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Living Lab Raversijde
Monitoring Soft Coastal Defences

Factual data report
1st working year 2021-2022

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Living Lab Raversijde – Monitoring Soft Coastal Defences

Factual data report 1st working year 2021-2022

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D/2022/3241/199

This publication should be cited as follows:

Montreuil, A-L., Verwaest, T., Dan, S. (2022). Living Lab Raversijde – Monitoring Soft Coastal Defences: Factual data report 1st working year 2021-2022. Version 2.0. FHR Reports, 21_012_1. Flanders Hydraulics Research: Antwerp.

Document identification

Customer:	Flanders Hydraulics	Ref.:	WL2022R21_012_1
Keywords (3-5):	Beach, shoreface, drone, bathymetry, hydrodynamics		
Knowledge domains:	Coastal protection > Coastal safety against extreme storms > Soft coastal defences > In-situ measurements Coastal protection > Coastal protection against erosion > Morphodynamics soft coastal defences > In-situ measurements		
Text (p.):	34	Appendices (p.):	5
Confidentiality:	☒ No	☒ Available online	

Author(s):	Montreuil, A_L.

Control

	Name	Signature
Reviser(s):	Dan, S.	Getekend door:Sebastian Dan (Signature Getekend op:2022-12-02 16:35:18 +01:0 Reden:Ik keur dit document goed Sebastian Dan Vlaanderen
Project leader:	Verwaest, T.	Getekend door:Toon Verwaest (Signatur Getekend op:2022-12-05 10:40:30 +01:0 Reden:Ik keur dit document goed Toon Verwaest

Approval

Head of Division:	Bellafkih, A.	Getekend door:Abdelkarim Bellafkih (Sig Getekend op:2022-12-02 13:50:44 +01:0 Reden:Ik keur dit document goed Abdelkarim Bellafkih

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Abstract

In the framework of the Raversijde Living Lab project, an intensive topo-bathymetric monitoring campaign of the soft coastal defences has started from the beginning of 2021. The aim of this report is to provide an overview of all the acquired surveys for topo-bathymetry and driving meteo-marine factors for the period from 2021 to 09/2022 as well as to document the processing on the raw data. Finally, a comparison of the bathy-topographic methods from the beach to the offshore area is presented.

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1 Introduction

In the framework of the Raversijde Living Lab project, an intensive survey monitoring has started from 03/2021. The detailed monitoring plan for the first working year 2021 - 2022 is presented in Verwaest and Willems (2021). Bathymetric surveys consisting of single and multibeam systems have been carried out in the shoreface zone and the neighbouring sea bottom. Also topographic surveys covering the area from the dike to the low water line have been acquired by UAV and field Real Time Kinematic-GPS (RTK-GPS) profiles obtained by walking or set up on a quad. Table 1 presents a timeline of the bathymetric and topographic campaigns. Figure 1 displays the bathymetric and topographic study zones (section 100-102). The aim of this report is to provide an overview of all the acquired surveys monitoring the soft coastal defences and to document the processing on the raw data. In this report a comparison of the bathy-topographic processing methods is included. Finally, an overview of the hydrodynamic measurements is also presented. Results regarding the dune morphological evolution are reported in more detail in Verwaest et al. (2022).

Table 1 – Timeline of the bathymetric and topographic surveys.
* Bathymetric data is based on an averaged-depth processing.
Previous data was based on minimum-depth processing for nautical purposes.

T0	31/03/2021	UAV & hand RTK-GPS profile
T1	28/04/2021	UAV & hand RTK-GPS profile
T2	27/05/2021	UAV & hand RTK-GPS profile
B0	09/06/2021	Bathy single-beam
T3	25/06/2021	UAV & hand RTK-GPS profile
B1	24/06/2021	Offshore Bathy multibeam
T4	08/09/2021	UAV & hand RTK-GPS profile
B2	19/10/2021	Bathy single-beam
B3	09/11/2021	Bathy single-beam
B1O	10/11/2021	Bathy multibeam
T5P	08/12/2021	hand RTK-GPS & Quad profile
T5	24/11/2021	UAV & hand RTK-GPS profile
T6	07/12/2021	UAV
B4	07/12/2021	Bathy single-beam
T7	18/01/2022	UAV & Quad profile
B5	26/01/2022	Bathy single-beam
T8P	03/02/2022	Hand RTK-GPS
T8	11/02/2022	UAV
T9	23/02/2022	UAV
B6	23/02/2022	Bathy single-beam
T10P	04/03/2022	Quad profile
T10	21/03/2022	UAV
B7	21/03/2022	Bathy single-beam
T11	19/04/2022	UAV
B8	19/04/2022	Bathy single-beam
T12	02/05/2022	UAV
B9	02/05/2022	Bathy single-beam

B10	30/05/2022	Bathy single-beam
T13	01/06/2022	UAV
T14	12/09/2022	UAV and hand RTK-GPS
B11*	12/09/2022	Bathy multibeam
B12*	13/09/2022	Offshore Bathy multibeam
B13*	10/10/2022	Bathy multibeam

