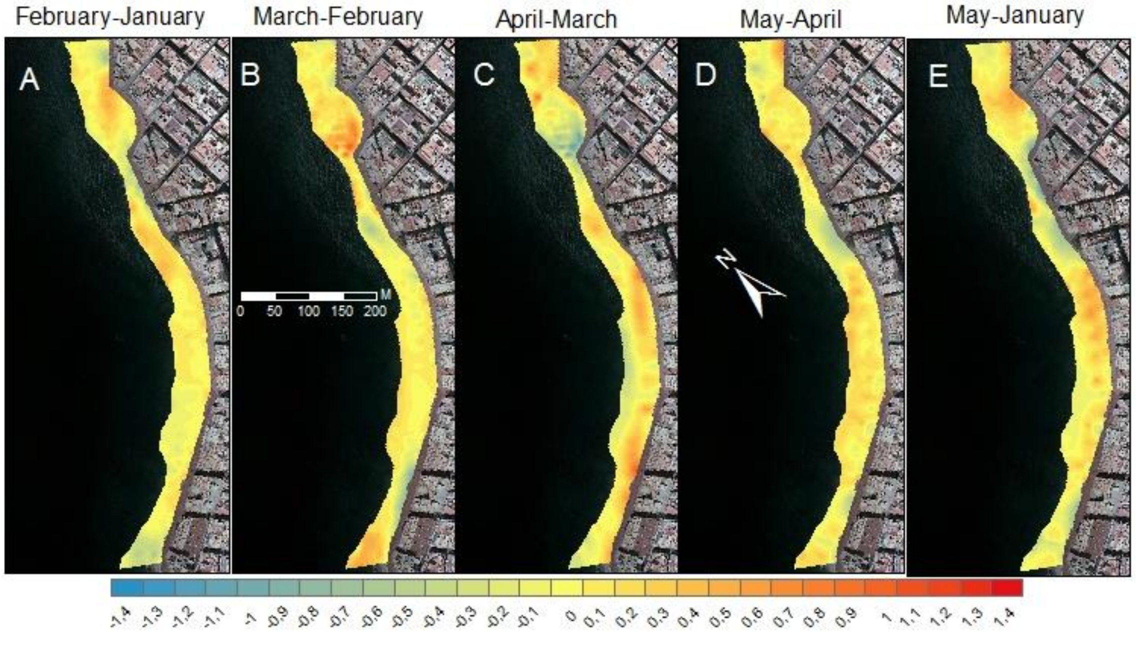

Figure 9: Sedimentary balances for the Central arc, red colours corresponds with accretion, the blue ones with erosion and yellow with no changes. A) February-January. B) March-February. C) April-March. D) May-April. E) Net balance May-January

In the south arc as shown in Figure 10, during the February-January period there was a big loss in the northern part of this arc and a gain in the southern part. In March-February balance in the northern zone there was a very big erosion in the upper part and accretion in the lower part. In the balance of April-March there was accumulation in the northern part and erosion in the southern part of the arc. Finally, in May-April balance there was erosion in the lower part and accretion at the top of the beach. In the net balance there is a clear accretion all along this arc, but mostly concentrated around the mouth of La Ballena ravine. This accretion accounts for nearly 20.000 m^3 of sand.

