LABORATÓRIO NACIONAL
DE ENGENHARIA CIVIL

MOSAIC.PT FIELD CAMPAIGNS

Cova-Gala beach, March 2020

REPORT 347/**2020 – DHA/NEC**

Work performed with:

universidade de aveiro

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MOSAIC.pt – Multi-source flood risk analysis for safe coastal communities and sustainable development
FCT – Fundação para a Ciência e a Tecnologia

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R&D HYDRAULICS AND ENVIRONMENT

REPORT 347**/2020 – DHA/NEC**

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Title

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MOSAIC.PT FIELD CAMPAIGNS

Cova-Gala beach, March 2020

Abstract

The present report describes a fieldwork campaign that took place within the scope of the project MOSAIC.pt. The campaign was performed in March 2020 at Cova-Gala beach. Cova-Gala beach is located south of the entrance to Figueira da Foz harbour, along central Portugal western coast. The campaign aimed to acquire hydrodynamic and topographic data on the subaerial beach cells between the groynes in front of Cova urbanization's waterfront promenade. These data aim to validate numerical models to simulate hydro- and morphodynamics.

Keywords: Topographic survey / Photogrammetric survey / Hydrodynamic measurements

CAMPANHAS MOSAIC.PT

Praia da Cova-Gala, março 2020

Resumo

O presente relatório descreve um trabalho de campo realizado no âmbito do projeto MOSAIC.pt. A campanha foi realizada no mês março de 2020 na praia da Cova-Gala. A praia da Cova-Gala encontra-se a sul da entrada do porto da Figueira da Foz, na costa ocidental de Portugal, Região Centro. A campanha teve como objetivo a aquisição de dados hidrodinâmicos e topográficos na praia subaérea das células sedimentares entre os esporões em frente ao passeio marítimo da zona urbana da Cova. Os dados visam a validação de modelos numéricos para simulações hidro- e morfodinâmicas.

Palavras-chave: Levantamentos topográficos / Levantamento fotogramétrico / Medições hidrodinâmicas

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1 | Introduction

1.1 Campaign objectives

1.1.1 MOSAIC.pt project

The MOSAIC.pt (PTDC/CTA-AMB/28909/2017) project is led by the Portuguese National Laboratory for Civil Engineering (LNEC) in partnership with the Centre for Social Studies from the University of Coimbra. The project aims to develop an innovative flood risk management framework for coastal zones, including estuaries, based on the integration of predictive models and real-time monitoring data, and taking into account the different dimensions of vulnerability. More information about the project team, approaches and results is provided at: http://mosaic.lnec.pt/.

In order to validate the process-based models used in the project, a three-day field campaign took place from 10 to 12 of March 2020 at one of the project study sites: Praia da Cova-Gala, an oceanic beach south of the entrance to Figueira da Foz harbour. The main objectives were to:

- collect hydrodynamic data to compare with simulated nearshore waves and currents;
- collect aerial and topographic data contemporaneous with the hydrodynamic data;
- test new sensors to provide real-time elevation data for the continuous validation of a forecast system.

Some data collection also took place at the S. Pedro de Moel area, which will be reported in a separate document.

Over the three days of fieldwork, an array of pressure sensors and current meters was deployed on the intertidal area of two adjacent beaches with contrasted morphologies, and the intertidal beach topography was surveyed three times, at 24h interval and over ~2-km extension. Two alternative sensors for water levels were tested in the Mondego Estuary close to its inlet.

1.1.2 Collaborative actions

At least three other local project/activities are relevant for MOSAIC.pt and the data presented in this report are expected to be useful beyond the project itself:

- For navigation purposes, harbour authorities dredge an average annual volume of about 150.000 to 300.000 m^3 from the harbour entrance. Additional dredge interventions are performed in inner channels of the harbour. The sediments are deposited in front of the Cova-Gala beach. This operation impacts wave refraction and breaking, and sediments are progressively released to the shore;
- Project NAVSAFETY, led by Paulo Baptista from the University of Aveiro (UA), aims to develop a service to estimate in real time mode the elevation of the submerged sand bar in front of the harbour channel as well as the local wave parameters (wave height, wave period and

associated direction) through the use of remote sensing tools (satellite images and video-monitoring stations);

- A PhD thesis on the modelling of the morphological impact of coastal structures is currently being prepared by João N. Oliveira, who is using the Cova-Gala beach as a testbed.

Given these shared interests, the campaign integrated both MOSAIC.pt team members, members of UA's Centre for Environmental and Marine Studies (CESAM) and the referred Ph.D. student, targeting the sharing of the effort, monitoring equipment and resulting data. Furthermore, Theo Moura participated in the campaign to test a low-cost directional wave buoy. However, the wave buoy could not be deployed because of the size of the waves.

1.2 People involved

Beyond LNEC's team members, six people from the University of Aveiro as well as one independent researcher participated in the fieldwork (Table 1.1).

Table 1.1 – People involved in the campaign

Group	***Participants***	***Main tasks***
LNEC / NEC Estuaries and Coastal Zone Unit	Alphonse Nahon André Fortunato Paula Freire Filipa Oliveira João Oliveira Luís Pedro Alberto Azevedo	Campaign conception & coordination Hydrodynamic deployment GNSS survey / georeferencing GNSS survey Hydrodynamic deployment Hydrodynamic deployment Video camera (São Pedro de Moel)
LNEC / GTI Information Technology Group	João Rogeiro Gonçalo Jesus Anabela Oliveira	Remote sensing tidal gauge Video camera (São Pedro de Moel) Camera and tidal gauge acquisition
LNEC / NGA Applied Geodesy Unit	Maria João Henriques Hugo Silva José Santos	Drone survey Drone survey Drone survey
UA / CESAM Centre for Environmental and Marine Studies	Paulo A. Silva. Paulo Baptista Rita Cavalinhos Tiago Oliveira Diogo Santos Thiago Gavazzoni	Coordination Quad survey GNSS survey / Hydrodynamic deployment Hydrodynamic deployment Hydrodynamic deployment Hydrodynamic deployment
Independent researcher	Theo Moura	Hydrodynamic deployment

1.3 Campaign organization and report structure

The fieldwork was planned to be carried out during the low tide of three consecutive mornings. The first day was dedicated to the installation of the hydrodynamic instruments (NEC and UA teams), the georeferencing of the equipment (NEC) and the survey of the intertidal beach (UA). On the first rising tide, a major issue occurred as several beach instruments were removed by the sea. Instruments were ripped out by plunging waves in a violent shorebreak that formed with the rising tide: with higher water level, wave dissipation over offshore bars progressively diminished and most of the incoming wave energy was dissipated in a very narrow area and over the instruments. Although no such shorebreak formed on the neighbouring dissipative beach, the remaining ones were recovered during the first night (NEC-UA). The second day was dedicated to the drone flight over the study area (NGA) and to the acquisition of water elevation data on the Mondego Estuary side (GTI). No more instruments were deployed on the last day so it was dedicated to the survey of the beach (NEC).

This report is divided into three sections, besides the present introduction and a short conclusion. The next section describes the study area and the forecasted metoceanic conditions during the campaign (2 |). Then Section 3 | presents the hydrodynamic and topographic acquisitions. Section 4 | describes the data and its preliminary analysis. Finally, the conclusion presents a brief evaluation of the campaigns.

