THE USE OF NUMERICAL MODELS AS COMPLEMENT OF WAVE MEASUREMENTS IN AMOREIRA BEACH, ALJEZUR

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Abstract

To characterize the hydrodynamics of the Aljezur Stream, which flows to the Amoreira beach (in the South-western coast of Portugal), and its impact on the water exchange with the sea, an estimation of the local wave climate was judged necessary. Therefore, both in-situ wave measurements and coastal wave propagation models, forced offshore by the results of the WaveWatch III (WWIII) regional wave model (Tolman, 2002), were used.

Three field campaigns were conducted to take measurements of the free surface elevation on the Amoreira beach. The data processing and analysis were obtained by applying classical time and spectral domain techniques. These allowed the computation, for each record, of equivalent parameters of significant wave height (HS and HM0, for time and spectral analyses respectively) and mean wave periods (Tmed and TZ, for time and spectral analyses respectively), which, alone or together, are useful to estimate the representative characteristics of the waves at the site.

However, these measurements, although being very useful to describe local wave characteristics, are of too short duration to characterize the long-term wave climate, and they also suffer from a restricted spatial representation of the wave conditions. Therefore, the NOAA archives of the WWIII model were used to produce offshore boundary conditions to the spectral wave propagation model SWAN (Booij *et al.*, 1999), which was used in this paper as complement of the in-situ measurements, enabling a better local wave climate characterization to be found.

This paper describes the measurement campaigns, the data analyses made, and the methodology for the characterization of wave conditions from offshore to inshore and its application to the study area using SWAN model. A comparison between measured and numerical data is finally made. The results from this comparison may be useful to assist the coastal management decision-making.

***Key-Words**: in-situ wave measurements**,** numerical modelling, SWAN.*

1 INTRODUCTION

The project MADyCOS (Multidisciplinary integrated Analysis of the sediment Dynamics and fecal contamination in intermittent Coastal Systems) is funded by the Portuguese Foundation for Science and Technology (contract DCPT/ECM/66484/2006). This project aims to improve the understanding of hydrodynamics, morphodynamics and fecal contamination of coastal streams. This will be achieved through the implementation of an interdisciplinary study that integrates three distinct methodologies: the acquisition of field data, the laboratory investigation and the numerical modelling. In this way an evaluation of the relative importance of the various forcing sources on the morphology of the system and its impact on quality of water from coastal rivers can be achieved. The system under study is the Aljezur Stream, which flows to the Amoreira beach, chosen due to their small size and the high morphological variability of its inlet.

The work presented in this paper addresses the first and third aspect, i.e., the acquisition, data processing and numerical modelling of sea waves.

Four field campaigns were carried out (Campaigns #0 to #3). In three of them (Campaigns #0, #2 and #3), carried out by LNEC, one took measurements of the free surface elevation (among others) with pressure sensors at points near the inlet of the Aljezur Stream and along the Amoreira beach. The processing and analysis of data were obtained by removing the tidal component and performing both a time and spectral analysis of the data records. For both analyses, computer programs for the automatic processing of the records were developed. The time analysis of the records was carried out using the programs "PRE-REGISTOS" and "REGISTOS" (Fortes and Capitão, 2009). Corresponding spectral analysis was carried out using the spectral analysis' module of SAM software (Capitão, 2002). These allowed the determination, for each record, of equivalent parameters of significant wave height (HS and HM0, respectively, for time and spectral analyses) and of mean or significant wave period (Tmed and TZ, respectively), which, alone or together, are of great interest to this project in order to determine the wave climate characteristics representative of the site under study.

However, in-situ measurements are too sparse to enable a full wave characterization of the waves at the study location. To overcome this difficulty, the use of wave propagation numerical models can be of great help.

In the present study, the spectral wave propagation SWAN model (Booij *et al.*, 1999), was chosen and applied considering the NOAA results of the WWIII model (Tolman, 2002) as offshore boundary conditions. Comparisons between numerical and in-situ measured data allow one to evaluate the performance of the numerical model and its adequacy to characterise the sea waves at that region.

This paper starts by briefly describing the local study area. Then, the campaigns performed and the methodology for the time and spectral analyses used are also described. After, the numerical modelling of the study area is presented. Finally, a comparison of the results obtained (in-situ measurements and numerical modeling results) is made, highlighting the main differences observed.

2 STUDY AREA

The site selected for this study was the Aljezur Stream and the Amoreira beach, located in the Natural Park of Southwest Alentejo and Costa Vicentina (Figure 1).

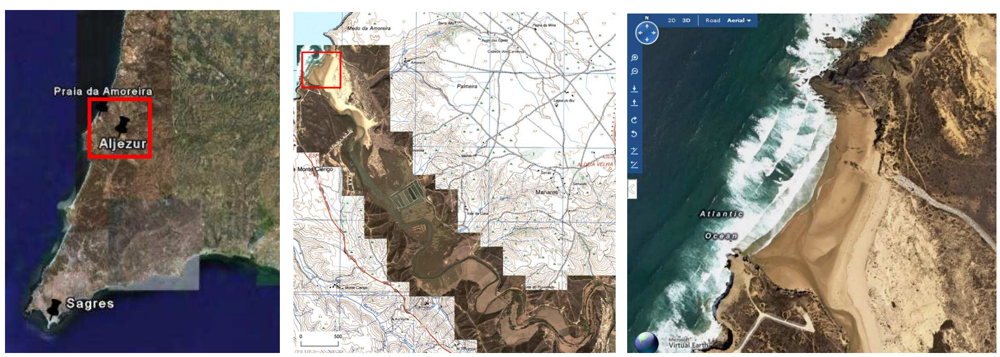


Figure 1 – Location of the study area, on the left (Google Earth©); details of the “Aljezur Stream”, at center (by Lourival Trovisco); detail of the “Amoreira beach”, at right (Virtual Earth©).

This is a small but highly complex system, which exhibits high morphological variability in the area of the inlet, including occasional interruptions of their connection to the sea. These interruptions are the result of the joint action of sea waves, tidal currents and intermittent river flows. The Aljezur Stream shows high variability of fluxes along seasons, with periods of floods during winter, contributing to the morphological changes at the Amoreira Beach. This beach is about 600 m long, delimited by cliffs at North and South and composed primarily by sand. At East, the beach is delimited by the sand dune system, which is the main source of sand along with the longshore drift.