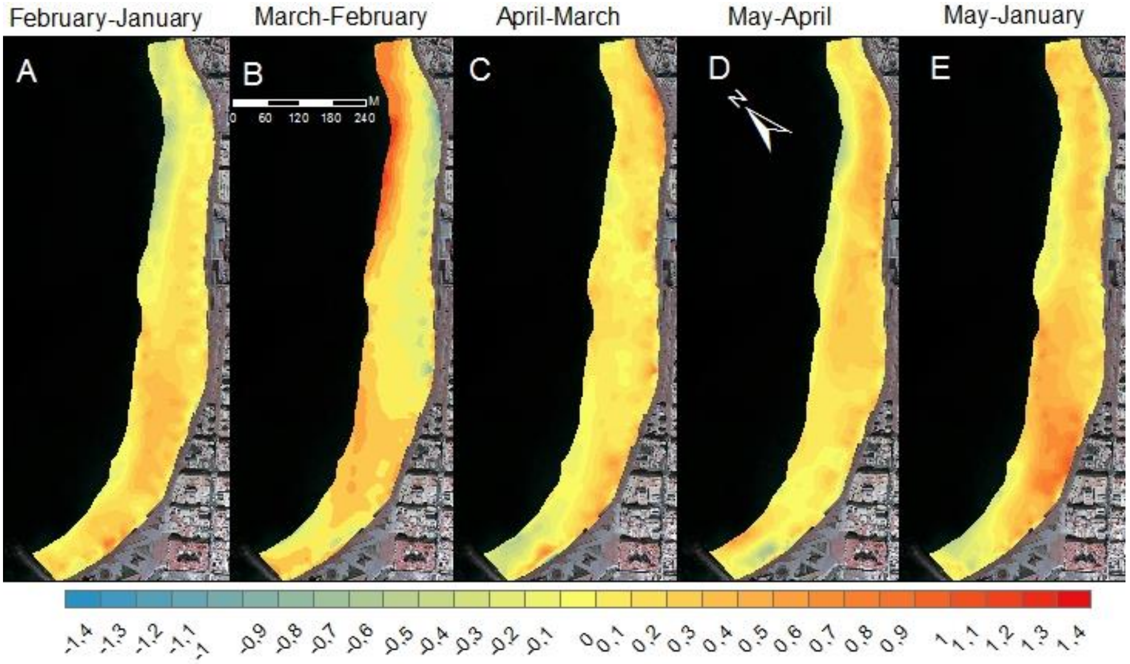

Figure 10: Sedimentary balances for the South arc, red colours corresponds with accretion, the blue ones with erosion and yellow with no changes. A) February-January. B) March-February. C) April-March. D) May-April. E) Net balance May-January

Wave data

Wave data were taken from Puertos del Estado web page and corresponds to Gran Canaria buoy (GCB) and Las Palmas Este buoy (LPEB), depending on their operation. Due to its location in the eastern part of the island, LPEB only registers waves coming from North to South but only with eastward component, since it is completely sheltered from western waves (see Fig. 5), which can be quite relevant in the study area.

January wave data were only collected from LPEB because GCB were not opperative. In this month, values for peak period were between 7 and 16s. Data collecting days were those in which the maximum peak periods were reached. Significant wave height were between 1,4 m and 2,6 m, but the major part of time were higher than 2 m. In January, the direction waves coming from were from NNE and NE, although this is not very significant because of the location of this buoy (Fig 11).

In February data from both buoys were collected. The peak period was between 4 and 17 s, even though normally was less than 12 s. We could observe a difference between data from GCB and LPEB in the 30 to 32 days, which is related to NNW swell waves recorded al GCB. This is because LPEB did not collect data from all possible wave directions. Significant wave height were between 1 and 1,5 m until the 32th day. After this day wave height increases up to 4 m due to northern waves recorded at both buoys (Fig 12).

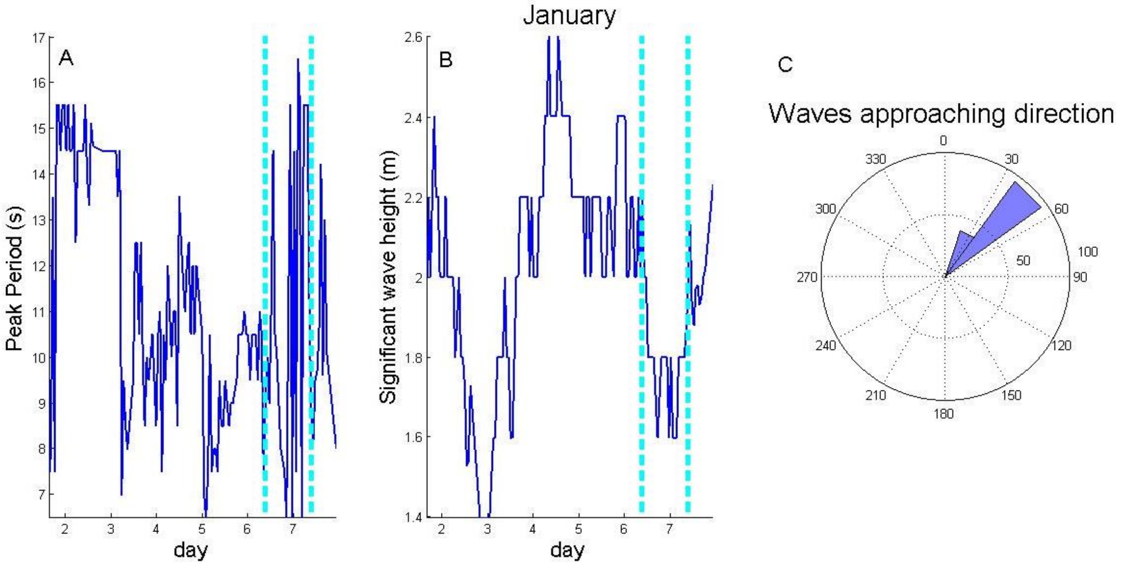

Figure 11: Wave data from January. Light blue dashed lines indicate the field trip days corresponding with 23th and 24th of January at 9 a.m. A) Peak period. B) Significant wave height. C) Waves approaching direction.