2 | Study area and metocean conditions

2.1 Beach of Cova-Gala

Cova-Gala is an open-ocean beach situated south of the entrance to the Figueira da Foz harbour (Freire *et al.*, 2019). The harbour was built inside the Mondego River estuary (Figure 2.1). The now jettied river mouth partially interrupts the north-to-south littoral drift. The beaches south of the southern jetty suffered erosion which however has decreased over the last years. The northern sector of the beach, or sedimentary cell, is mostly backed by sand dunes. At south, cross-shore groynes (E1-E5, Figure 2.1) delineate four sedimentary cells in front of the Cova urbanization, three of which are equally backed by alongshore defence structures / seawalls (DL2-DL4, Figure 2.1). South of the last breakwater (E5) starts the south section of the beach, approximately 250 m of exposed geotextiles sandbags protect the sand dunes. The study area consists of this 2.2 km coastal stretch from the southern jetty of the river mouth to the south limit of the sandbags (south of E5).

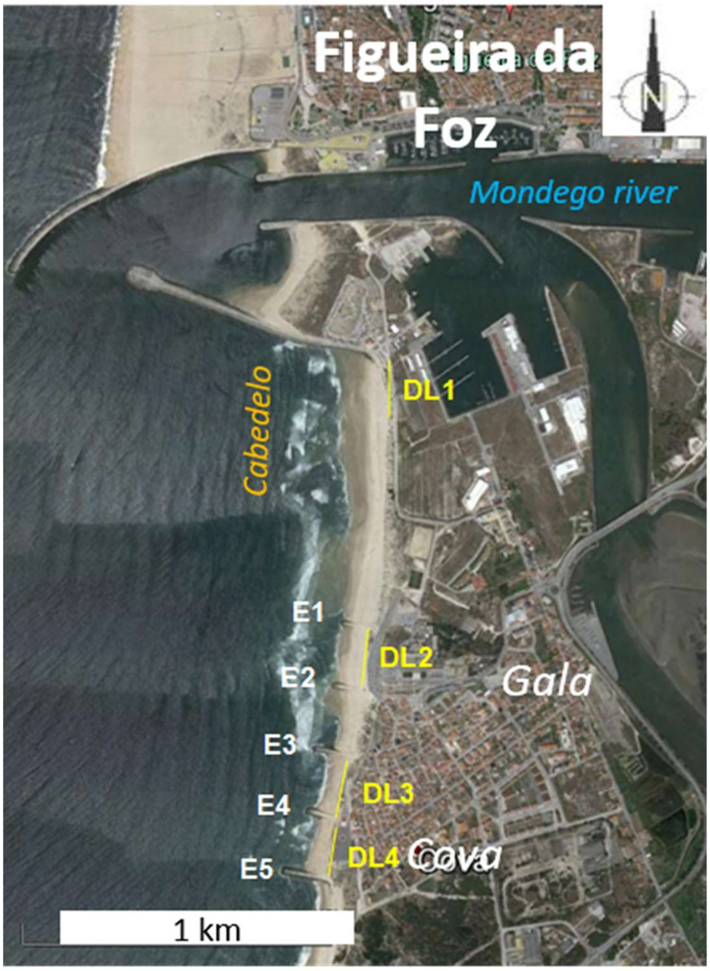

Figure 2.1 – Study area. Google Satellite view of the Figueira da Foz harbour and the coastal stretch of Cova-Gala, with its four alongshore defence structures (DL1 to DL4) and five groynes (E1 to E5)

2.2 Metocean conditions

The campaign was scheduled during the spring tides of March Equinox; the tidal range varied from 3.3 m to 3.5 m (Figure 2.2). The campaign took place under fair weather conditions with predominantly light offshore (easterly) winds in the morning and stronger northerlies in the afternoon (Figure 2.3). The sea state was dominated by clean and long period WNW swells.

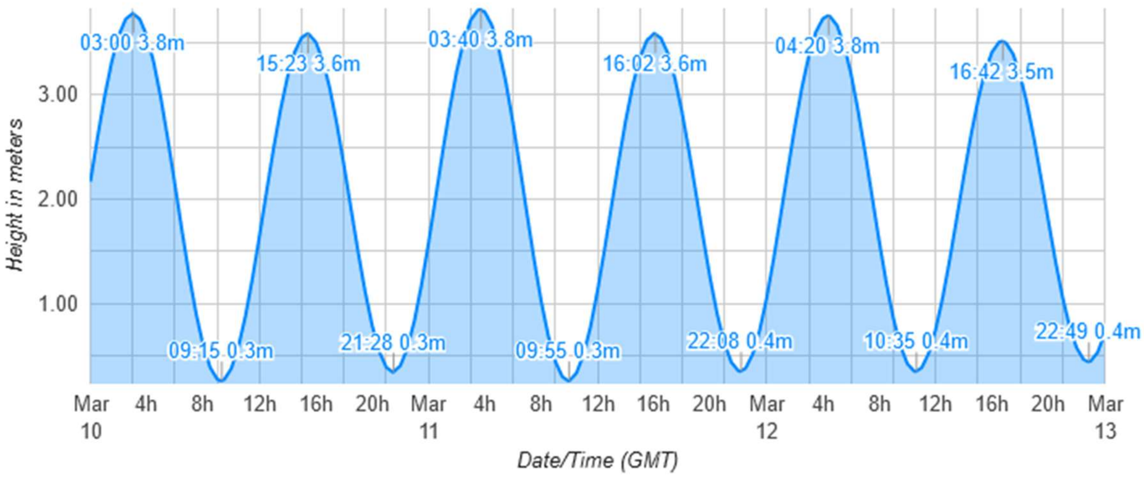

Figure 2.2 – Tide level predictions for Figueira da Foz harbour, relative to chart datum (source: https://www.worldtides.info)

WG	Tu 10. 04h	Tu 10. 06h	Tu 10. 08h	Tu 10. 10h	Tu 10. 12h	Tu 10. 14h	Tu 10. 16h	Tu 10. 18h	Tu 10. 20h	Tu 10. 22h	We 11. 04h	We 11. 06h	We 11. 08h	We 11. 10h	We 11. 12h	We 11. 14h	We 11. 16h	We 11. 18h	We 11. 20h	We 11. 22h	Th 12. 04h	Th 12. 06h	Th 12. 09h	Th 12. 12h	Th 12. 15h	Th 12. 18h	Th 12. 21h
Wind speed (knots)	3	3	3	3	4	7	7	6	5	5	4	4	4	3	5	8	9	9	8	8	8	8	10	10	13	12	11
Wind gusts (knots)	5	5	5	6	7	10	11	11	8	8	5	5	5	5	7	11	13	14	13	13	12	12	16	14	18	20	19
Wind direction (→)	↙	↙	←	←	↘	↘	↘	↓	↓	↓	↙	↙	←	↙	↓	↘	↓	↓	↙	↓	↓	↓	↓	↓	↓	↓	↓
Wave (m)	2.3	2.3	2.2	2.1	2	1.9	1.9	1.9	1.9	1.8	2	2	2.2	2.3	2.3	2.4	2.4	2.4	2.4	2.4	2.3	2.4	2.7	2.8	2.9	3	3.3
Wave period (s)	12	12	12	12	12	12	12	12	12	12	16	16	15	15	15	15	15	14	14	14	13	13	14	13	13	13	12
Wave direction (→)	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘

Figure 2.3 – Local wind and wind-wave forecast (source: https://www.windguru.cz/827)

3 | Material and methods

3.1 Intertidal hydrodynamic data

The main objective of the campaign was the acquisition of hydrodynamic (wave and current) data. As to fit with the project objectives, the decision was made to place instruments on two adjacent cells (Figure 3.1) that differ from one another: one is backed by a sand dune (northern cell, between groynes E2 and E3) and the other by an alongshore seawall (southern cell, between groynes E3 and E4).