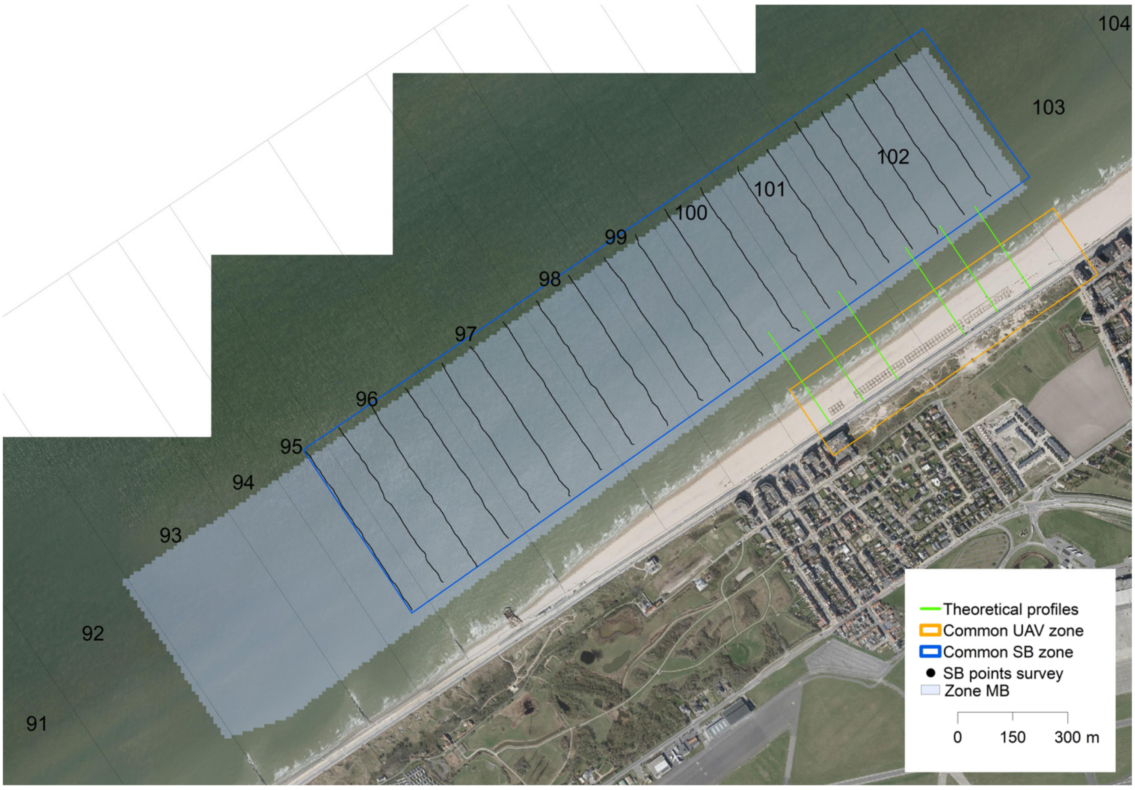


Figure 1 – Map of the monitoring coverage at Raversijde.

2 Bathymetric monitoring

2.1 Surveys

Normally, a single beam bathymetric survey is composed of 20 profiles (except on 19/10/2021 when only 12 profiles were surveyed, Table 1). The coverage of the total zone is of 2 km alongshore and 500 m cross-shore. The distance between profiles is about 100 m (Figure 1). They extend from 0 m to nearly -7 m TAW. Data acquired with an echo sounder of 200 kHz and 38 kHz are available and processed by Flemish Hydrography. Data correspond to minimum depth (depth points selected for nautical purposes). For this study, the survey data at 200 kHz are processed to generate DEMs of 10 m cell size after creating a TIN (Figure 2).

A multibeam bathymetric survey with an echo sounder of 400 kHz took place on 24/06/2021. It covers an area of 2.6 km alongshore and 560 m cross-shore. Both the processed data points and a derived raster were obtained. The cell size of the raster is 10 m. For the multibeam bathymetric survey carried out from 9/2022, the data correspond to the averaged-depth (depth points selected for morphological purposes).

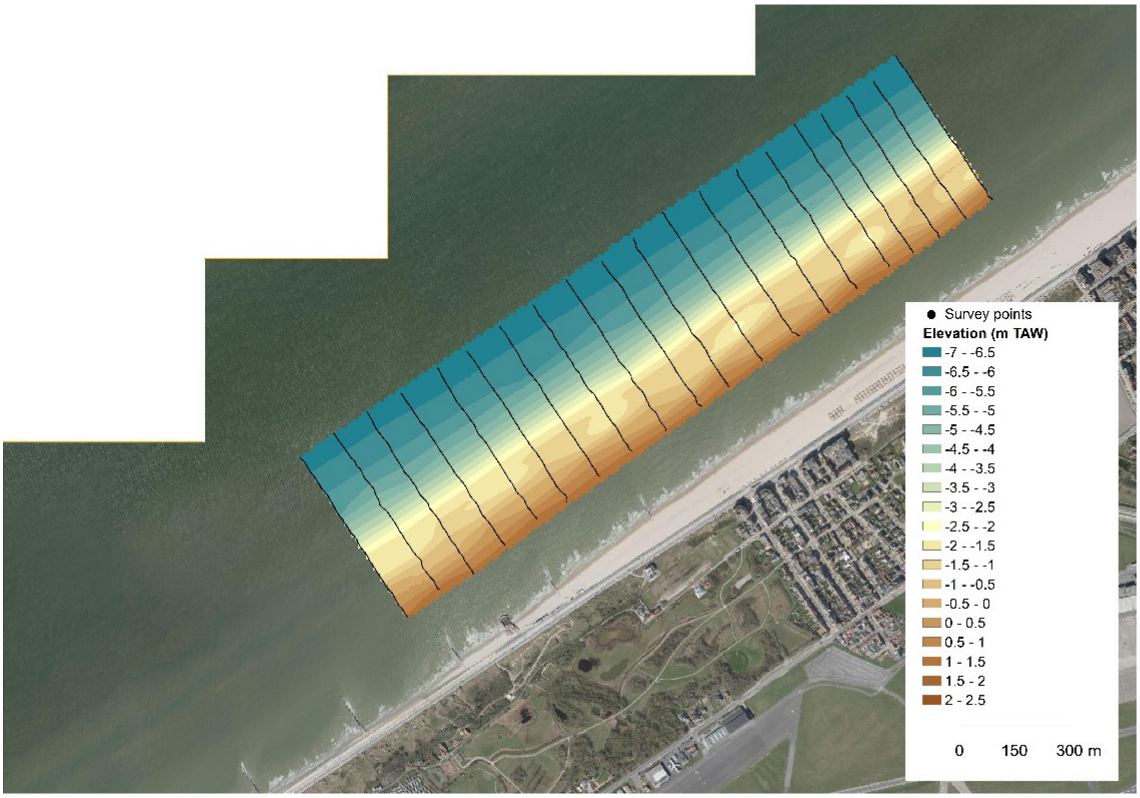


Figure 2 – Example of profile points and generated DEM of the survey on 23/02/2022.

Additionally, one offshore multibeam bathymetric survey was carried out on 10/11/2021 (Table 1, Figure 3). Also, the area was also covered in 09/2022 (not presented here). It covers part of the Stroombank and Kleine Rede bank-gully system, and extends from 2.6 km length and 3 km wide and also located 1.6 km from the coast.