The Portuguese Southwest coast is characterized by semi-diurnal ocean tides with winds and waves along the seasons predominantly coming from Northwest, being the most energetic during winter (Pereira, 2004; Costa *et al.*, 2001).

3 IN-SITU MEASUREMENTS

3.1 Description

Sea wave data acquisitions were performed with pressure sensors placed at different locations of the study area, both near the inlet of the Aljezur Stream and along the Amoreira beach during three campaigns.

Depending on the campaign, different sampling intervals and different measuring equipments were considered. This variability of measuring points and equipments was deemed necessary due to the fact that one objective of this project was to refine measurement methods while other was to check which types of equipment are best suited to that task.

Until now, 4 field campaigns were conducted within the project, three of them (Campaigns #0, #2 and #3) carried out by the LNEC team - see Table 1, Figure 1, Figure 2 and Figure 5 for details on these campaigns.

Table 1 – Description of campaigns carried out by LNEC.

Campaign number	**Start**	**End**	**Number and type of used sensors**	**Locations**
#0	2008/05/05	2008/05/07	3 cabled pressure sensors, "Honeywell"	Not considered in this paper. P11: 37°20'55.90"N, 8°50'46.7"W P14: 37°21'1.19"N, 8°50'50.42"W P16: 37°21'8.10"N, 8°50'43.19"W
#2	2009/05/11	2009/05/13	1 autonomous pressure sensor, "Infinity" 2 cabled pressure sensors, "Honeywell"	See Figure 2 P11:37°20'56.72"N,8°50'47.80"W P15:37°21'6.30"N, 8°50'41.78"W P16:37°21'6.98"N, 8°50'41.39"W
#3	2009/09/07	2009/09/09	1 autonomous pressure sensor, Infinity (P11) 1 cabled pressure sensor, "Honeywell"	See Figure 5 P11:N37º 20' 56.7",W8º 50' 47.8" P16:N37º 21' 7.0"; W8º 50' 41.4"

For the treatment of the collected data (discrete time series of the surface elevation at the measurement locations) time and spectral analyses were performed, both described very briefly in section 3.3.

In what follows, a brief description of the measurements taken in Campaigns #2 and #3, and their treatment, is made. One should note that only these campaigns are described in this paper (Campaign #0 is omitted) since they were the ones used in the comparisons with the numerical models.

3.2 CAMPAIGNS'S DESCRIPTION

3.2.1. CAMPAIGN #2 - MAY, 11 TO 13, 2009

In this campaign, the free surface elevation was measured at three points located along the Amoreira beach using two wired (cabled) pressure sensors "Honeywell", located on the North of the beach in very close positions (P16 and P15, Figure 2), and one autonomous pressure sensor "Infinity", located on the South of the beach (P11, Figure 2).

Figure 2 – Campaign #2 - May - 11 to 13, 2009. Positions of the probes (Google Earth©).

As an example of the data collected in this campaign, Figure 3 and Figure 4 show, respectively, for position P11 (see Figure 2) the one measured "Infinity" record and the corresponding final record, corrected after removing the tide component, using the SAM software.

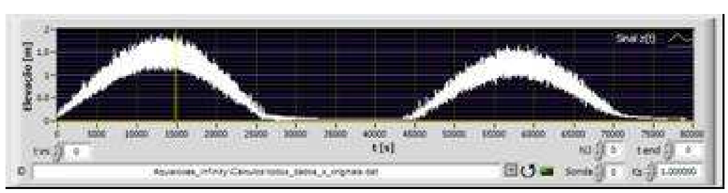


Figure 3 – Campaign #2 – May, 11 to 13, 2009. Measured record - P11.

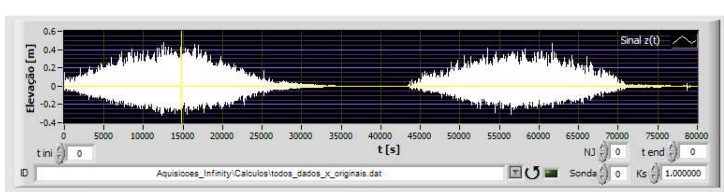


Figure 4 – Campaign #2 – May, 11 to 13, 2009. Final wave record - P11.

3.2.2. Campaign #3 – September, 7 to 9, 2009

During campaign #3, one used a wired pressure sensor “Honeywell” only and an autonomous pressure sensor "Infinity." Those devices were placed, respectively, in positions P16 and P11 (see Figure 5).

Figure 5 – Campaign #3 – September, 7 to 9, 2009. Positions of the probes. (Google Earth©)

3.3 DATA ANALYSIS

3.3.1. Time analysis of records

For the time analysis of a wave record a criterion for defining what a "wave" is in the "oscillations" observed in the sea surface elevation record, $\eta\ (t)$, has to be used. This definition is by no means consensual (Goda, 1985). However there is a criterion that is undoubtedly more used due to its simplicity: the zero-upcrossing criterion, used in this work, which consists in identifying a wave based on the consecutive up-crossings of the average level (zero) of the sea surface elevation record. Each wave is thus limited by any two of these upcrossing zeros.

After defining the reference level for the record, a series of heights, H, and periods, T, of the waves that define the surface elevation record, $\eta\ (t)$, are computed, and the following parameters of interest to this work are determined:

- The significant wave height, HS, i.e., the average of the thirds’ highest wave heights of the record.
- The mean wave period, Tmed, i.e., the average of all periods of the wave record.

A further important element to study under a time analysis procedure is the mean wave direction, Θ, often associated with the above parameters, although not directly obtained from the wave record. In this study, however, this parameter was not considered due to limitations of the used equipments.

3.3.2. SPECTRAL ANALYSIS OF RECORDS

In addition to the time description of the waves, there is another type of analysis often used: the frequency or spectral analysis. The description of the record in the frequency domain can be achieved through harmonic analysis and/or spectral analysis of the sea surface elevation record, $\eta\ (t)$, by defining a function, $S\ (f)$, which represents the spectral density of the waves on a frequency axis. Spectral analysis is of great interest to these type of studies since it highlights important information in the time signal $\eta\ (t)$, as allows one to it immediately reveal frequencies and patterns, hidden when one simply observes the time series.

The estimation of the spectral density function from wave records is well documented in several texts, such as Carvalho (1973) and Bendat & Piersol (1986). Several spectral wave parameters may be derived from the spectral information using the *moments*, m_n, of the spectrum, $S\ (f)$. Two of them are of interest to this work and are defined below:

- The (spectral) significant wave height, HM0 = $4\sqrt{m_0}$.
- The (spectral) mean wave period, TZ (or T02) = $\sqrt{\frac{m_0}{m_2}}$.