Figure 3.1 – Hydrodynamic instruments deployment at Cova-Gala: Google Satellite view of the instrumented beach cells with the position of all deployed instruments, solid lines are the respective coastlines (in blue: sand dune foot; in red: seawall toe)

Figure 3.2 – Hydrodynamic instruments deployed at Cova-Gala: Top, south-to-north view of the northern cell where the array of PTs is being installed; Middle, photos of the anchored ADP and PUV1 structure; Low, photos of PUV2 structure and view of the southern cell and its alongshore seawall

Overall, seven structures were installed (Figure 3.2):

- four pressure transducers (PT) were mounted on single screw anchors;
- two PUV, composed of a pressure (P) transducer and an electromagnetic current (UV) meter, were mounted on tripods composed of three screw anchors and horizontal bars;
- one current profiler (ADP) was mounted on a single screw anchor and was anchored to a 20 x 20 x 20 cm^3 concrete block; the ADP's X axis was aligned in the alongshore direction oriented northward.

3.2 Testing of remote sensors for water level measurement

On 11 March, two new sensors were deployed on the harbour side of the Cabedelo beach (Figure 3.3). The sensors were perched on a pole overlooking a still water surface. Each sensor was connected to power and data storage devices and operated over a period of 8 hours.

- LiDAR: **TeraRanger Evo 60m** model from Terabee, reach: 60 m, sampling freq.: 240 Hz;
- Echo sounder: developed within LNEC project **UBEST**, has a reach of 10 m, it was programmed to make 5.5 acquisitions per minute, each acquisition consisting of 10 sampled measurements.

Figure 3.3 – Left: Location of the remote sensing tidal gauges within the harbour; right: perched sensors

3.3 Aerial and topographic surveys

Over the three days, three surveying methods were employed. This was mainly for logistic purposes although each method has its own advantages and limitations:

- A GNSS system mounted on a motor quad bike allowed the fast survey of the intertidal beach but with a limited access to areas closest to the waterline and no coverage of the dunes;
- The UAV system allowed a detailed survey of the dunes and the coastal structures, however with a consequent on-field effort. Plus, the post-processing of the data is also relatively time consuming;
- The backpack GNSS system is very quick to be deployed and allows to cover areas either close to the waterline and on top of dunes of coastal structures, although with a survey point density relatively low compared to other acquisition methods.

3.3.1 Quad GNSS survey and instrument georeferencing

The first survey was carried out on March 10 during the morning low tide; it covered the area from the river mouth southern jetty to the southernmost groyne (E5) in Cova. The integrated system of high spatial resolution INSHORE was used. It was adapted to a quad vehicle (Figure 3.4A). The INSHORE survey system consists of a metallic structure that holds a set of sensors. The objective of the system is to determine, with a high level of accuracy, the three-dimensional coordinates of points in the ground surface. The structure has a triangular shape with two vertices fixed along the side of a motor-quad; the third vertex points horizontally out of the vehicle. Over each of the three vertices, a dual-frequency (L1/L2) GPS antenna is connected to high grade GPS receivers (that store the raw data received from the GPS satellites); the outer antenna is the one that is used as the coordinate reference (Figure 3.4A). Additionally, a laser sensor synchronized with the GPS antenna is used to measure the vertical distance between the outer antenna and the ground surface.

A fourth GPS receiver is installed over a fixed point near the survey site so that differential GPS processing can be performed. The base antenna of this receiver was placed at a previously georeferenced point (COVA-GALA-1A, Figure 3.1). The positions of the phase centre of the outer antenna are then determined through dedicated GPS processing software, fixing the L1/L2 ambiguities, which lead to instantaneous positions. As a result, the coordinates of the terrain surface are determined with an accuracy of 2 to 3 centimetres (Baptista et al., 2011). In addition, in areas not accessed by the INHORE system, a GPS-RTK (Real Time Kinematic GPS) receiver (Trimble R8) was carried on foot by the operator, using a stick with a wheel that allows the distance to the terrain to be kept constant (Figure 3.4B). The total survey extended 1600 meters and consisted of a set of cross- and alongshore profiles for a total of 3750 points (Figure 3.4C).

Figure 3.4 – Quad survey. Upper left panel: Quad-mounted GNSS antenna; lower left panel: Wheel mounted GNSS antenna; right panel: Post processed survey points

3.3.2 UAV photogrammetric flight

The second survey was carried out by drone on March 11; a series of flights covered the entire area during the morning low-tide. A quadcopter (drone) DJI Inspire I V2 was used with a camera Zenmuse X3, a remote control with a tablet and six batteries (Figure 3.5). The six flights were performed at a height of 50 m. A total of 1276 photos were taken. The overlap (longitudinal and transversal) was 80%. To georeference the final products (point cloud, orthomosaic and digital surface model) and to improve the quality of these, 53 ground control points were established. To control the quality, 19 additional points were established.

To georeference these points, a pair of GNSS antennas were used in RTK mode (one antenna was successively fixed on a tripod at three different locations; the other was mobile and was placed over the points using a pole). In the office, the data registered by the fixed antenna was processed using the software Pinnacle. Data from the nearest national GNSS reference stations were integrated. This allowed the definition of more accurate coordinates for the base and the improvement of the coordinates of all the other points, the ones coordinated by RTK.

The photographs, and the coordinates of the ground control points, were processed by the software Agisoft Metashape V1.6.2. The following items were produced: i) a dense point cloud with about 7 GB; ii) an orthomosaic with a pixel of 2 cm; iii) a digital surface model in a grid format with distance of 1 m between nodes, for purposes such as beach morphology analysis and numerical modelling. The point cloud and the orthomosaic were subsampled to create lighter files, more usable by analysis software.

Figure 3.5 – Upper panel: drone operator; lower panel: camera locations and photo overlap during the drone survey of Cova-Gala beach on 11/Mar/2020

3.3.3 Backpack GNSS survey

The third and last survey took place following 4 high tides, on 12 March morning. It was performed using LNEC's TOPCON antennas. The base antenna was placed at a previously georeferenced point (COVA-GALA-1A, Figure 3.1); it was started in RTK-PP mode in case some post-processing became necessary. Then the rover antenna was mounted on a backpack and programmed to register a point (RTK-fixed) every second. Overall, 4015 points were collected over an area of approximately 0.11 km^2, corresponding to a point density of ~0.037 $pt.m^{-2}$.