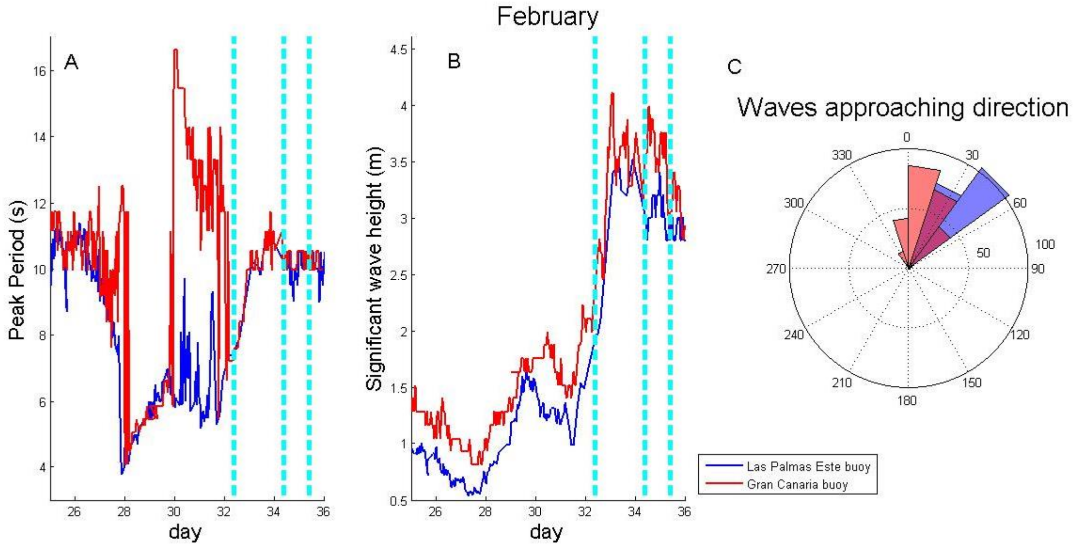

Figure 12: Wave data from February. Light blue dashed lines indicate the field trip days corresponding with 17th, 19th and 20th of February at 9:00 a.m. A) Peak period. B) Significant wave height. C) Waves approaching direction.

In March, there were peak periods between 5 and 16 s. From days 57 to 62 there was a significant difference in peak period data recorded at both buoys, but since then data are in very good agreement for GCB and LPEB. Significant wave height had a biggest difference between the two buoys. GCB values range between 1,5 and 3,5 m, while LPEB values were much lower (1-1.5 m) until day 67. Since then Hs values increase due to the arrival of higher northern waves, which were recorded at both buoys (Fig 13).

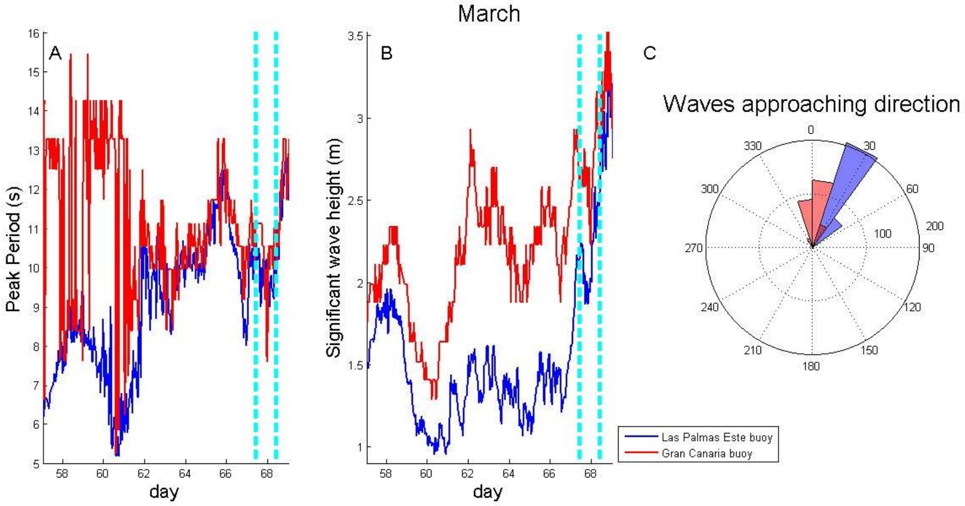

Figure 13: Wave data from March. . Light blue dashed lines indicate the field trip days corresponding with 24th and 25th of March at 9:00 a.m. A) Peak period versus time. B) Significant wave height versus time. C) Wave approaching direction.