3.3.3. PROCEDURES

As referred, the equipments used in the measuring campaigns were of two types: a cabled “Honeywell” pressure sensor and an autonomous “Infinity” pressure sensor. The analysis of the records involved the following set of procedures:

- Removal of the tidal component;
- Separation of the original “Infinity”-type records into sub-records with 30-minutes duration. This operation was not necessary for the “Honeywell” pressure sensors, because its records had already that duration;
- Time analysis of the 30-min records with the REGISTOS (Fortes and Capitão, 2009) and ANOIAGI programs (Carvalho, 1973). The values of

HS (significant wave height) and Tmed (mean wave period), among others, were then obtained for each record;

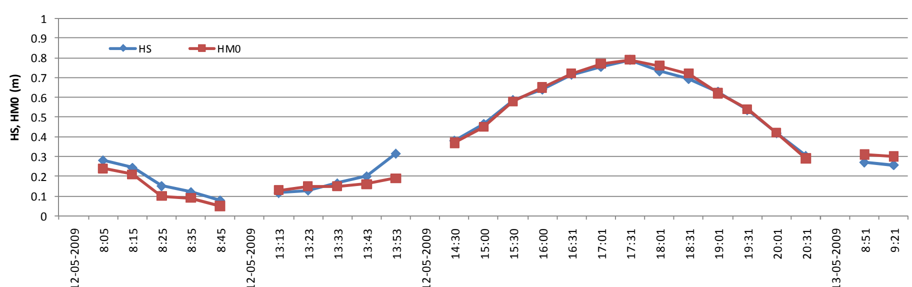
- Spectral analysis of the 30-min records with the SAM software (Capitão, 2002). With it, the energy density associated with each frequency spectrum was calculated. Based on the spectrum and its moments, the significant wave height HM0 (equivalent to HS) and TZ (equivalent to Tmed), among others, were obtained for each record.

For both types of analyses, the PRE-REGISTOS computer program was used for the automatic data processing, Fortes and Capitão (2009).

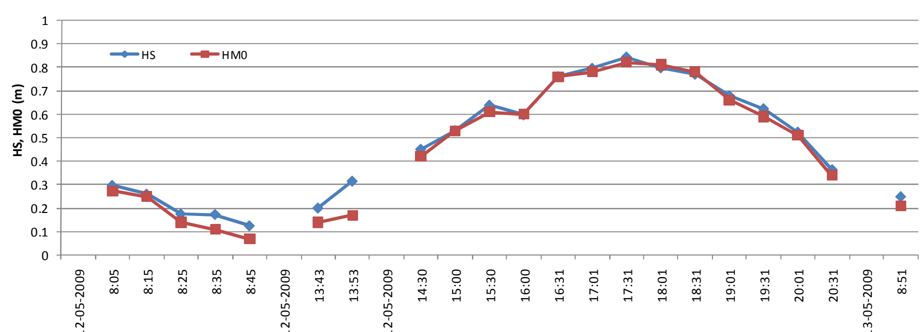
The following two sections describe the comparisons made between the time and spectral analyses performed on the 30-min records, considered valid for each campaign. These comparisons include values of the significant wave height (HS and HM0) and of the mean or significant wave period (Tmed and TZ).

3.4 COMPARISONS OF SIGNIFICANT WAVE HEIGHTS (HS AND HM0)

Figure 6 and Figure 7 show the values of the significant wave heights, HS (time analysis) and HM0 (spectral analysis), obtained in campaigns #2 and #3, using “Honeywell” sensors at positions P15 and P16 (see also Figure 2 and Figure 5).



a)



b)

Figure 6 – Honeywell pressure sensors. Campaign #2 – May, 11 to 13, 2009. Comparison of significant wave height, HS and HM0, at position: a) P15; b) P16.

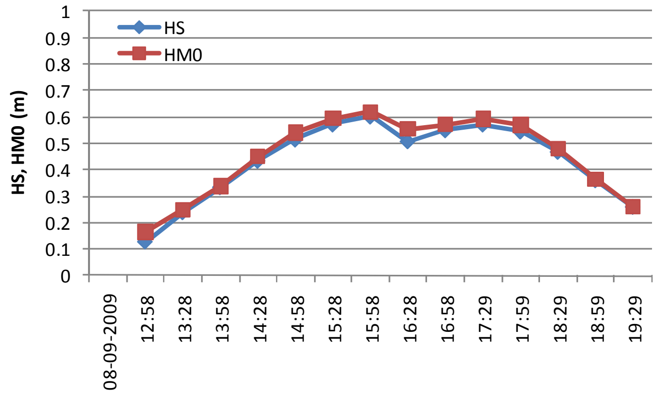


Figure 7 – Honeywell pressure sensors. Campaign #3 – September, 7 to 9, 2009. Comparison of significant wave height, HS and HM0, at position P16.

Figure 8 and Figure 9 show the values of the significant wave height, HS (time analysis) and HM0 (spectral analysis) obtained in campaigns #2 and #3, with the "Infinity" pressure sensor at position P11 (see Figure 2 and Figure 5).

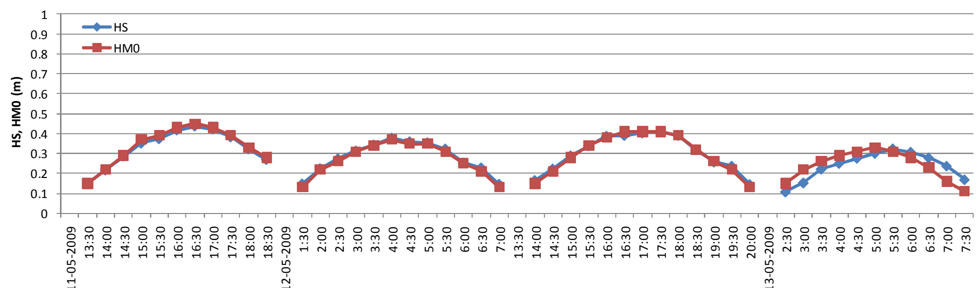


Figure 8 – "Infinity" sensor pressure. Campaign #2 - May,11 to 13, 2009. Comparison of significant wave heights, HS and HM0, at position P11.