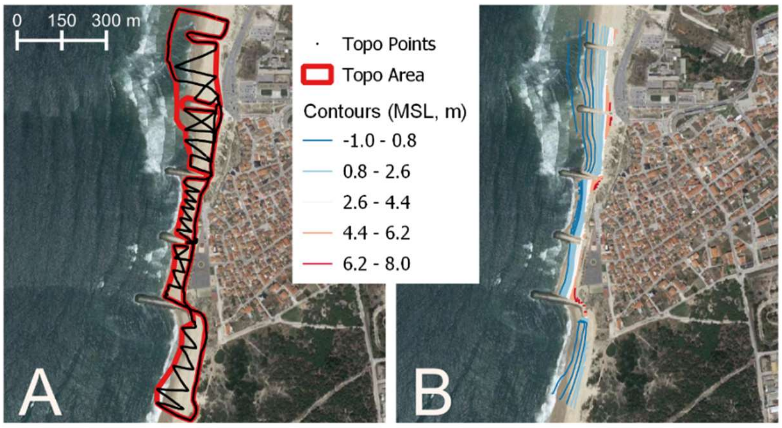

Figure 3.6 – Left panel: survey point and contour of the surveyed area on March 12; right panel: interpolated contour lines

4 | Results

4.1 Hydrodynamic data

Some details on the data processing are given in ANNEX I.

4.1.1 Southern cell - Alongshore wall

Figure 4.1 presents raw and low-pass filtered elevation data derived from ADP's pressure measurements. The low-pass filtered data reveal the instant when the structure came off the ground, approximately after burst number 10 and apparently following the high tide. At this instant, the significant wave height in the gravity band was in the order of 1.7 m while infragravity waves close to 1 m height were also present.

Figure 4.2 presents alongshore (u, positive northward) and cross-shore (v, positive westward /offshore) velocities synchronised with the pressure measurements.

Nine-min averaged velocity profiles on Figure 4.3 suggest velocities were quite homogeneous over the water column and primarily directed northward and eastward (onshore).

Unfortunately, the PUV1 structure was recovered without the sensors.

Data from the PUV2 are shown on Figure 4.4. Both velocity and pressure measurements indicate the structure came off shortly after 13:00. So the velocity record is limited to 2 20-min bursts during which the sensor still emerged several times. Significant wave heights in both gravity and IG bands are coherent with the ADP's measurements. Mean surface heights diverged from the ADP measurements. Because of significant inconsistencies between the ADP record and model results (not shown), data from the PT record seem more reliable.

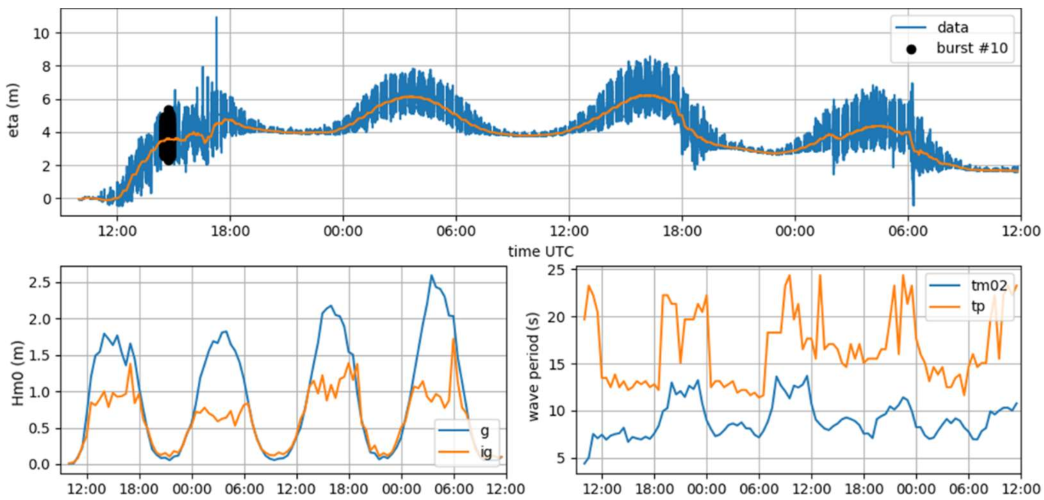

Figure 4.1 – Water levels and mean sea state parameters, record starts on March 10, 11:00 UTC. Upper panel, free surface elevation derived from the ADP pressure transducer measurements; Lower left, significant wave height estimated by integrating the spectral energy in gravity (g) and infragravity (ig) bands; Lower right, spectral mean and peak periods in the gravity band

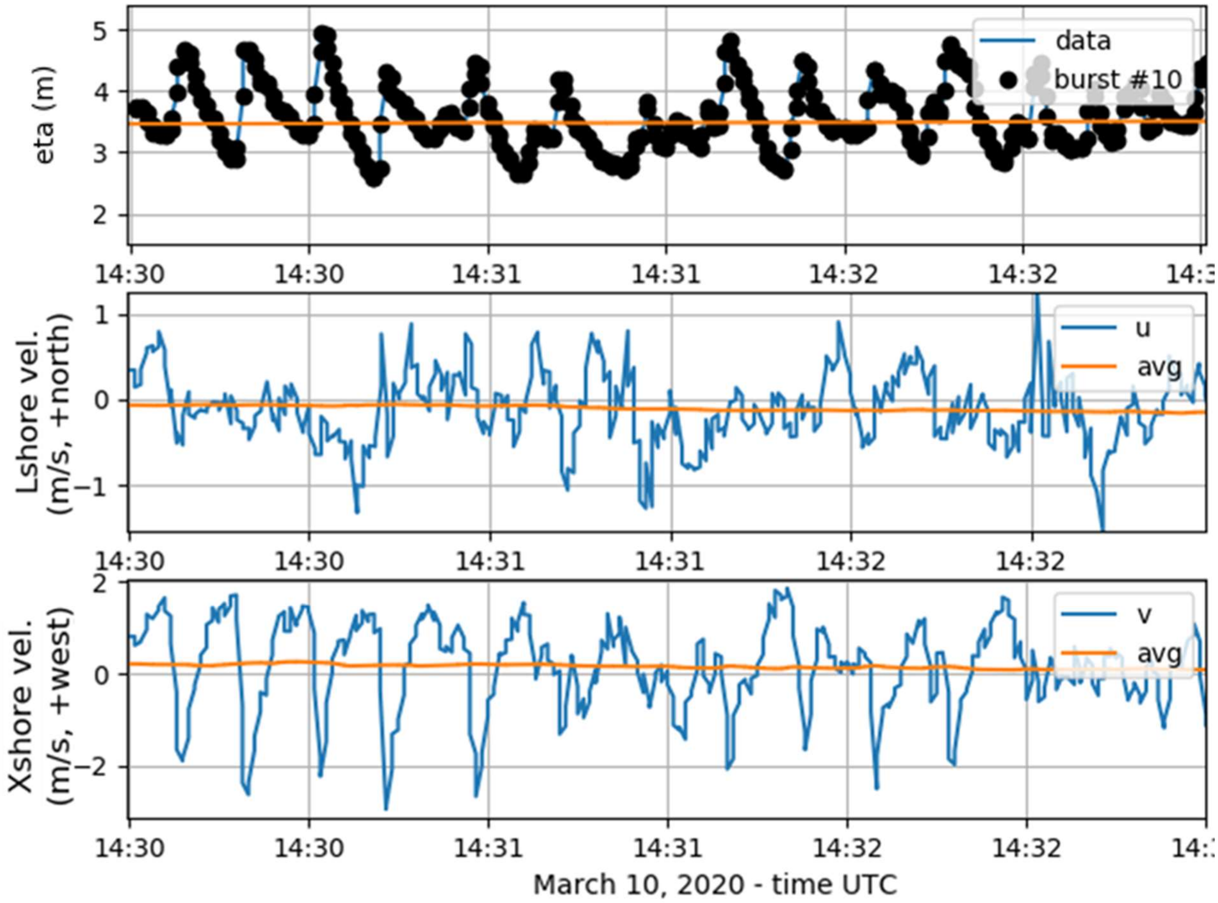

Figure 4.2 – Velocity measurements during ADP's wave burst #10. Upper panel, free surface elevation derived from the ADP pressure transducer measurements and absolute mean surface elevation; Middle, 2 Hz and 3 min averaged alongshore velocity, positive towards north; Lower, same as middle for cross-shore velocity, positive offshore