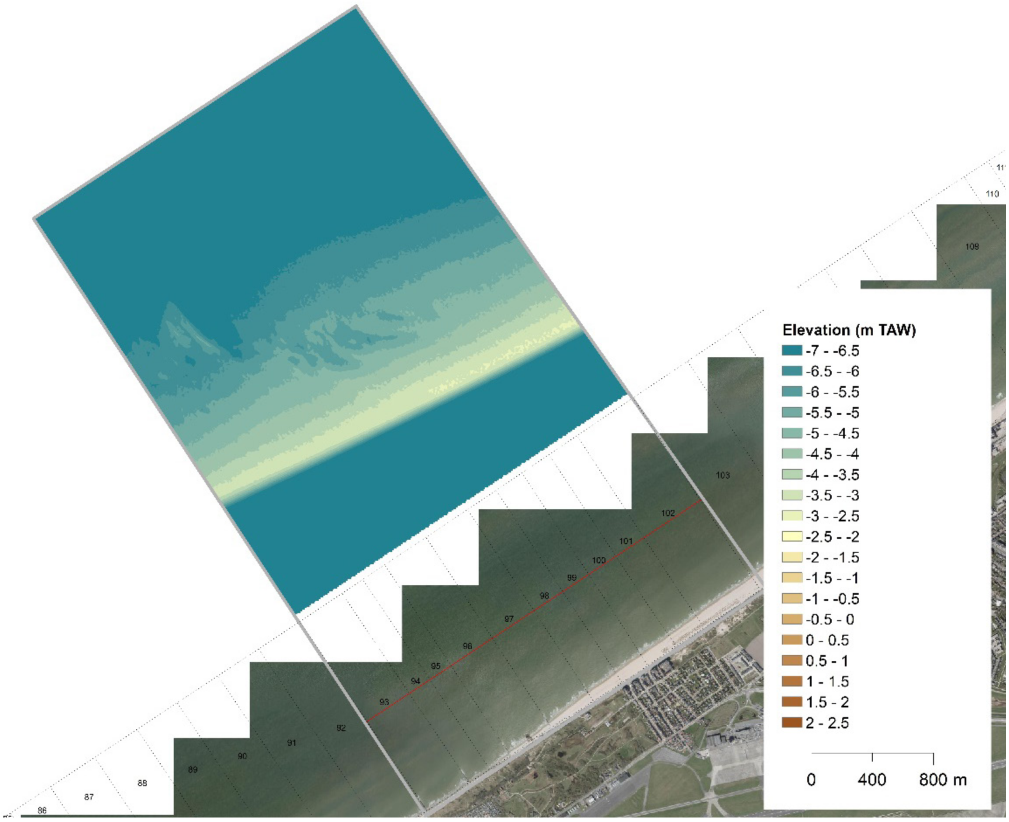
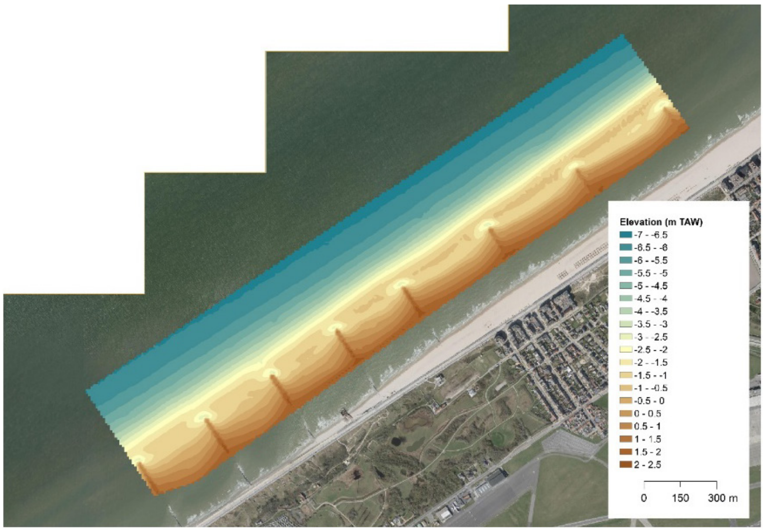


Figure 3 – Offshore DEM of the multibeam bathymetric on 10/11/2021.
Grey and red lines correspond to the entire study site and active zone respectively.

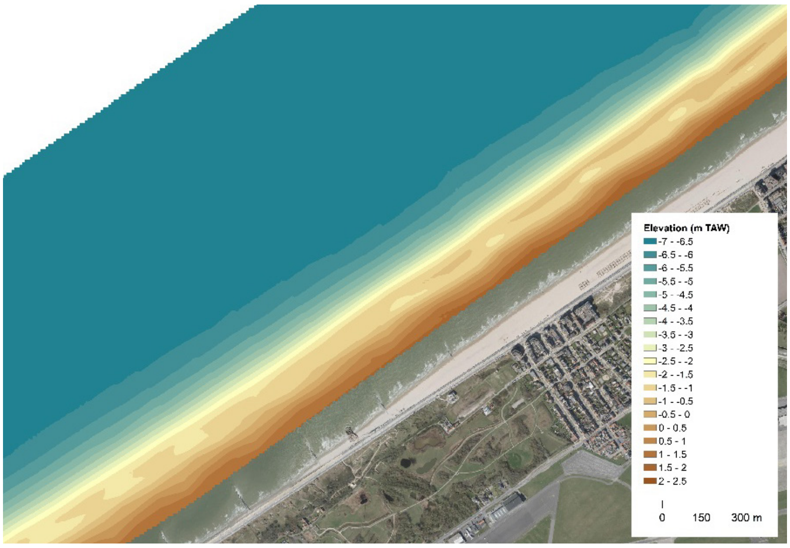
2.2 Comparison single and multibeam surveys

A comparison between a multibeam and a single beam survey was done to investigate whether the generated DEM from single-beam survey is representative of the morphology (Figure 4). We are aware that the difference of penetration depth from the echosounders used for the two methods (400 KHz multibeam and 200 KHz single beam) limits the quality of the comparison. This analysis allows insight into the difference of morphological patterns rendering and thus to verify in how far DEMs generated from the single-beam profiles are representative of the shoreface bathymetry.

A)



B)



C)

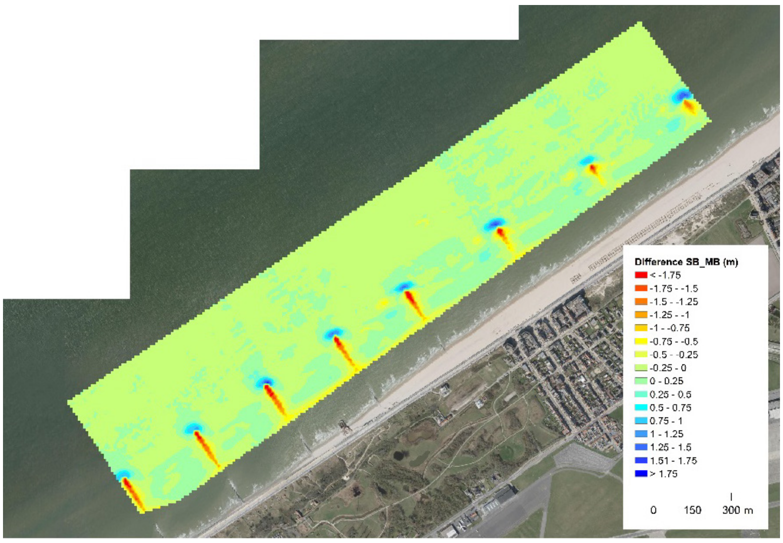


Figure 4 – DEM of A) multibeam bathymetric survey on 24/06/2021,
B) single beam on 09/06/2021 and C) difference between single and multibeam.