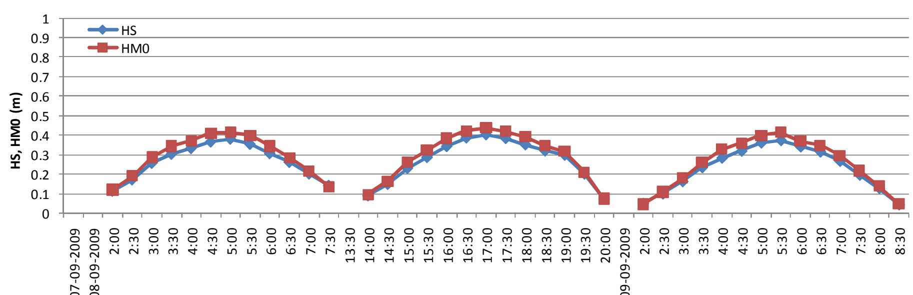


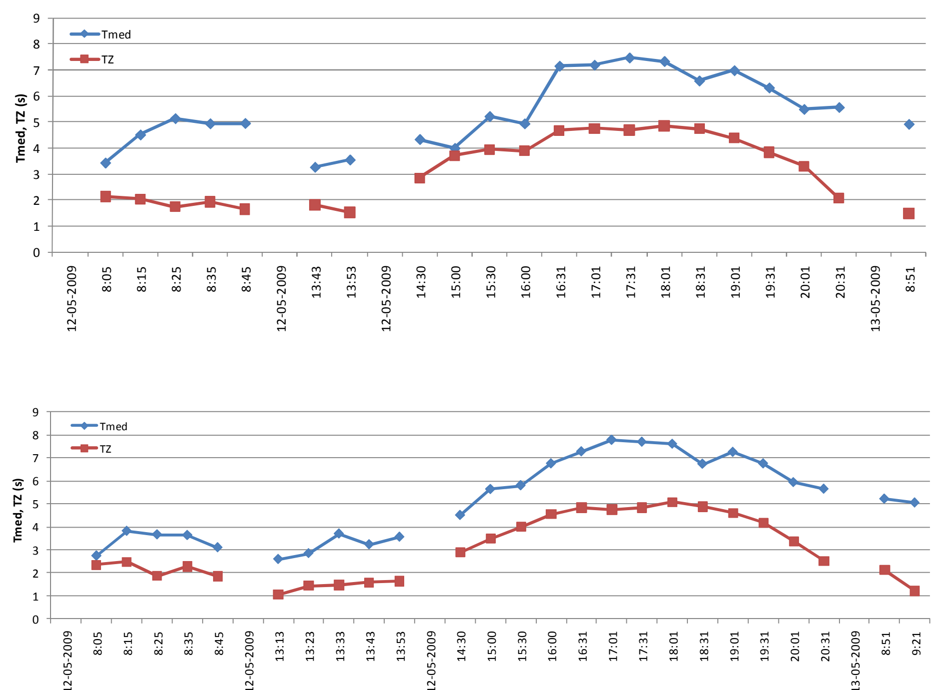
Figure 9 – "Infinity" sensor pressure. Campaign #3 – September 7 to 9, 2009. Comparison of significant wave heights, HS and HM0, in position P11.

From the above figures, one can draw the following conclusions in terms of significant wave heights:

- HS and HM0 values along time agree very well, i.e., both time and spectral analyses do provide values which are very close, whatever the equipments is used;
- Also the differences between the significant wave height at positions P15 and P16, of campaign #2 - Figure 6 a) and b) - are quite small. This was expected since both locations are quite close. That was the reason why the campaign #3 took place with a pressure sensor only, at position P16;
- Generally, higher significant wave heights are found at position P16, than at position P11. This may be due to the wave protection of P11 location.
- The limitation of the waves due to the depth is also clearly seen in the measurements shown in the referred to figures.

3.5 COMPARISONS OF MEAN WAVE PERIODS (TMED E TZ)

Figure 10 and Figure 11 show the values of the mean wave periods (Tmed, for the time analysis, and TZ, for the spectral analysis) obtained in campaigns #2 and #3, with "Honeywell" sensors at positions P15 and P16 (see Figure 2 and Figure 5).



a)

b)

Figure 10 – Honeywell pressure sensors. Campaign #2 – May, 11 to 13, 2009. Comparison of averaged wave period, Tmed and TZ, at position: a) P15; b) P16.

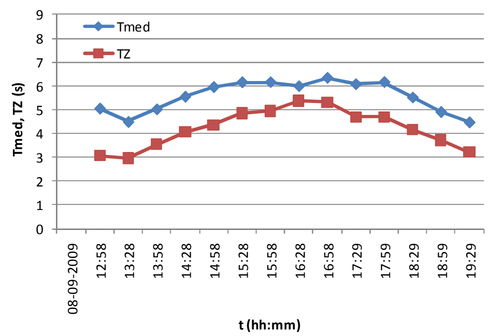


Figure 11 – Honeywell pressure sensors. Campaign #3 – September, 7 to 9, 2009. Comparison of the mean wave period, Tmed and TZ, at position P16.

Figure 12 and Figure 13 show the values of the mean wave period (Tmed, for the time analysis, and TZ, for the spectral analysis) obtained in campaigns #2 and #3, with the "Infinity" pressure sensor, at position P11 (see Figure 2 and Figure 5).

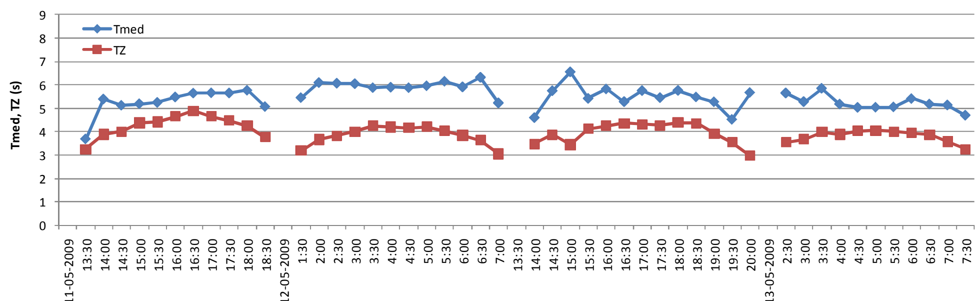


Figure 12 – "Infinity" pressure sensor. Campaign #2 – May, 11 to 13, 2009. Comparison of the mean wave period, Tmed and TZ, at position P11.