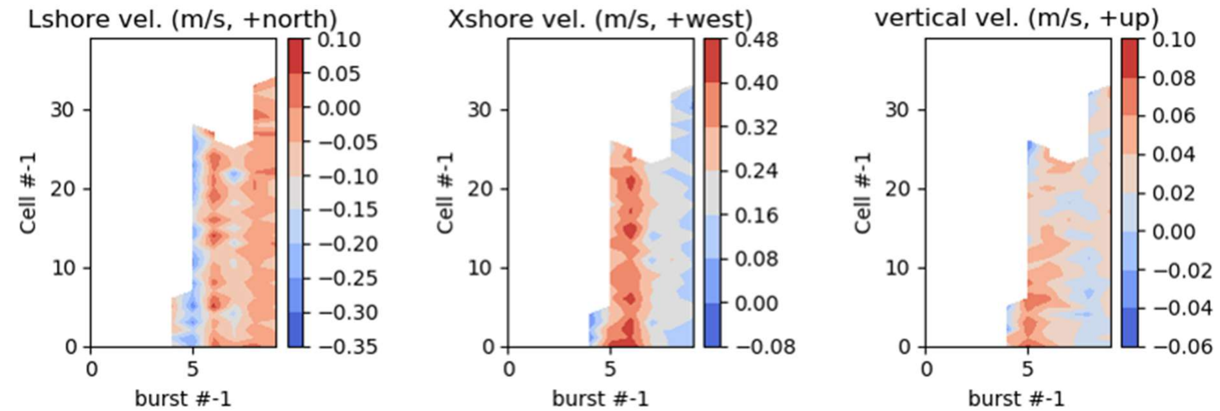

Figure 4.3 – Nine-minutes 3D velocity profiles during the first 10 bursts at 30-interval

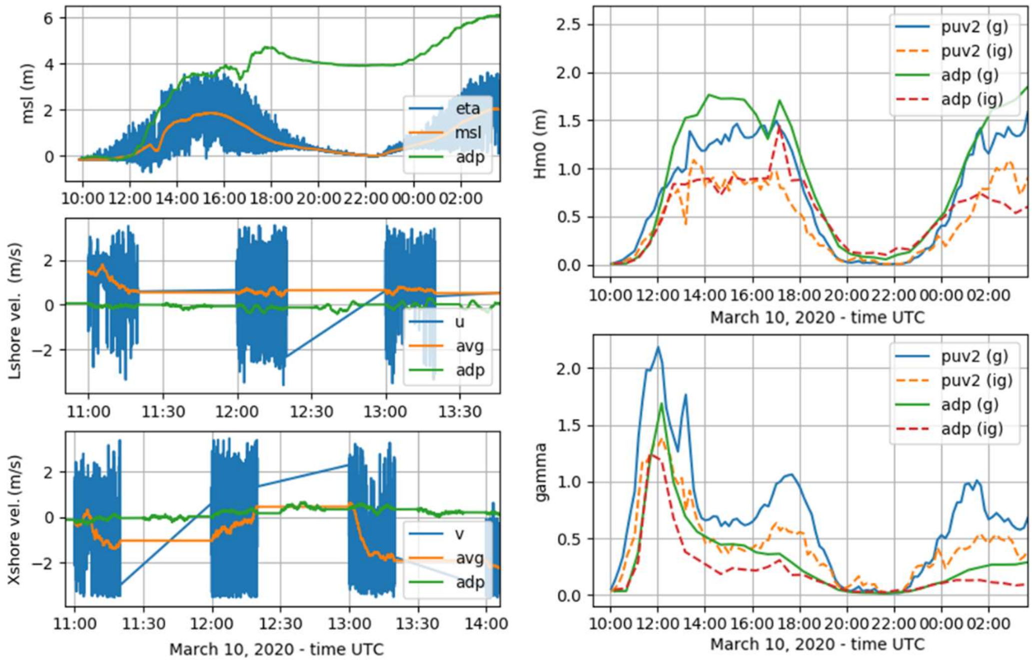

Figure 4.4 – PUV2 measurements, msl is relative to the National Altimetric Datum of 1938

4.1.2 Northern cell - Sand dune

PT measurements from the 4 locations on the beach cell backed by a sandy dune were used to compute mean surface elevations as well as mean sea state parameters in the gravity and infragravity bands. Considering that all sensors were placed at 15 cm above ground, as specified on Paula Freire's notes (see appendix 6.2), PT1, PT2 and PT3 present some vertical discrepancies: around high tide PT1's surface is ~7 cm below PT3's one, and ~11 cm above PT2's one.

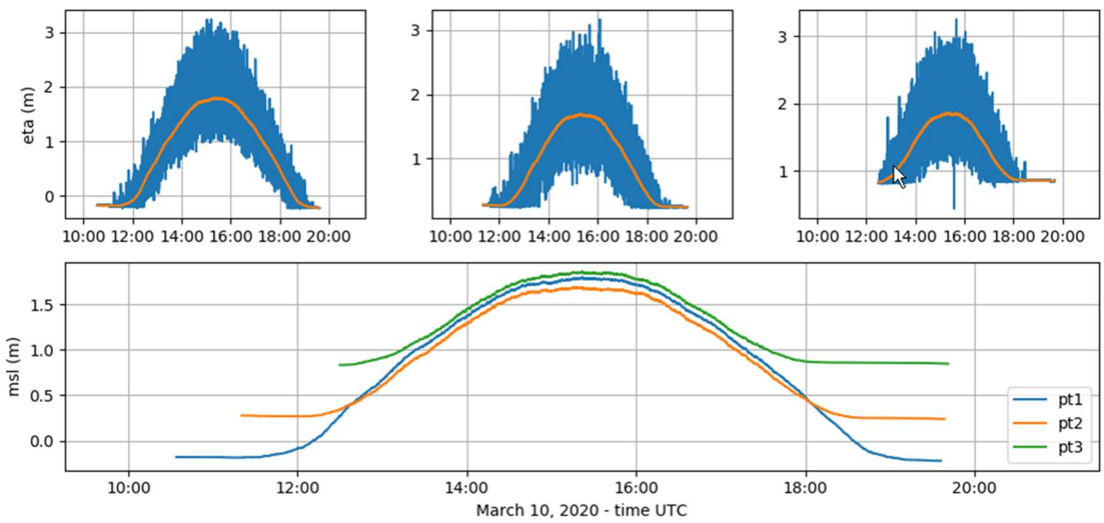

Figure 4.5 – Water levels and mean sea state parameters. Upper panels: free surface elevation derived from the pressure transducer 1, 2 and 3; Lower panel: absolute mean surface elevation, zero is the National Altimetric Datum of 1938