The peak period in April was between 16 and 4 s, with a big variability each day and among the different buoys. There was a lag in the period during the 91st and 93rd day of 7 s. Minimum significant wave height was 0,6 m and the maximum was 2.4 m the 89th day. Also in this parameter, there was differences between the two buoys. GCB wave approaching direction was from NNW and NW. and LPEB was from NE and NNE (Fig 14).

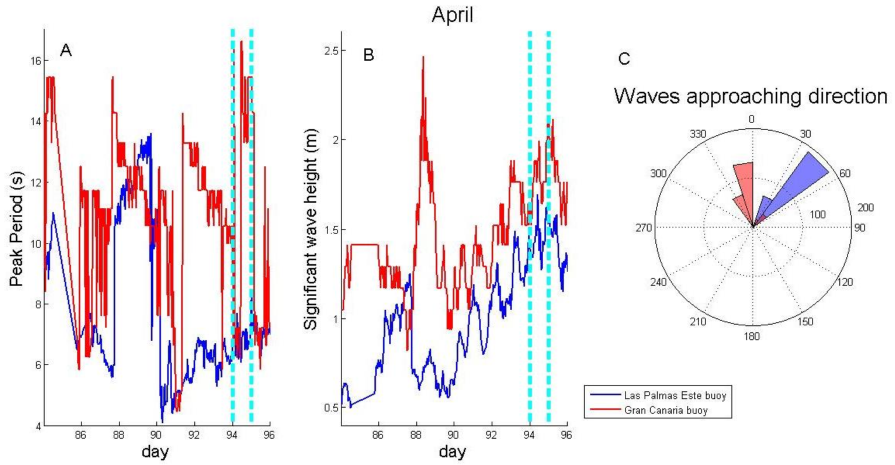

Figure 14: Wave data from April. Light blue dashed lines indicate the field trip days corresponding with 20th and 21st of April at 9:00 a.m. A) Peak period versus time. B) Significant wave height versus time. C) Wave approaching direction.

Peak period in May was between 14 and 6 s. Being only greater than 10 in the days 112, 113 and 114 (8th 9th and 10th of May), in Las Palmas Este Buoy. In which days de approaching direction was form west. About the significant wave height was less than 2 m except on 15th, 16th, 17th ,20th and 21st of May (days 119,120 and 121) when the height was around 3 and 4 m. Wave approaching direction was predominant from NNE on Gran Canaria buoy (Fig 15).

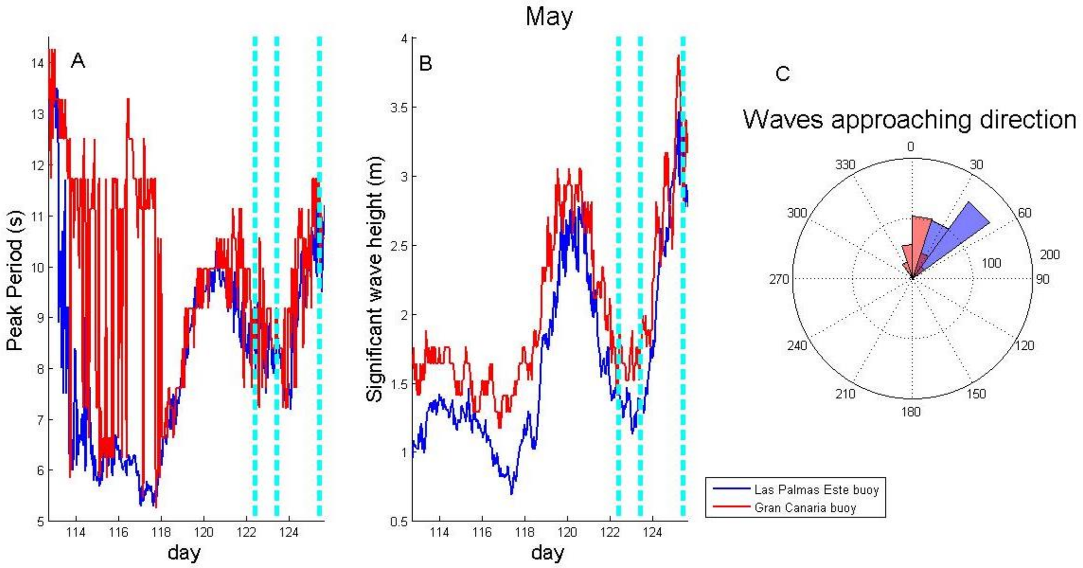

Figure 15: Wave data from May. Light blue dashed lines indicate the field trip days corresponding with 18th and 19st and 21st of May at 9:00 a.m. A) Peak period versus time. B) Significant wave height versus time. C) Wave approaching direction.