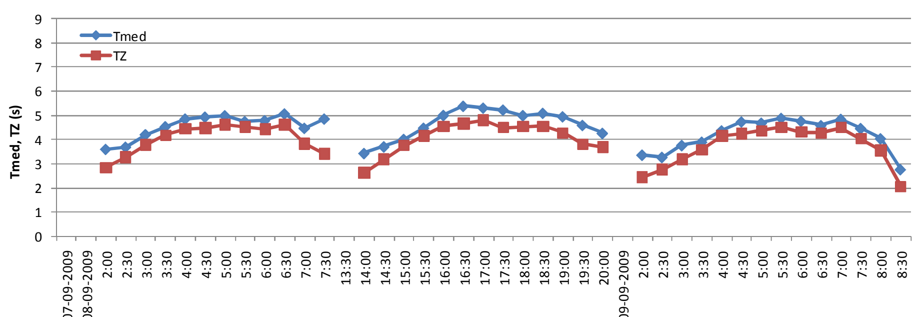


Figure 13 – "Infinity" pressure sensor. Campaign #3 – September, 7 to 9, 2009. Comparison of the mean wave period, Tmed and TZ, at position P11.

From the above, the following conclusions may be drawn:

- In all campaigns, one found that the values of the mean wave period as obtained from the spectral analysis (TZ) are always and, many times, significantly lower than those obtained with the time analysis (Tmed). The reason for this difference may lie in the formulae used in the spectral method, which implicitly (through the spectral moments), consider all the waves in the record, however small they are, while the direct method, used in time analysis, only consider waves that cross the mean level in the upward direction, and do not take into account all the small oscillations occurring only above or only below that intersection level. Despite this, the behaviour of Tmed parameter is similar to TZ parameter whatever the measurement equipment used.

- For positions P15 and P16 of campaign #2, there are no significant differences between the values of the mean wave period;
- Also, at positions P11 and P16 the mean wave periods are similar, whatever the campaign considered.

4 NUMERICAL MODELLING

4.1 BRIEF DESCRIPTION OF SWAN MODEL

The numerical model SWAN (Simulating WAves Nearshore), Booij *et al.*, 1999, computes sea-wave generation, propagation and dissipation based on the wave action balance equation. This freeware wave model, which is continuously being upgraded by Delft University of Technology (The Netherlands), is able to propagate sea waves from offshore up to the shoreline and takes into account the major physical processes of wave refraction, diffraction and shoaling due to bottom depth variation and to the presence of currents. It also includes wind-induced wave growth, wave breaking due to bottom variation and to whitecapping, energy dissipation by bottom friction, wave blocking and reflection by opposing currents as well as wave transmission.

The wave field at the study region is characterized by a 2D wave action spectrum which enables the model to represent the wave growth caused by wind or the presence of swell. In this paper, one considered the waves to propagate in stationary mode over a rectangular grid with Cartesian coordinates.

The required data to run the SWAN model are the bathymetry of the study region and the boundary conditions at the domain entrance, in addition to a set of computation parameters. Among the several results produced by SWAN it is worth mentioning the significant wave height, the average and the peak periods, the directional spreading, the bandwidth parameter and the mean water level at any point of the defined computational domain.

4.2 APPLICATION OF THE SWAN MODEL

4.2.1. GENERAL

In this section one describes the numerical calculations made with SWAN model to reproduce the wave characteristics observed along the days of the campaigns. For the application of model, the following steps were taken:

1. Use the wave conditions given by the WWIII model (Tolman, 2002) as SWAN offshore wave conditions.
2. Computation of wave characteristics (HS, TZ, Θ) at different point locations (as closest as possible to the measuring equipment), by using SWAN model, for the period in study.

The comparisons between numerical and measurement data, as will be described in 4.3, enables one to evaluate the performance of the numerical model and its adequacy to characterise the waves in this region.

4.2.2. OFFSHORE SEA STATE

The offshore sea state estimates used in this study were produced by the Global Ocean Data Assimilation Experiment (GODAE, 2010), as output of the WWIII model. These data contain the following wave parameters: HS (significant wave height), TZ (mean wave period) and Θ (wave direction), obtained every 3 hours, referring to the period from 2009-05-11 to 2009-05-13 and from 2009-09-07 to 2009-09-09 at grid points located at nodes: 38ºN10W and 37ºN10W, which were found to be the closest (wet) points to the Amoreira beach, see Figure 14.

Once the offshore sea state estimates are known, characterized by its significant wave height, HS, peak period, TP, and average direction at the peak period, or peak direction, DIR, the SWAN model is able to transfer these values to the Amoreira beach.

4.2.3. Computational domain and Model conditions

The computational domain of the numerical model SWAN was discretized by means of three rectangular grids, Figure 14. The larger grid (SWAN 1st mesh) is 60 km long and 20 km wide and is made of square cells, 500 m-wide. The medium grid (SWAN 2nd mesh) is 8 km long and 3 km wide and is made of square cells, 50 m-wide. The smaller, nested, grid (SWAN 3rd mesh) is 1.2 km long and 1 km-wide and has a resolution of 5 m.

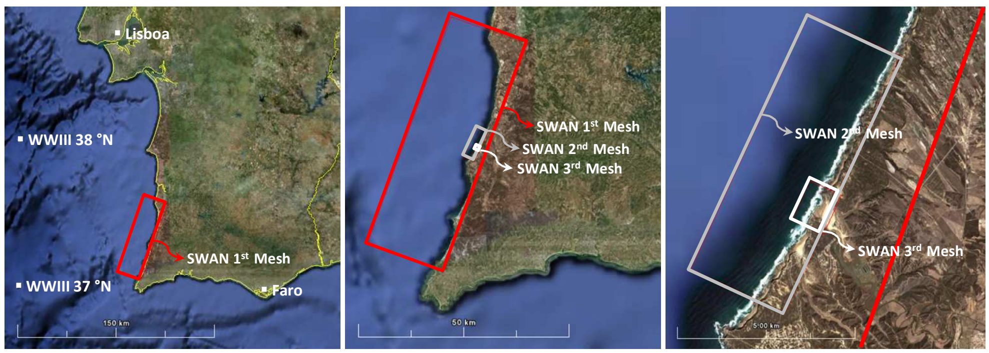


Figure 14 - WWIII offshore points (left) and SWAN computational domains (center and right).