The groynes and the surrounding areas are clearly visible on the multibeam bathymetry, while they are not displayed on the single-beam bathymetry. In general, the difference between single and multibeam DEM is up to +/- 0.15 m in the offshore area. The sea bottom in front of the tip of the groynes is overestimated up to 1.5 m by the single beam surveys. This is caused by the interpollation carried out between neighbouring survey lines. Thus, the comparison suggests that DEMs generated from single beam profiles are representative of the bathymetry for the shoreface excluding the area around the groynes. Consecutive DEMs of difference (DoD) of 10 m cell size including the presence of groynes were processed. Also cumulative DEMs of difference (DoD) are established corresponding to the difference of elevation between a recent survey and T0 (09/06/2021).

A method to improve single beam survey DEMs is to use information on the geometry of the groynes which can be considered as static. As an exercise, the groynes were digitized following the edge of the highest elevation and confirmed with the most recent aerial image in 2022. Then they were extracted from the multibeam DEM of 1 m cell size. Next, a new raster integrating the single beam DEM of 10 m cell size with the groynes was generated using the mosaic tool in ArcGIS (i.e. no interpolation is applied) (Figure 5). This exercise shows that if the multibeam survey is not available, then the accuracy of the nearshore bathymetry can be improved by adding the groynes from previous surveys.

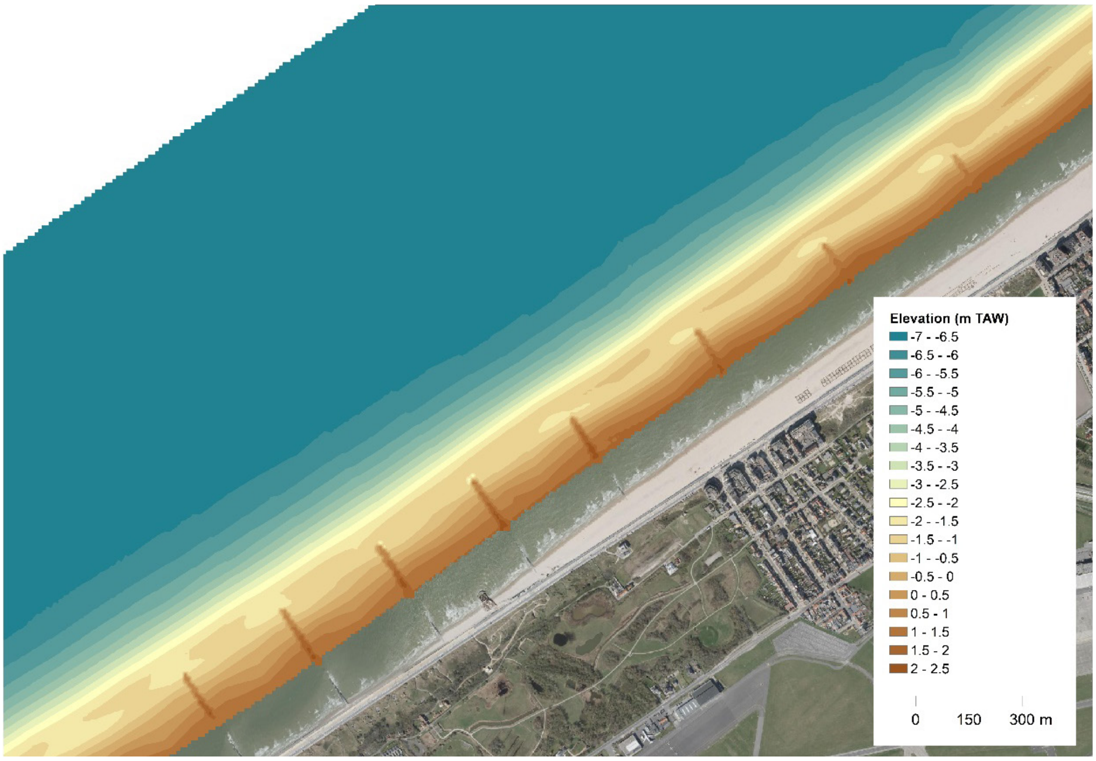


Figure 5 – DEM integrating single beam survey in 09/06/2021 and the groynes extracted from multibeam DEM in 06/2021.

All the data can be found:
E:\RaversijdeLivingLab_21_012\Data\TritonBathyData

3 Topographic monitoring

3.1 UAV surveys

From 03/2021, monthly UAV surveys have been carried out by ATO (Afdeling Algemene Technische Ondersteuning). For more details we refer to Verwaest et al. (2022). Orthophotographs of 2.5 cm resolution and DEMs of 5 cm resolution are usually provided together with the quality report. The error of the surveys ranges from 0.8 to 1.4 cm (Verwaest et al., 2022). Figure 6 displays an example of produced data from the survey on 01/06/2022 (T13). From the DEMs, consecutive DEMs of difference (DoD) were generated as well as DoDs starting from the first survey as reference. DEMs and DoDs from 31/3/2021 to 23/02/2022 are reported in Verwaest et al. (2022).

A)

B)

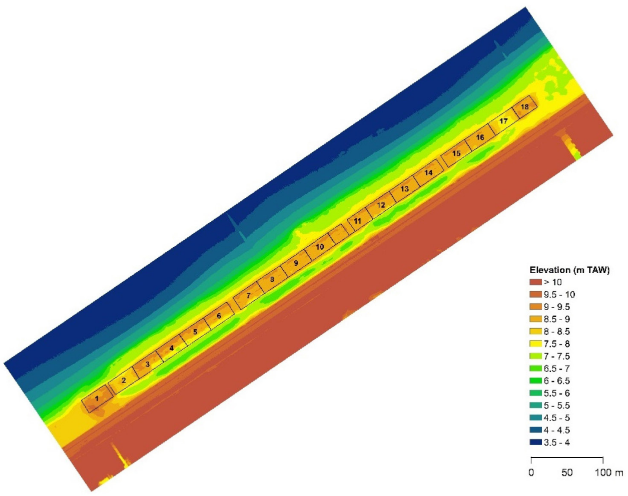


Figure 6 – Example of A) orthophotograph and B) DEM (T13 survey).