Beach Profiles

In beach profiles (Fig 16), in the first one there is a difference between January and February in the middle of the beach where in February there were more sand and a little berm. Also in March and April profiles there were more sand than in January, but the berm had disappeared. In profile 2 the major difference is between March and April where in de middle and upper part of the beach in April was an accretion and erosion in the lower part of the profile. Profile 3 in March has much more sand than the rest of months. This profile corresponds to Playa Chica, and it has been already shown (Fig. 9) the big accumulation that took place in this month. Profile 4 is very stable, except in April when there was an accumulation at the top of the beach and an erosion in de low part. Profiles 5 and 6, corresponding to the southern arc, show big differences between months. In February there was an accretion in the upper part of the beach, in March there was a big erosion in this part. April and January were intermediate between February and March. In the lower part of the beach there was a bar April and March. In profile 6 there was an accumulation since January, although in march there was a loss compared with February (Fig 8).

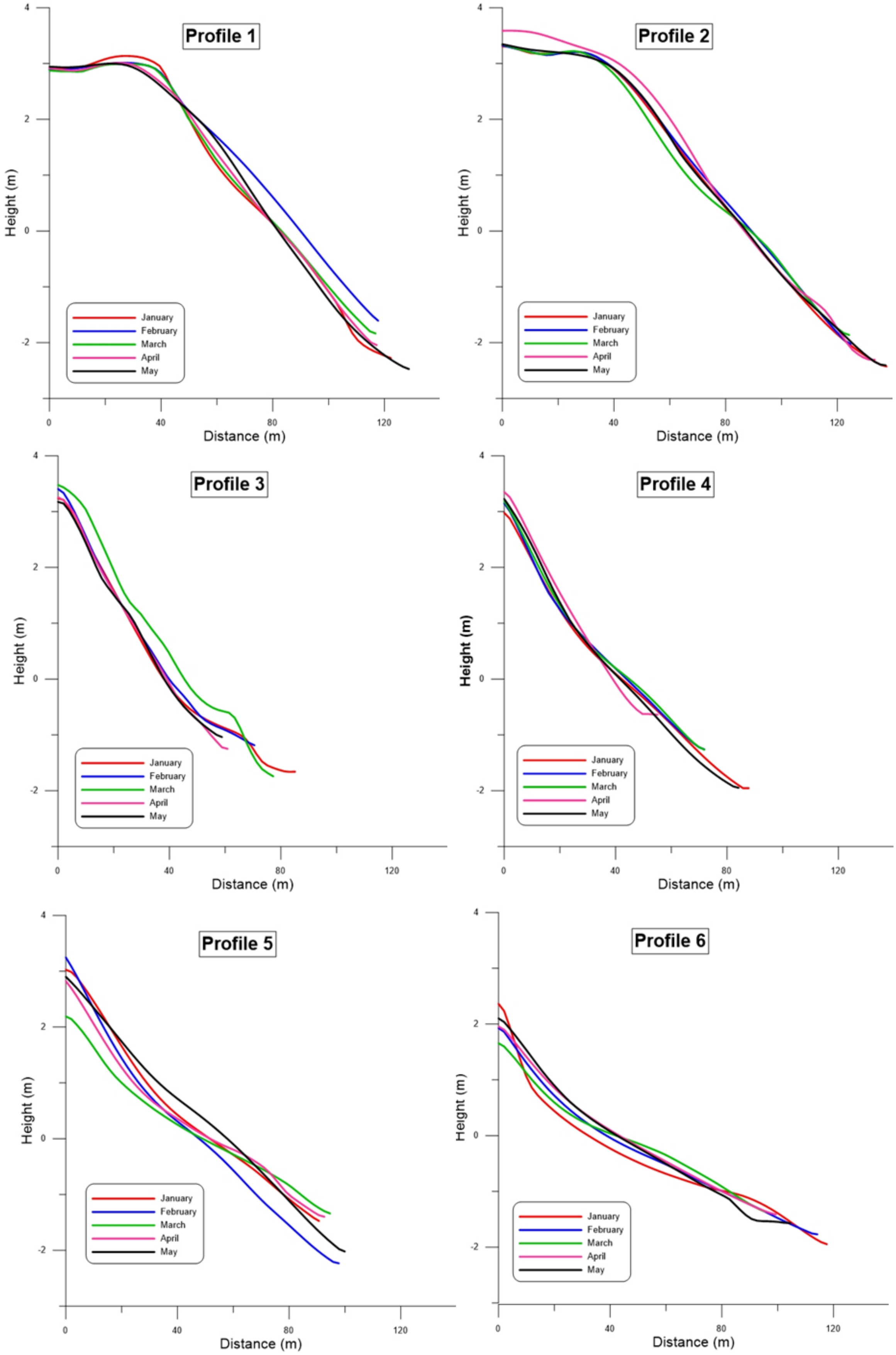

Figure 16: Beach Profiles by months. The first two profiles were measured in the North arc, profiles 3 and 4 in the central arc, and profiles 5 and 6 in the South arc

Larson's (1988) criteria (eq. 1) has been applied for wave data sets from both buoys, and considering the wave attenuation due to the presence of the calcarenitic bar suggested by Alonso (1993). Table II shows that considering GC buoy, all profiles are always bar type in any situation, which is clearly wrong since the north arc is clearly reflective and has berm type profiles. Nevertheless, Larson's (1988) criteria fit better when considering LPE buoy wave data, since beach profiles at the northern sector are berm type.