The bottom computational grids at the region adjacent to Amoreira beach were based upon:

- The Portuguese Hydrographic Institute chart no. 6, scale 1/150 000, Portuguese Coast, from Cabo de Sines to Cabo de São Vicente.
- Bathymetry surveys – May 2009 and September 2009, Figure 15.
- Bathymetry survey from the BayBeach Project (PTDC/CTE-GEX/66893 /2006).

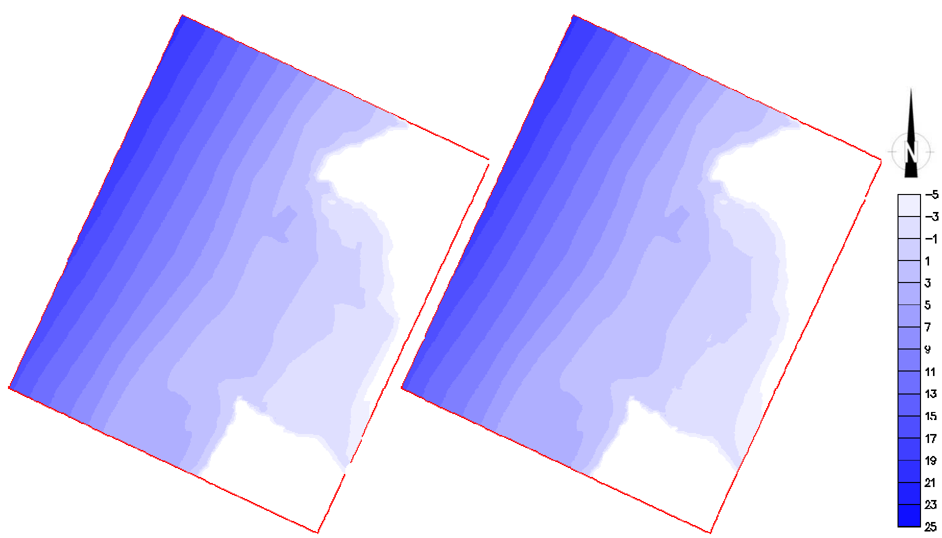


Figure 15 - Bathymetry surveys, as of May 2009 (left) and September 2009 (right).

Note that the 1st and 2nd grids were both used in the simulations of May and September, while two different 3rd type grids were constructed separately for May and September based on associated bottom topographies.

Following some sensitivity tests made with the SWAN model to check the parameters related with wave breaking (varying from 0.5 to 0.8) and the bottom friction (varying from 0.2 to 0.5), as well as the type of frequency spectrum (JONSWAP and GAUSS), the model was executed for the following conditions:

1. The SWAN 40.72 version was considered, using a stationary mode, with no consideration of currents or winds.
2. A directional spectrum was defined by a JONSWAP spectrum with 21 frequency intervals and a directional discretization of ~10º covering the whole 270º range.
3. For each hour, the tide level varied along the beach according to the values observed in Sines harbour (about 65 km to the North), during the study periods.
4. The wave breaking coefficient was kept constant: 0.65 for the May simulations and 0.8 for the September simulations.
5. The Law of Madsen was used for the bottom friction parameter: 0.05.
6. The offshore wave conditions defined by WWIII at point 38N10W were considered since no significant differences were observed between the values for that point and point 37N10W.

Based upon the above conditions, the set of simulations made with the SWAN model includes the three days on May (11 to 13) and the three days on September (7 to 9), considering the offshore wave conditions defined by WWIII at the boundaries W, N and S of the first grid, for point 38N10W, see Figure 16.

Although the wave periods are quite similar in both periods of time, the wave heights are higher from 11 to 13 of May (around 2.0 m) than from 7 to 9 of September (around 1.5 m). Concerning the wave directions, they are found to vary more significantly and to be less perpendicular to the bathymetry during May than during September.

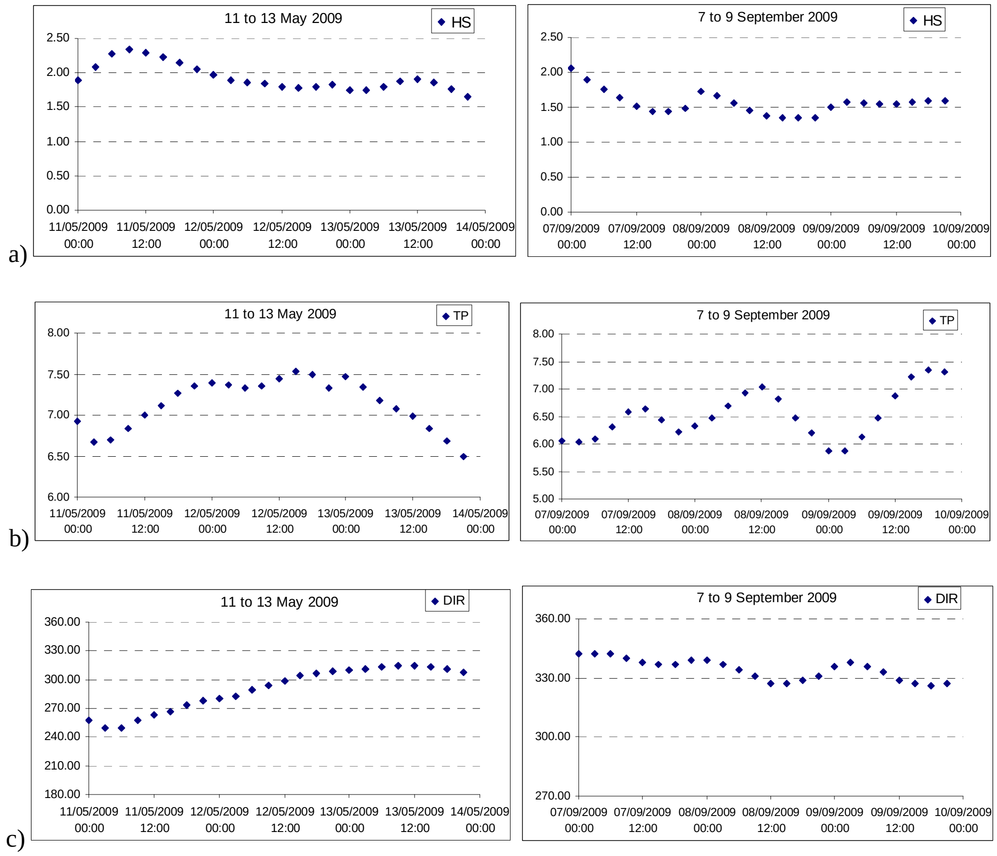


Figure 16 – WWIII results on May (11 to 13) and on September (7 to 9) 2009 at point 38N10W.