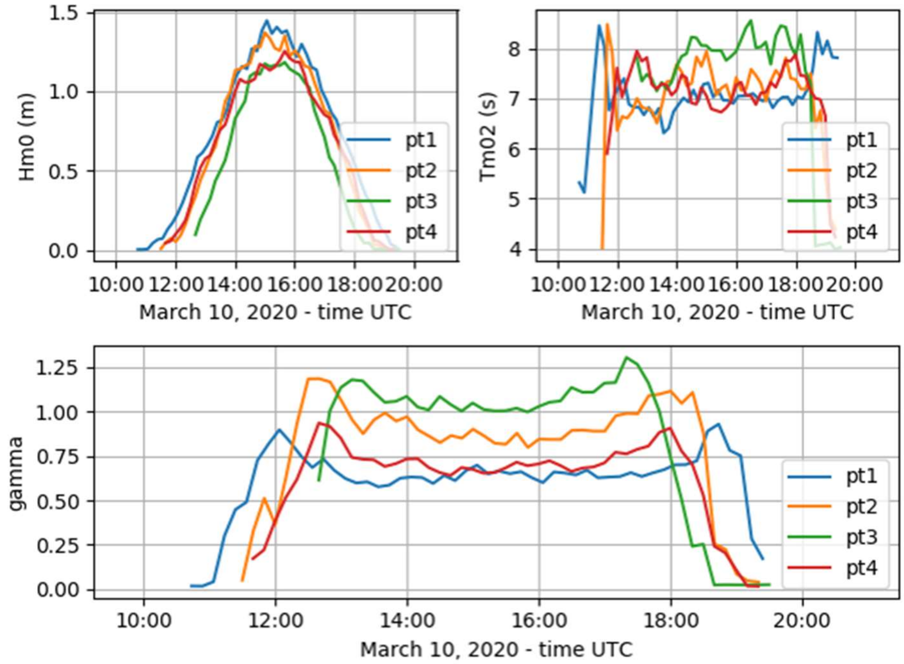

Figure 4.6 – Sea state parameters measured on the northern beach in the gravity band. Upper left: Significant wave height; Upper right, spectral mean period Tm02; Lower panel: estimated breaking parameter gamma (Hs/h)

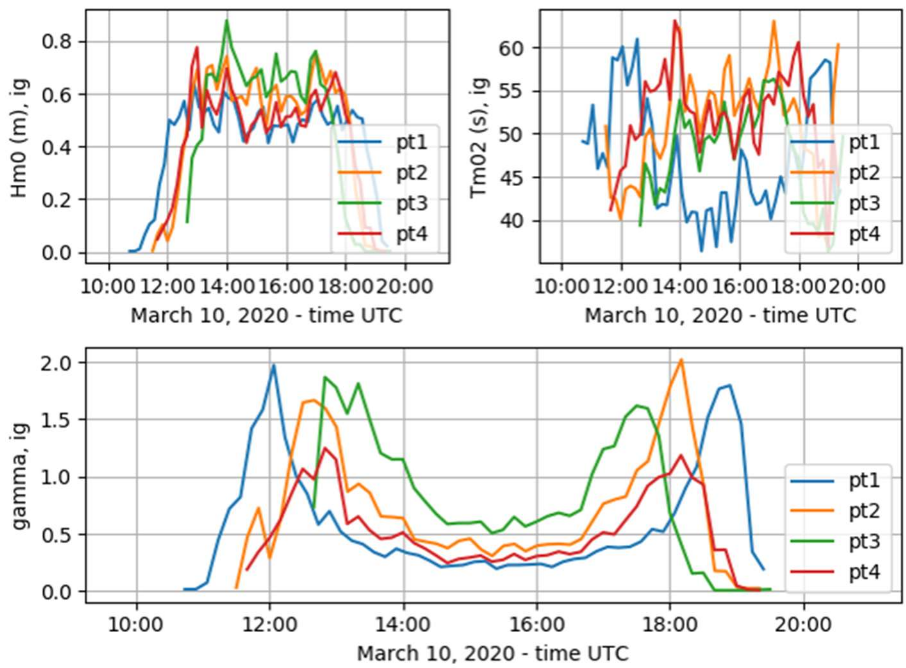

Figure 4.7 – Same as Figure 4.6 but for the infragravity band

4.1.3 Remotely sensed tidal data

The data captured with the LiDAR sensor and the echo sounder were compared to Instituto Hidrografico's tidal gauge located in the Figueira da Foz Marina. Figure 4.8 shows this comparison of the raw data. In the case of the echo sounder (lower panel) the blue curve is the median value of all ten samples. This was done to easily remove outliers.

- LiDAR data displayed a prohibitive noise and neither the extreme returns (min and max) nor the average and median of all returns appeared to be robust enough for the measurements requirements;
- The echo sounder data appeared to be much more robust, with standard deviation of 4.3 cm compared to the reference tidal gauge (calculated after bias removal).