	North arc		Central arc		South arc	
	LPE	GC	LPE	GC	LPE	GC
January	berm	-	berm	-	bar	-
February	berm	bar	berm	bar	bar	bar
March	berm	bar	berm	bar	bar	bar
April	berm	bar	berm	bar	bar	bar
May	berm	bar	berm	bar	bar	bar

Table II: Application of Larson's (1988) criteria to classify bar/berm profiles by arcs and months. Data required to calculate the type of profile are shown in annex I.

Dean's parameter (eq. 2) has been also calculated for the two wave data sets and for the three arcs of the beach. Table III shows differences depending on the wave data used: with GCB data the south arc and many times the central one are dissipative, and the rest of them are intermediate. On the other hand, when LPEB data are used, only the south arc is dissipative, the central one is intermediate and the north arc is reflective in any month.

	North arc		Central arc		South arc	
Buoys	GC	LPE	GC	LPE	GC	LPE
January	-	1,63 reflective	-	4,10 intermediate	-	10,91 dissipative
February	4,36 intermediate	1,51 reflective	5,35 dissipative	3,79 intermediate	11,38 dissipative	10,08 dissipative
March	4,43 intermediate	1,48 reflective	5,43 dissipative	3,73 intermediate	11,55 dissipative	9,92 dissipative
April	5,06 dissipative	0,97 reflective	3,91 intermediate	2,43 intermediate	8,30 dissipative	6,46 dissipative
May	4,12 intermediate	1,55 reflective	5,05 dissipative	3,88 intermediate	10,73 dissipative	10,33 dissipative

Table III: Dean's parameter for each arc of the beach by months and for the two buoys we had taken data from. Data necessary to calculate this values are shown in annex II. Values related with wave data are the mean of the 10 previous days of the field trips.

DISCUSSION

An electronic total station was used to collect topographic data during the field measurements. Other authors used a differential Global Positioning System (dGPS) that has an accuracy of 2,5 cm in the horizontal an 4 cm in the vertical (Batiau-Queney et al, 2003; Pardo-Pascual et al, 2005; Quartel et al, 2008). This method has good accuracy but could have errors with satellite reception, data communication with the satellite and the verticality of the antenna. There are also other methods to calculate the changes but in long and medium term scales and for large areas, such as LIDAR and ortophoto (Batiau-Queney et al, 2003; Pardo-Pascual et al, 2005; del Rio et al, 2013).

During the study period, net volumetric changes showed an accretion in the South and North arcs of 19.934 m^3 and 1.051 m^3 respectively, and a little erosion in the Central arc of 1.105 m^3, which could be considered as a null volume exchange like Alonso (1994) said. In this paper the greatest accretion has been found in the southern sector, which initially doesn’t agree with previously published papers (Martinez et al, 1990; Alonso, 1993, 1994, 2005; Alonso and Vilas, 1996) that refers to erosive patterns in this sector during the winter months. However, it has to be noted that the erosive season related by previously mentioned authors normally covers from November to April, and we only have data from January to May, and figure 7 clearly shows that the sand accumulation begins in April and continues in May. This seems to be related to waves characteristics, since sorter and smaller waves normally generates accretion, while erosion is normally consequence of larger and higher waves (see annex II).

Apart from that, it should be considered that this kind of studies should last at least one full year, and this is not the case due to time limitations.

Looking at volume data it could be noticed that when there was loss of sediment, this occurs in both North and South arcs, and when there was accretion it happened in the same way except during the last balance. This indicates there was a cross-shore sediment transport from January to April, and a long shore sediment transport between April and May. In central arc it is seen very small variations, which indicates that this sector has very small capacity to accumulate sediments and to be eroded. It is due to the presence of the rocky substrate in the lower beach all along this sector.

In the February-January balance, with NE predominant waves, there was a berm in the part of the beach cusps as seen in beach profile 1, which indicates onshore transport in the north arc. In the South arc there was also cross-shore transport from the submerged zone to the emerged beach and a little longshore transport from the north part of this arc to the south.