The simulations were made for each hour of the considered periods, which involved 72 (3x24) calculations. Since the values of the WWIII model are 3 hourly-taken, the sea state during that period was considered to be unmodified and therefore the wave condition values were kept constant in that period, which is somewhat a simplification.

SWAN results at any point of the computational domain are the significant wave height (HS), average period (TZ), peak period (TP), mean direction (Θm), peak direction (Θ), wave length (L) and directional spreading. In particular, one obtained HS values at P11, P15 and P16 positions.

To illustrate this procedure, Figure 17 shows the SWAN results at a) May, 12, 16:00 (HS=1.78 m, T=7.53 s, DIR=310º and b) September 9, 21:00 (HS=1.35 m, TP=6.82 s, DIR=327º).

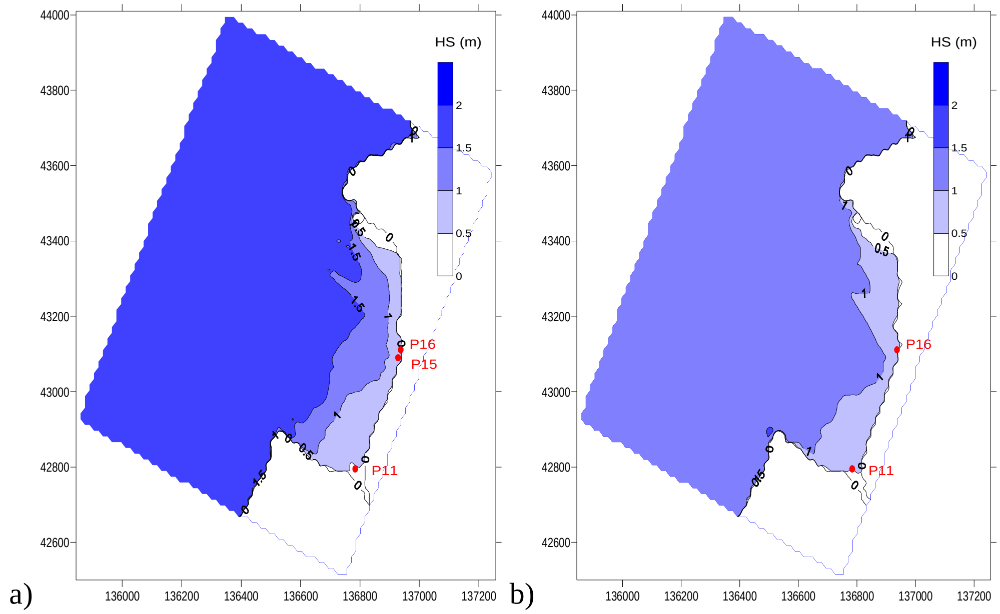


Figure 17 – SWAN results. HS as of a) May, 12, 16:00; b) September 9, 21:00.

As it can be easily observed in this figure, there is a decrease of the significant wave height as the wave propagates inshore. Since the incident wave height is more significant in May, the values near the beach are higher than the corresponding ones of September.

4.3 RESULTS, COMPARISONS AND DISCUSSION

Figure 18 and Figure 19 show the HS values produced by SWAN at positions P11, P15 and P16 for days 11 to 13, May, 2009, considering the offshore wave conditions, and the corresponding in-situ measurements ("HS_num (SWAN)" and "HS_meas", respectively).

The same is shown in Figure 20 and in Figure 21, for positions P11 and P16, for days 7 to 9, September, 2009, considering the offshore conditions.

Note that all the numerical values (from SWAN model) were obtained considering a wave breaking coefficient equal to 0.65, for May 2009, and 0.8, for September 2009.

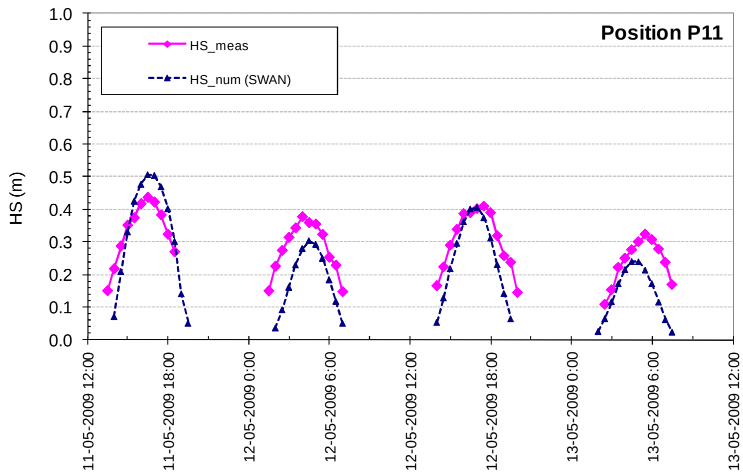


Figure 18 – May, 11 to 13, 2009. Comparisons between measured, HS_meas, and SWAN, HS_num (SWAN), values at position P11, for offshore wave conditions at point 38N10W.

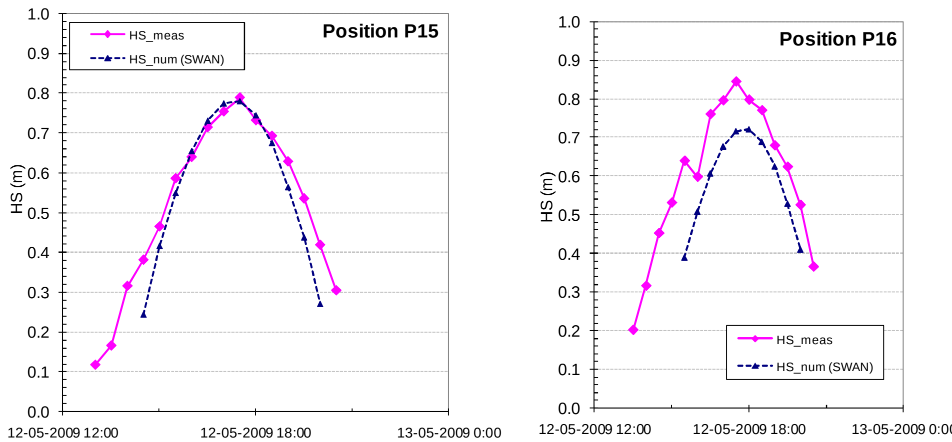


Figure 19 – May, 11 to 13, 2009. Comparisons between measured, HS_meas, and SWAN, HS_num (SWAN), values at positions P15 & P16, for offshore wave conditions at point 38N10W.