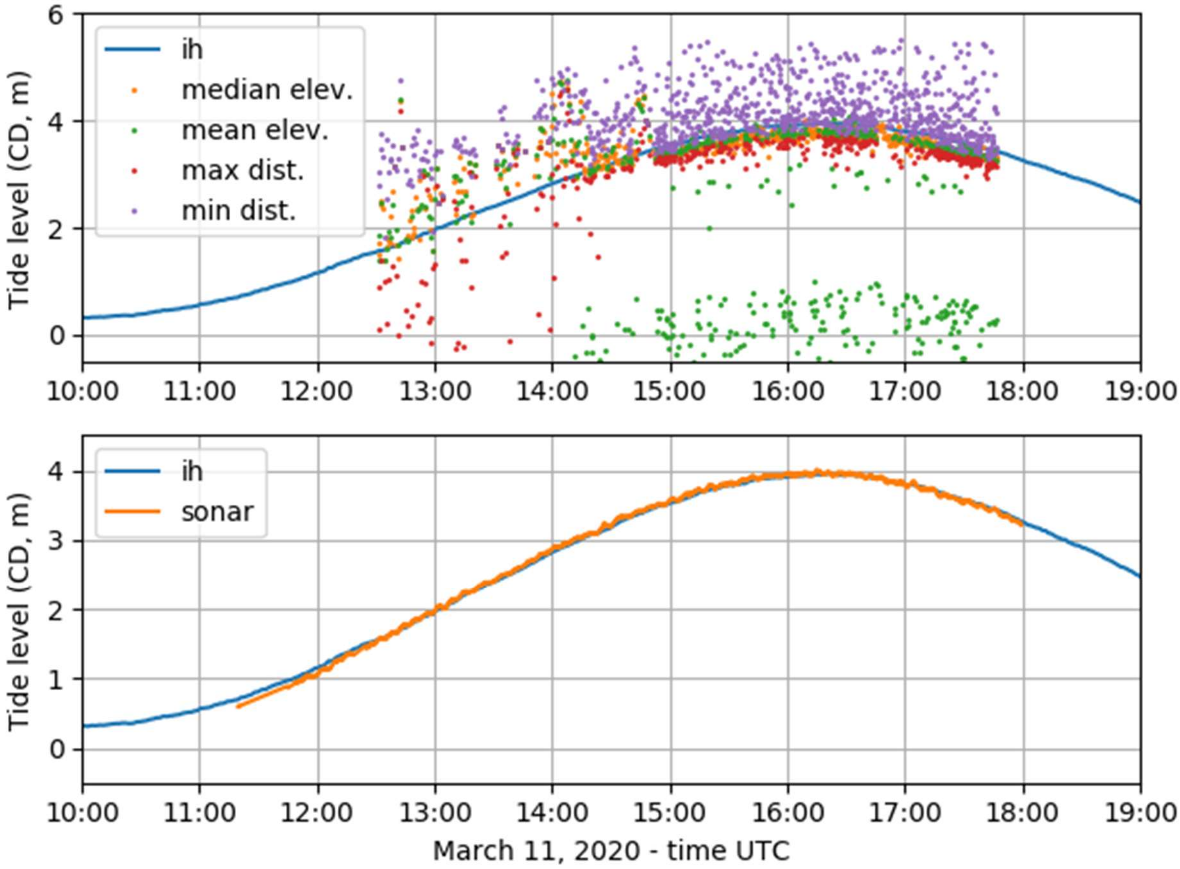

Figure 4.8 – Comparison of remotely sensed tidal level in Figueira da Foz harbour, with Instituto Hidrografico's tidal gauge (ih, blue curve), the upper panel shows the LiDAR median and mean measured elevations with the elevations corresponding to maximum and minimum measured distances, the lower panel shows the median value of the ten sampled measures of the echo sounder; elevations are given in meters above chart datum

4.2 Aerial and topographic data

GNSS surveys were interpolated using a kriging interpolator (see details in ANNEX II). Figure 4.9 shows the digital elevation models (DEMs) for the three days of campaign. A preliminary analysis of the measured beach changes was performed for beach cells between E1 and E4 (see location on Figure

2.1). These cells correspond to the main overlap between the quad and backpack GNSS surveys. It provided an indication of the amount of changes that occurred at 48h interval. Figure 4.10 presents the spatial distributions of the beach evolution, which are quite contrasted from one cell to the other. At the reflective beach between E3 and E4, the upper intertidal beach accreted at the toe of the alongshore structure while the lower intertidal beach slightly eroded. At the dissipative beach between E2 and E3, the dune foot eroded and the lower intertidal beach accreted. This cell also presents some alongshore variability as dune erosion mostly concerned central and southern parts of the cells while the northern part was more stable. Then, north of those two cells the beach globally accreted. This accretion seemed related to an approaching inter- to subtidal bar in front of E1, part of which was well captured by the drone survey (Figure 4.9, central panel).

Three selected profiles confirmed these patterns as shown on Figure 4.11. Furthermore, the profiles attest of the good correspondence between the two GNSS surveys, as for instance the merging of the upper beach on both profiles from E1 to E2 (upper panel), or the crossing of both surveys on the profiles from E2 to E3 (middle panel) or again the good superposition of the profile from E3 to E4 (lower panel). In term of spatial average and based on the interpolated 5 x 5 m^2 DEMs, the mean elevation changes range between 2 to 11 cm for the three sedimentary cells between E1 to E4 (Figure 4.10). These positive values suggest accretion has dominated over the 48h period. On top of this apparent accretion, some spatial variability exists within each of the three cells. This variability can be expressed in terms of the standard deviation of the difference maps, which ranges from 10 to 30 cm. Therefore, the expected accuracy of the RTK GNSS surveys appeared to be sufficient to capture the morphologic evolution over the 48 hours covered by the data, which was also reflected in the good correspondence of the evolution along the selected profiles. These data will then serve to validate/improve morphodynamic models over this temporal range. To complete this dataset, the DEM derived from the aerial survey will undergo further quality control which will be reported in separate document.

Further processing and analysis are still required, for instance:

- The integration of the drone survey into this analysis;
- The comparison between the past drone surveys from summers 2018 and 2019 (COSMO[1]) and the winter 2019 survey (this project).

[1] Programa de Monitorização da Faixa Costeira de Portugal Continental, https://cosmo.apambiente.pt/.

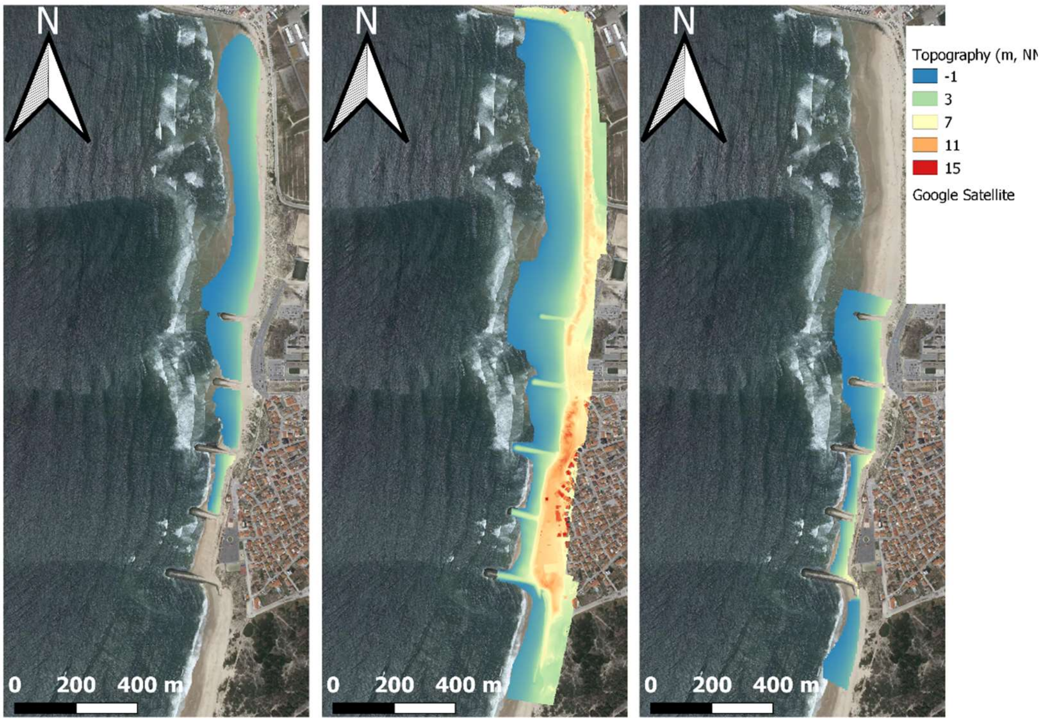

Figure 4.9 – Digital Elevation Models from 2020/03/10 (left), 2020/03/11 (centre) and 2020/03/12 (right), altimetric zero is the National Altimetric Datum of 1938