3.2 Hand RTK-GPS profiles

Hand RTK-GPS surveys were carried out along 6 profiles (Table 1 and Figure 1). Each profile extends from the seaward vegetation boxes to the low water line over a length of ca. 250 m. The distance from the first survey points to the dike is ca. 40 m. The interval between profiles is 110 a 215 m. Since the measurements are not always located along a straight line, they have been re-projected on planned profiles in ArcGIS using the linear reference tool (Figure 7). Then, they were interpolated at a distance of 1 m. This allows easier comparison of the profiles over time. Figure 8 is an example of re-projected points for profile 3 for all the hand RTK-GPS surveys.

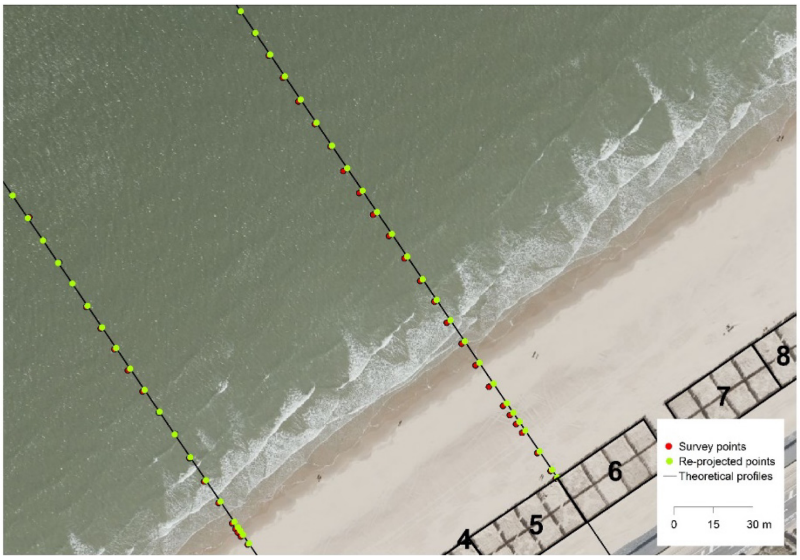


Figure 7 – Example of survey re-projection.

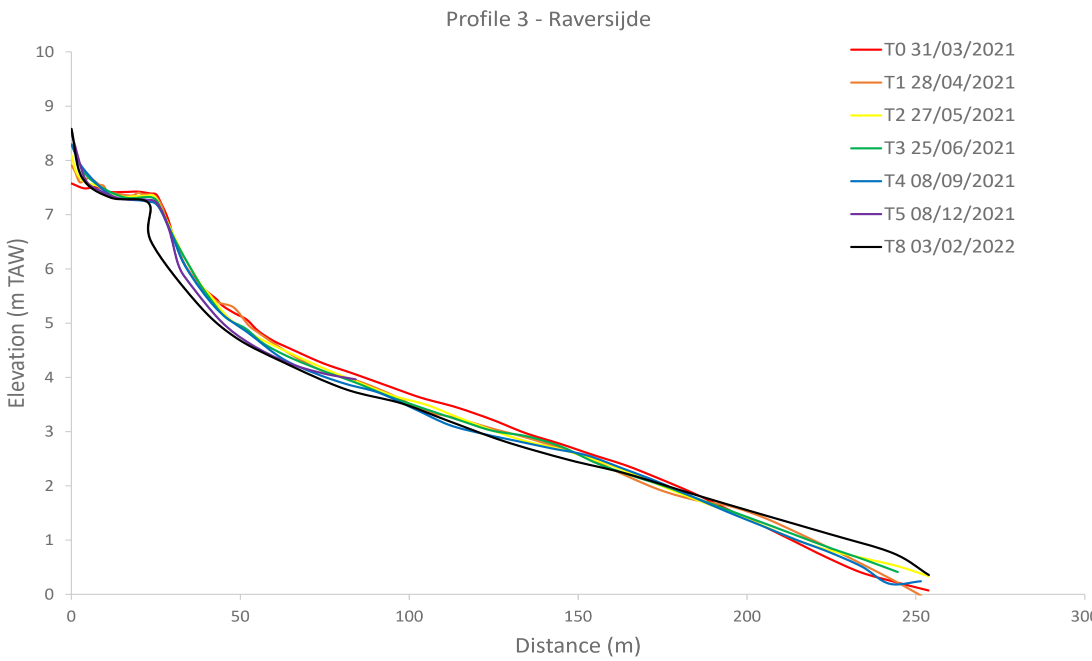


Figure 8 – Example of re-projected profiles (profile 3) for all the hand RTK-GPS.

All the raw and re-projected profiles can be found:
E:\Duin voor dijk pilots_21_014\Analyses\raversijde_mariakerke\Profiles

3.3 Merging UAV and hand GPS-profiles

Since the hand RTK-GPS profiles do not cover the area landward of the vegetation boxes, we extracted the topography along the theoretical profiles from the UAV DEMs to obtain complete beach profiles. RTK-GPS and UAV surveys are usually carried out on the same day (Table 1). Then, all the profiles were interpolated to 1 m in order to allow easier comparison over time. Figure 9 presents a typical time series of profiles merged from UAV (dike – upper-beach part) and hand RTK-GPS (upper-beach to low water line part). The observed peaks at a distance from 20 to 40 m from the dike correspond to the vegetation boxes area.