In the March-February period, with under very high northern waves, there was offshore transport both at the North and the South arcs, with erosion in the upper part of the beach and accumulation in the lower one (see profiles 1, 2, 5 and 6 in figure 16). This great erosion of 17.000 m^3 was generated by the major stormy event recorded during the study period. In Playa Chica in this period there was an onshore transport as could be seen in profile 3.

In April-March balance there was onshore transport both in the North and South arcs, as a result of quite calm conditions. In North arc the berm was formed again on to the middle part of the beach an there was an erosion in the lower part as that could be observed on profile 2. In this balance in Playa Chica there was an offshore transport. In the rest of Cental arc there was onshore transport as seen in profile 4 with an accretion in the emerged zone.

In May-April balance, with Northern waves the beach cusps fully developed in the northern part of the North arc, which losses 2.400 m^3 of sand. Since the South arc accumulates 10.200 m^3, it seems to indicate that there was long-shore transport from north to south, combined with some onshore transport as it could be observed in profiles 5 and 6.

In the net balance main gain of sand was in South arc where looking at profiles and balances could be seen an onshore transport. In profile 6 it is observed an erosion at the end of the profile. In addition, it could be seen in the North arc that the berm of January in profile 1 had less slope than in May. There was a long-shore transport from North part of Central arc to the south part.

As it is said by van Rijn (2003) and Quartel et al (2008), there is a on shore bar migration when there was good weather conditions and an offshore sand bar migration when the weather conditions where worst. In this case onshore bar migrations came about when there was East swells because the beach is protected from these swells and when there were not big storms. When there was the biggest storm, in March, is when off-shore transport happened.

As said by Masselink and Short (1993), Las Canteras is a dissipative beach in the South arc because the dimensionless Dean’s parameter is greater than 5. Central and North arcs behave as intermediate and reflective beaches when it is used the wave energy dissipation proposed by Alonso (1993). If any wave energy dissipation is considered, Dean’s parameter could not be applied to Las Canteras beach, because of the boundary conditions of this particular beach (Alonso and Vilas 1994).

Similar results are obtained after applying Larson's (1988) criteria, since we know that the North arc is a berm type profile, and it is only found with LPEB wave data and after considering the wave energy attenuation proposed by Alonso (1993).

CONCLUSIONS

Wave data showed an approaching predominant direction from NNW and NE. The highest significant wave height was 4 m in storm conditions although the average Hs was around 1,5 and 2 m, with an average peak period of 12 s.

Sediment volume data show a gain of sand of the beach during the period of study. The net balance of the beach was a gain of almost 20.000 m^3 in the entire beach. Changes in volume were mainly in North and South arcs, while the Central arc had very little changes.

Sediments in North and South sectors followed the same pattern during the first three balances, which only can be explained by cross-shore transport. Onshore transport in the periods January-February and March-April, with net accumulations of 18.500 and 10.700 m^3 respectively; and offshore transport in the period February-March, as a result of the very big stormy events that took place, and generated an erosion of nearly 17.000 m^3.

The main gain was in South arc, where there was an accretion of 20.000 m^3. This was a result of the mild wave conditions since the end of March, which generated a southward longshore transport of nearly 3.000 m^3 and the arrival of ~17.000 m^3 from the submerged beach by onshore transport.

Dean's parameter and Larson's (1988) criteria have been applied to determine the morphodynamic state of the beach and the beach profile type respectively. Results agree with previously published data when LPEB wave data are used, but not with GCB wave data. With these results, the southern sector is a dissipative beach with bar type profiles, the central sector is an intermediate beach and the northern sector behaves as a reflective beach with berm type profiles.

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Annex I: Data required for estimate deepwater wave steepnes values with Larson, 1988 method and all the calculations needed.

	S				**C**				**N**			
GC	H_0/L_0 (1)	$0.00070*(H_0/wT)^3$ (2)	1-2	Profile	H_0/L_0 (1)	$0.00070*(H_0/wT)^3$ (2)	1-2	Profile	H_0/L_0 (1)	$0.00070*(H_0/wT)^3$ (2)	1-2	Profile
January			0				0				0	
February	0,0126	0,4177	-0,4051	bar	0,0091	0,1595	-0,1504	bar	0,0071	0,0741	-0,067	bar
March	0,0113	0,4099	-0,3986	bar	0,0082	0,1565	-0,1483	bar	0,0064	0,0727	-0,0663	bar
April	0,0076	0,1205	-0,1129	bar	0,0055	0,046	-0,0405	bar	0,0043	0,0214	-0,0171	bar
May	0,0138	0,3704	-0,3566	bar	0,01	0,1414	-0,1314	bar	0,0078	0,0657	-0,0579	bar
LPE												
January	0,0106	0,3326	-0,3220	bar	0,0058	0,0547	-0,0489	bar	0,0018	0,0017	-0,0001	berm
February	0,0139	0,3076	-0,2937	bar	0,0076	0,0505	-0,0429	bar	0,0024	0,0016	-0,0008	berm
March	0,0119	0,2674	-0,2555	bar	0,0065	0,0439	-0,0374	bar	0,0021	0,0014	-0,0007	berm
April	0,085	0,0604	-0,0519	bar	0,0046	0,0099	-0,0053	bar	0,0015	0,0003	-0,0012	berm
may	0,0149	0,3462	-0,3313	bar	0,0082	0,0569	-0,0487	bar	0,0026	0,0018	-0,0008	berm