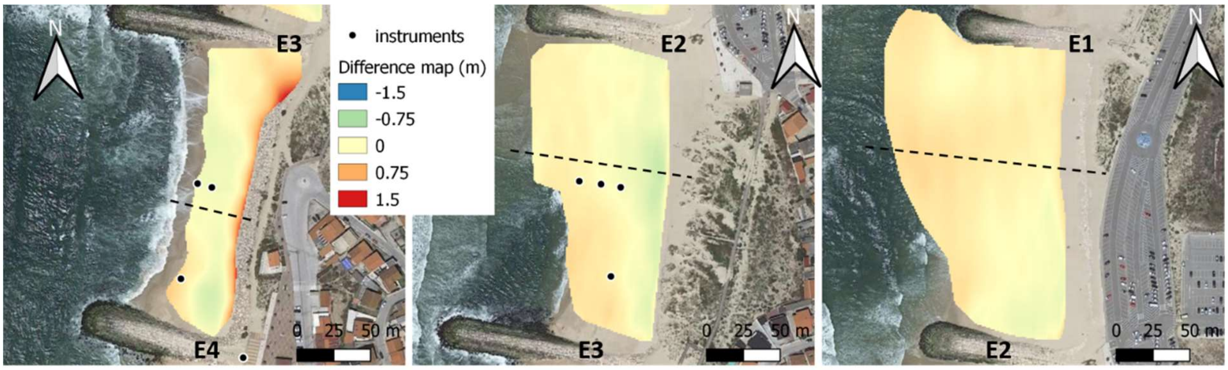

Figure 4.10 – Difference map from DEMs of 2020/03/10 (Quad) and 2020/03/12 (backpack) in the instrumented cells (left and centre) and the cell between groynes E1 and E2

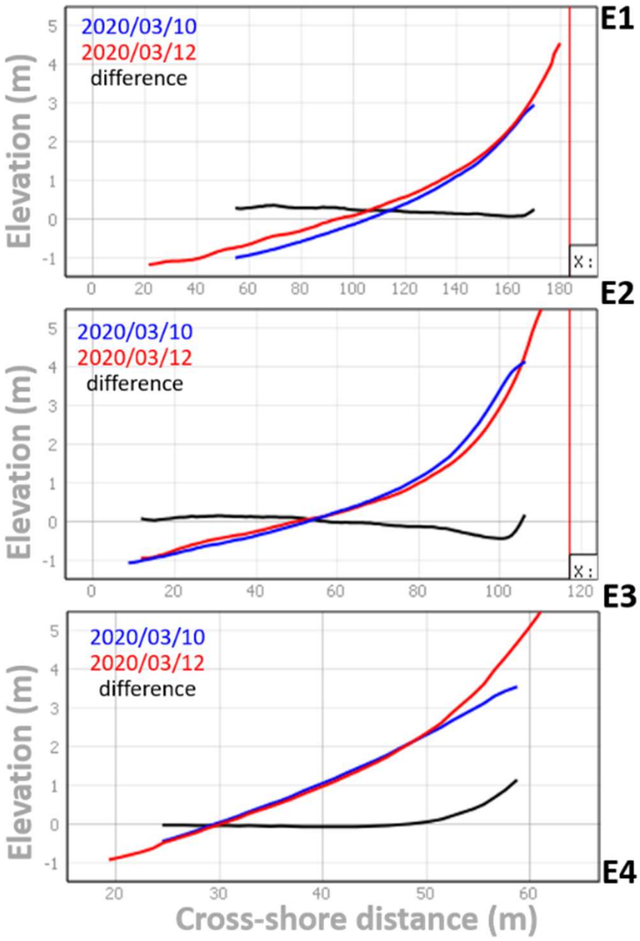

Figure 4.11 – Topographic profiles from DEMs of 2020/03/10 (Quad) to 2020/03/12 (backpack) and their differences, E1-E4 refers to the groynes and the profile positions are indicated on Figure 4.10, elevations are relative to the National Altimetric Datum of 1938

5 | Concluding remarks

- The initial campaign objectives were mostly achieved:
  - Current, wave and water level data were recovered and will be used for model validation;
  - Subaerial beach topography at 48h intervals will be a good testing bed for morphodynamic models;
  - Two solutions for remote sensing tidal gauges were tested: a preliminary assessment indicates the LiDAR data seemed to be inappropriate for the measurement purposes while the multiple sample of the echo sounder apparently presented a good accuracy.
- All structures installed on the southern beach cell were ripped out by the waves during the first rising tide. Fortunately, most of the instruments and all the steel structures were recovered; only one PT and one ECM installed at the PUV1 location were lost.
- The structures were ripped out as the beach turned into a violent shore break. Compared to the dissipative beach profile in the northern beach cell, the southern cell presented a reflective profile which is often associated with longitudinal beach structures. This difference explains why to the north waves were spilling throughout the surf zone while they were plunging right above the sensors to the south. It should be stated that a visit to the beach on the previous high tide would certainly have helped to better evaluate the risks at this particular location.
- The recovered instruments and measurements will be used to improve SCHISM and XBEACH predictions.

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Annexes

ANNEX I
Processing of hydrodynamic data

Hydrodynamic data processing

Text files exported from each instrument were read with python routines[2] using numpy and pandas functionalities. The data was stored in dictionaries and in the form of numpy array, each dictionary corresponding to a measurement location and was initialized with at least:

- path to the record file;

- sampling frequency;

- sensor position horizontal coordinates;

- sensor height and/or “ground elevation + sensor distance to ground”.

Time series spectral analyses were done using the matplotlib Power Spectrum Density (PSD) function and were filtered using scipy uniform_filter1d functions. For estimating sea state average parameters, the PSD was integrated using numpy’s trapezoidal integrator (trapz) to calculate zeroth, first and second order moments. The significant wave height was computed as $H_{m0} = 4\sqrt{m_0}$, mean periods as $T_{m01} = m_0/m_1$ and $T_{m02} = \sqrt{m_0/m_2}$, and the peak period T_p corresponds to the frequency beam with maximum energy. Furthermore, a distinction is made between “gravity” and “infragravity” waves, the cutoff frequency between the two being set at 0.04 Hz. Then, for both the gravity and infragravity bands, the gamma parameter is computed as Hs/h, were h is mean water depth.

[2] The routine and data are accessible here: https://github.com/anahon/hydro_sensors.git (email anahon@lnec.pt for access).

ANNEX II
Interpolation and analysis of the sparse GNSS topographic data

Sparse topographic data

DEMs based on the quad and backpack GNSS surveys were created using kriging interpolator:

- Surveys were interpolated over the same 5 x 5 m^2 grid using the OrdinaryKriging method of the python package PyKrige;
- Each sedimentary cells were treated separately because of the geomorphological discontinuities caused by the groynes and the beach rotation patterns that existed in-between groynes;
- Overall 4 DEMs were created in the quad case and 6 in the back pack case separated by the 5 groynes (Figure 4.9);
- Anisotropy parameters (mainly to compensate for the different cross- and alongshore resolutions) were adjusted for each cell the algorithm show great sensibility and did not always converge for constant values (direction was set between -7º and -9º and the coefficient between 0.1 and 05).

Difference maps and raster analysis (calculation of mean and standard deviation values) were performed with QGIS software, with the Profile Tool Plugin installed in order to create and extract topographic profiles.

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