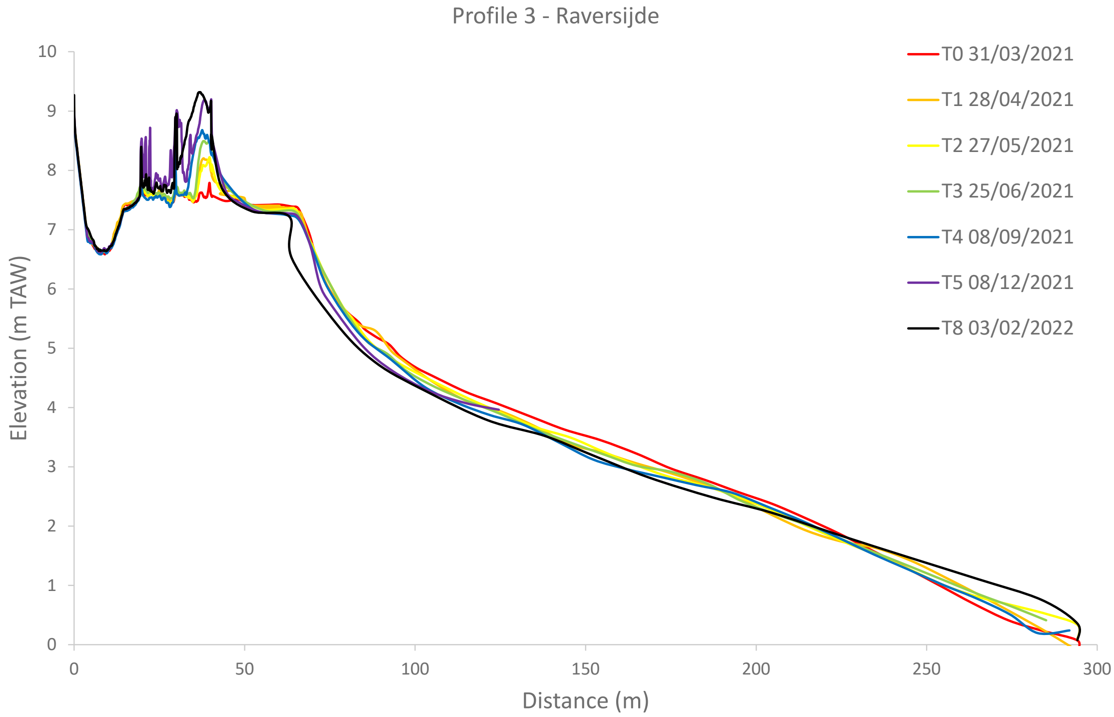


Figure 9 – Profiles from the dike to the low water line combining UAV and hand GPS surveys.

All the processed data can be found:
E:\Duin voor dijk pilots_21_014\Analyses\raversijde_mariakerke\Profiles

3.4 Quad RTK-GPS profiles

Three quad profiles were surveyed with a RTK-GPS set-up on the vehicle (Table 1). In general, the distance between survey points was around 5 m. The profiles cover along a coastal length of 2.5 km for survey T7 (18/01/20222) and T10 (04/03/2022), while the survey length in T5 (08/11/2021) was 0.66 km (Figure 10). T5 survey measurements were close to the theoretical profiles. However, the distance to the RTK-GPS profile lines ranged from 17 to 70 m for T7 and T10. Due to it, we could not re-project the points on the theoretical profiles (i.e. quad survey profiles are unlikely to be representative of the topography along the theoretical profiles).

A)

B)

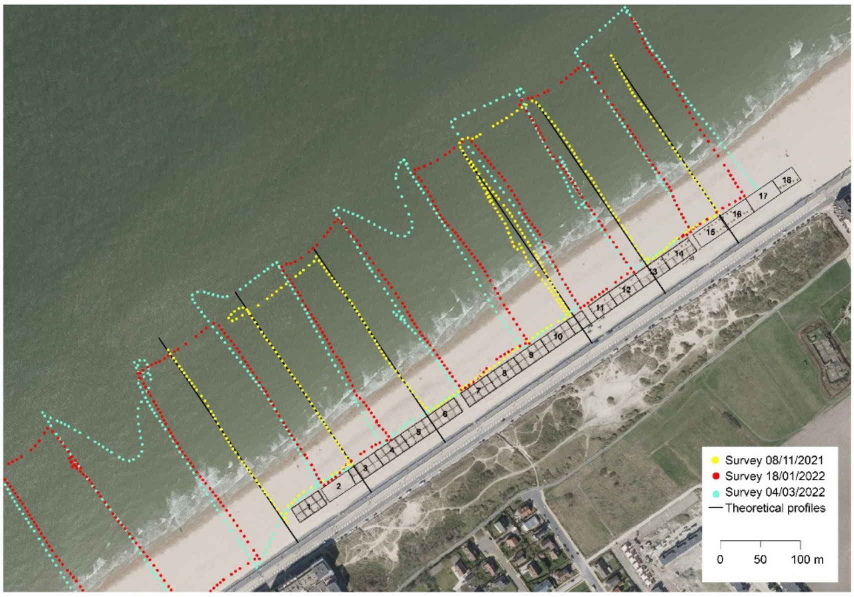


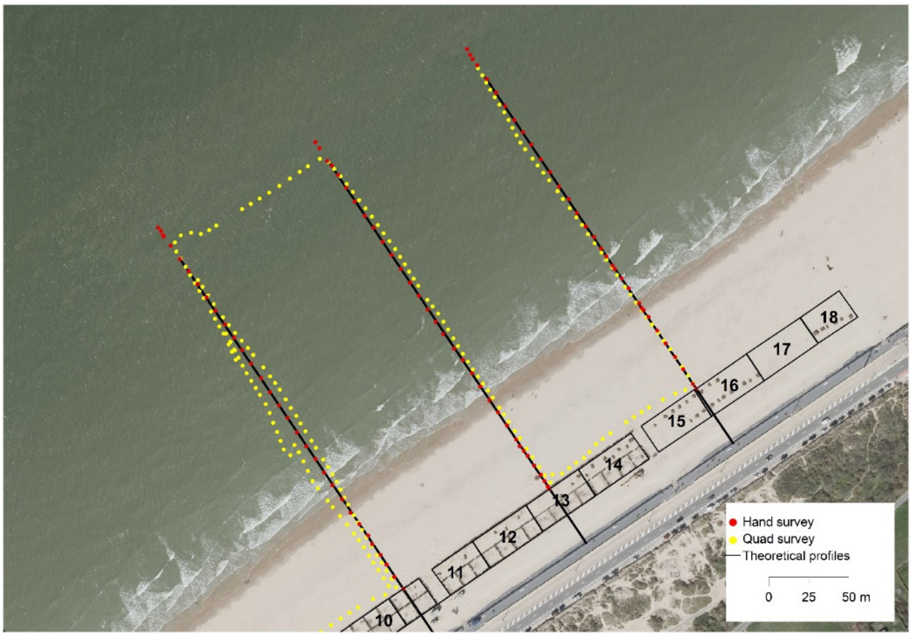
Figure 10 – Map showing all the quad profile surveys: A) entire coverage, B) nearby the vegetation boxes.

All the raw profiles can be found:
E:\Duin voor dijk pilots_21_014\Analyses\raversijde_mariakerke\Profiles

3.5 Comparison between hand RTK-GPS vs quad profile surveys

Profile 4, 5, and 6 from 12/2021 were carried out by both hand RTK-GPS and the quad system, which give an opportunity to compare the RTK-GPS and quad survey systems. In general, the number of quad topographic points are slightly larger than the hand RTK-GPS (ca. 5 extra points per profile). All the profile surveys were re-projected onto the theoretical profiles (Figure 11). Figure 12 and Table 2 presents the difference between the systems. The absolute elevation difference ranges from 0.07 to 0.11 m. By assuming that the hand RTK-GPS is a true representation of the topography, the quad method thus underestimates the elevation.