Annex II: Data used to calculate the values on tables II and III

	H_0 GC (m)	H_0 LPE (m)	H_b GC (m)	H_b LPE (m)	T_p GC (s)	T_p LPE (s)
January	-	2,0154	-	2,1702	-	11,0373
February	2,0264	1,4615	2,7241	1,6266	10,0257	8,2154
March	2,2250	1,5540	3,0553	1,7314	11,0779	9,1533
April	1,4560	0,8080	2,1625	0,9466	10,9034	7,8160
May	1,7041	1,4736	2,2486	1,5942	8,7759	7,9631

Oceanographic data.H_0 is the deepwater wave height, H_b is the breaking wave height and T_p the peak period. H_b was calculated from H_0. These values are the mean of the 10 previous days from field trips.

	D_{50} (mm)	**W (m/s)**
North arc	0,27	0,03847
Central arc	0,29	0,04100
South arc	0,20	0,02340

Sediment data. D_{50} is the gran size and w the fall velocity of sediment particles.

Descripción detallada de las actividades desarrolladas durante la realización del TFT

1. Con los datos obtenidos en las prácticas externas de la topografía de la playa he creado modelos digitales de elevaciones.
2. Comparando los modelos digitales de dos campañas sucesivas y de la primera con la última he hecho balances sedimentarios de la playa y he calculado los volúmenes de arena ganados y perdidos, con ArcGIS 10.1 y Surfer 11, en toda la playa y por arcos. La playa la hemos dividido en tres arcos, arco norte, sur y centro.
3. Me he descargado los datos de oleaje de la boya de Las Palmas Este y de la boya de Gran Canaria de la página de Puertos del Estado. Hay datos cada hora desde finales de enero hasta finales de mayo.
4. Con los datos de oleaje he hecho gráficas, en Matlab, del periodo frente al tiempo, de la altura significativa frente al tiempo y una rosa de los viento con las direcciones de las olas. Hay una gráfica de cada para cada mes los 10 días antes de cada campaña.
5. Con los datos de oleaje y de tamaño de grano en cada uno de los arcos he calculado algunos parámetros como el parámetro de Dean y el peralte de la ola, con el Matlab, para poder explicar junto a los balances y las gráficas de oleaje como se mueven los sedimentos en la playa.
6. Finalmente con todos los datos y gráficas y buscando y leyendo mucha bibliografía he redactado el TFT.

Formación recibida (cursos, programas informáticos, etc.)

He realizado dos cursos de ArcGIS uno de introducción al ArcGIS 10.2 y otro de análisis espacial con ArcGIS 10.2. Ambos son cursos de extensión universitaria de la ULPGC. Además para poder realizar los balances y el cálculo de los volúmenes me enseñaron a usar el Surfer. El Matlab lo sabía utilizar por las prácticas de otras asignaturas de cursos anteriores del grado además de tener que buscar información en internet para poder realizar algunas operaciones.

Además he aprendido en la revisión bibliográfica y en las reuniones con el tutor el funcionamiento de la dinámica litoral, y en concreto de la Playa de las canteras.

Nivel de integración e implicación dentro del departamento y relaciones con el personal.

El nivel de integración ha sido bueno. Ha habido buenas relaciones con el personal del grupo de investigación.

Aspectos positivos y negativos más significativos relacionados con el desarrollo del TFT

Cuando me he reunido con el tutor se ha interesado por mi duda y me ha facilitado documentación y orientaciones para resolverlos. En ocasiones he tenido que resolver problemas por mis propios medios. Valoro como aspecto positivo haber aprendido a hacerlo aunque a veces resultaba complicado encontrar la solución adecuada.

Valoración personal del aprendizaje conseguido a lo largo del TFT.

Considero valioso el aprendizaje logrado con el TFT. Ha sido la primera vez que he tenido una experiencia directa de investigación y me he dado cuenta de cómo pueden condicionar los factores externos (como el mal tiempo) y de las dificultades de trabajar con datos reales que no suelen aparecer en los problemas preparados de la facultad. Por otra parte me ha permitido ampliar mis conocimientos sobre el trabajo en equipo y la redacción de artículos científicos.