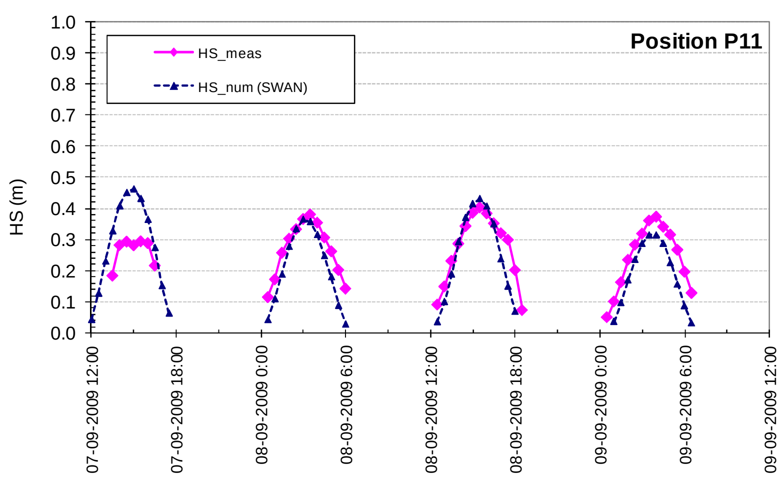


Figure 20 – September, 7 to 9, 2009. Comparisons between measured, HS_meas, and SWAN, HS_num (SWAN), values at position P11, for offshore wave conditions at point 38N10W.

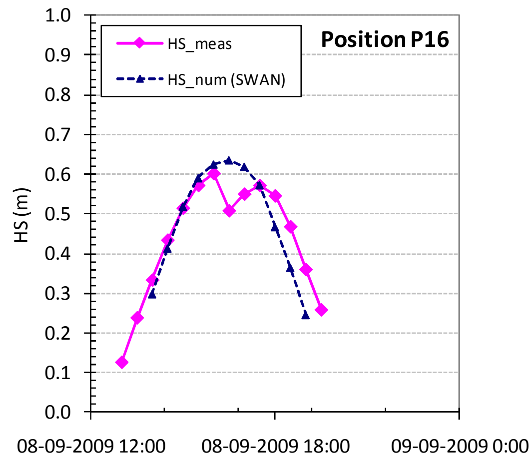


Figure 21 – September, 7 to 9, 2009. Comparisons between measured, HS_meas, and SWAN, HS_num (SWAN), values at position P16 for offshore wave conditions at point 38N10W.

These figures show that, for the two days of simulations shown in this paper:

- The general trend of the significant wave height values estimated using the numerical model SWAN is very similar to that obtained in the analysis of measured values, for both periods of May and September and for all positions P11, P15 and P16. Moreover, in general, the numerical and measured values especially agree for the September period.
- In more detail one can observe that:

  Campaign #2: 11 to 13May, 2009. The numerical results are similar to the measured ones in both positions but, in general, are lower than the observed ones. This is more apparent for position P11, a location where the water depth is quite small and almost in the middle of the Aljezur stream. These location constraints (currents and tide flow), that occur in nature, are not simulated with SWAN. This model's limitation can explain some of the observed differences.

  Campaign #3: 7 to 9 September, 2009. The trend of numerical and measured values agree quite well. However, some differences do occur between some particular values, mainly for position P11.

It is important to note that several sources of error were identified in the numerical results:

- Due to the lack of information, the simulations were made for offshore wave conditions' values only. These conditions were kept constant for a period of three hours, although the tide varied each hour. This is a simplification that may be responsible for the differences one observed between numerical model results and the measured data.
- The tide values are associated to the Port of Sines which is about 65 km far (to the North) from the Amoreira beach, so that a tide shift between the two places is expected, which may also contribute to the observed differences between numerical and measured values.
- No wind, diffraction or currents were considered in the simulations.
- Last but not the least, point P11 is located at the entrance of the Aljezur stream, and so is strongly influenced by the stream generated by local currents. This is a condition that was not considered by the SWAN model.

As a final note, it should be emphasised that also the in-situ measurements are subjected to many sources of error or inaccuracies. These, together with the above numerical errors, are likely to justify the observed differences in the above comparisons.

5 CONCLUSIONS

In this paper, one described the wave data collection campaigns carried out on the Amoreira beach, the analysis methodologies used for that data and a number of simulations made with SWAN model for the period's campaigns, under the project MADyCOS.

The results one obtained comparing the time and spectral analyses enabled one to draw the following conclusions:

- For all campaigns and for all instruments, the behaviour of parameters HS and HM0 was found to agree very well.
- For campaigns #2 and #3, the behaviour of Tmed and TZ are similar. However, values of period coming from the time analysis (Tmed) are systematically higher than corresponding values of period coming from the spectral analysis (TZ).

- For positions P15 and P16, in campaign #2, there were no significant differences between both significant wave heights and both wave periods. This was expected due to the proximity of the position of pressure sensors, and that was the reason why only one sensor was used on that area in campaign #3.

From the above, and considering the data produced within the three referred campaigns only, one can conclude that for the calculation of wave heights, both time and spectral procedures produce similar results. The same does not seem to be true for the periods, where spectral analysis produced values for this parameter significantly lower than for the time analysis. The reason for this difference may lie in the formulae used in the spectral method, which implicitly (through the spectral moments), consider all the waves in the record, however small they are, while the direct method, used in time analysis, only consider waves that cross the mean level in the upward direction, and do not take into account all the small oscillations occurring only above or only below that intersection level.

Concerning the comparisons between measured data and numerical simulations made with SWAN, one may conclude the following:

- The general trend of the significant wave height values estimated using the numerical model SWAN is very similar to those measured in-situ, for positions P11, P15 and P16.
- In particular for campaign #2, from 11 to 13 May, 2009, the numerical results are similar to the measured ones in both positions but in general are lower than the observed ones, whereas for campaign #3, from 7 to 9 September, 2009, the trend and the values are quite similar. However, in both cases the major differences occur for position P11, which is located in almost the middle of the Aljezur stream.

Finally, the SWAN model has shown to be a tool quite adequate to predict the wave conditions at Aljezur, and therefore its application to a wide range of wave conditions can contribute to a better wave regime in this area to be established.

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