A)



B)

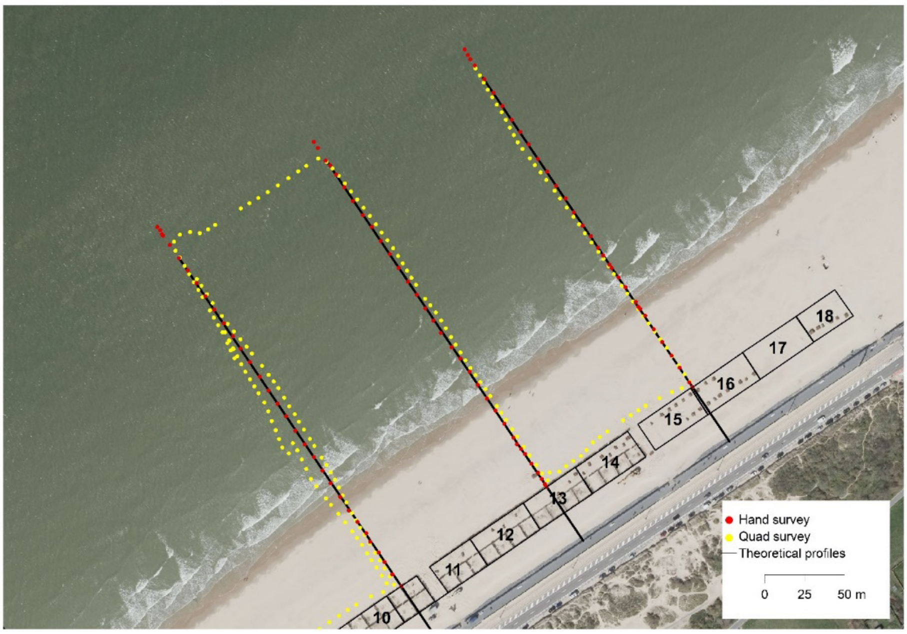
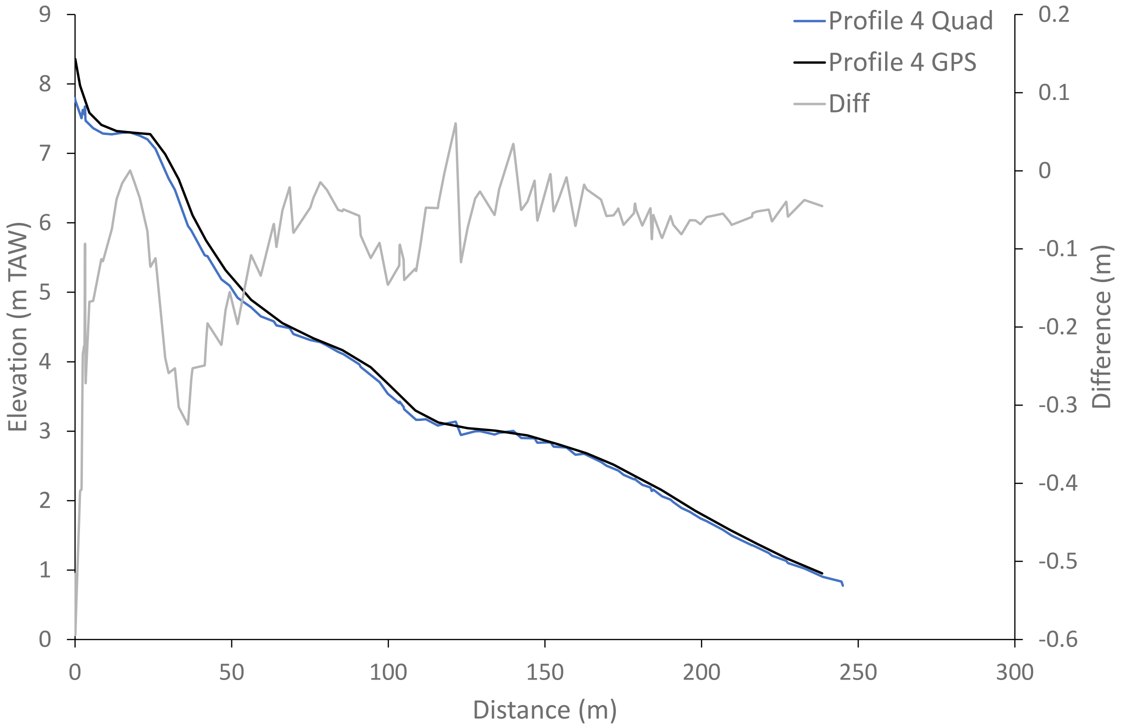
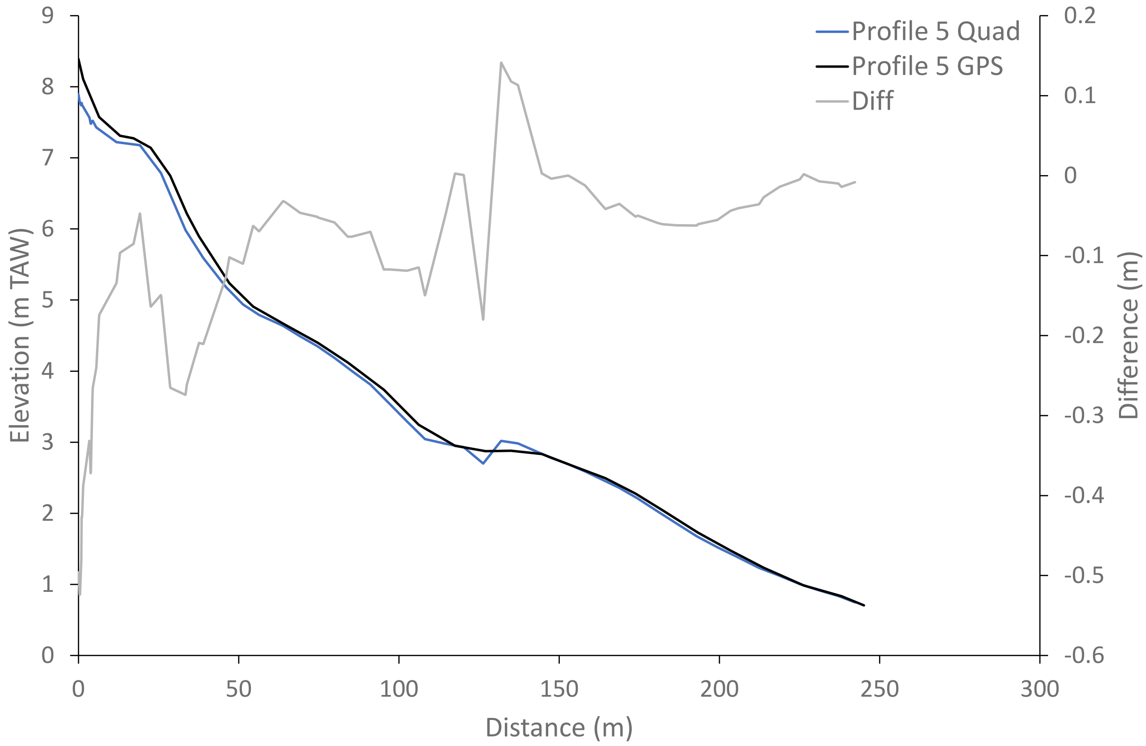


Figure 11 – Maps of A) raw and B) re-projected point surveys for both hand RTK-GPS and quad systems (Profile 4, 5, 6).

A)


Profile 4 Quad
Profile 4 GPS
Diff
Elevation (m TAW)
Difference (m)
Distance (m)
9
8
7
6
5
4
3
2
1
0
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
0
50
100
150
200
250
300

B)


Profile 5 Quad
Profile 5 GPS
Diff
Elevation (m TAW)
Difference (m)
Distance (m)
9
8
7
6
5
4
3
2
1
0
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
0
50
100
150
200
250
300

C)

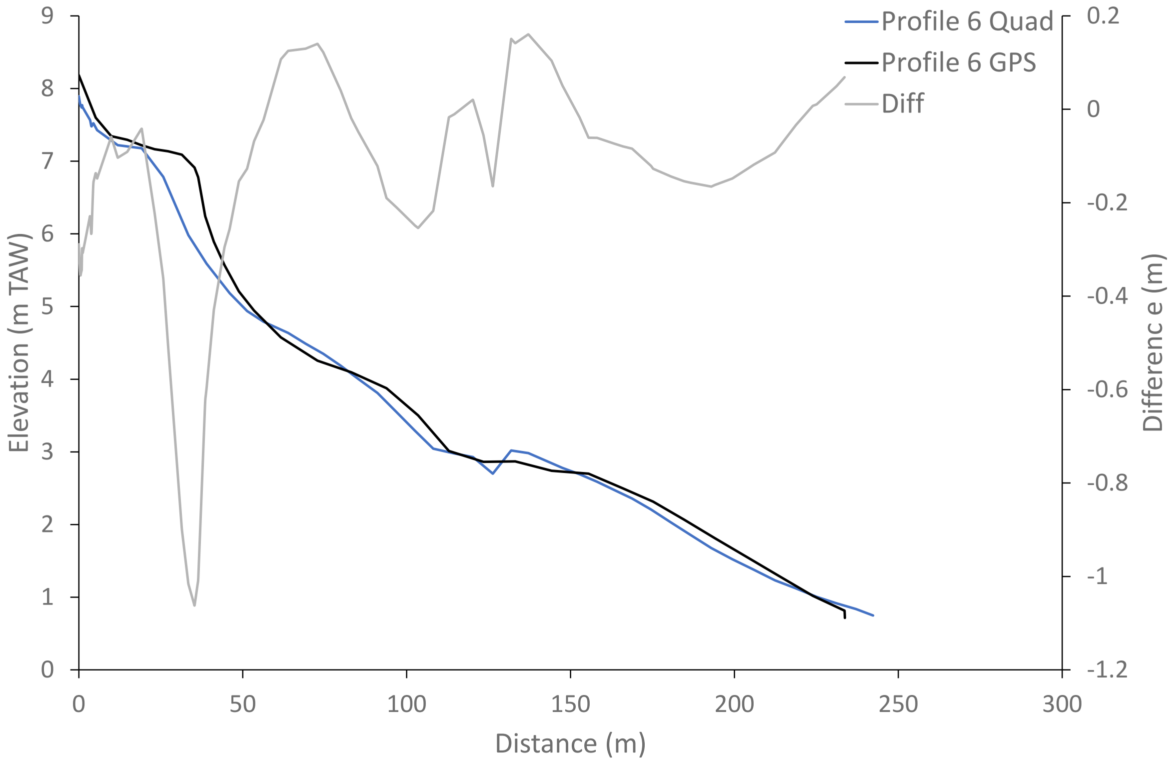


Figure 12 – Hand and quad reprojected profile surveys. Note: the difference of 2nd y-axes between graphs.

Table 2 – Statistical summary of the elevation difference between hand and quad re-projected profile surveys.

Difference hand-quad	Profile 4	Profile 5	Profile 6
Avg	-0.08 m	-0.07 m	-0.11 m
Max	0.06 m	0.14 m	0.17 m
Min	-0.59 m	-0.52 m	-1.06 m
SD	0.08 m	0.08 m	0.21 m

Note: Standard deviation (SD) is a parameter to quantify the overall scatter around the average. Total deviation is the combination of the systematic difference (Avg) and SD. Max and Min correspond to the highest positive and lowest negative values.

Data can be found here:
E:\Duin voor dijk pilots_21_014\Analyses\raversijde_mariakerke\Profiles\T5\ReprojectedPoints

3.6 Comparing handheld RTK-GPS and UAV across the beach

For the UAV survey in 09/2022 (T14), the cross-shore distance of the UAV survey was extended up to 1 m TAW which is about 265 m from the dike (Figure 14). The most seaward area of the DEM around 300 - 400 m was removed due to the omnipresence of points with low confidence flagged by the photogrammetric processing procedure (Figure 14, subplot C). This is related to the presence of the water and saturated sand in this area characterized by less or none beach structures. Then the reprojected hand RTK-GPS profiles taken on the same day as the UAV survey were compared to the extracted UAV profiles from DEMs. Figure 13 presents the error estimation based on the ground control points (GCPs) on the beach on the day of the measurement. The reported root-mean square error is of 0.022 m.

To assess the accuracy of the UAV survey further analyses were performed. Results are displayed in Figure 15, Table 3 and Appendix A. In average, the difference between the UAV and RTK-GPS profiles is around 0.04 m. Thus, the UAV slightly overestimates the real topography observed across the beach but it is still within acceptable range. In general, the error between UAV and RTK-GPS is higher for the upper-beach (from top to 4.39 m TAW) where the complexity of the beach topography is greater. This is clearly displayed for Profile 3 (complex morphology) versus Profile 1 (smooth morphology). For the lowest part of the beach (< 1.39 m TAW), the average error is smallest (systematic error around 0.01 m).

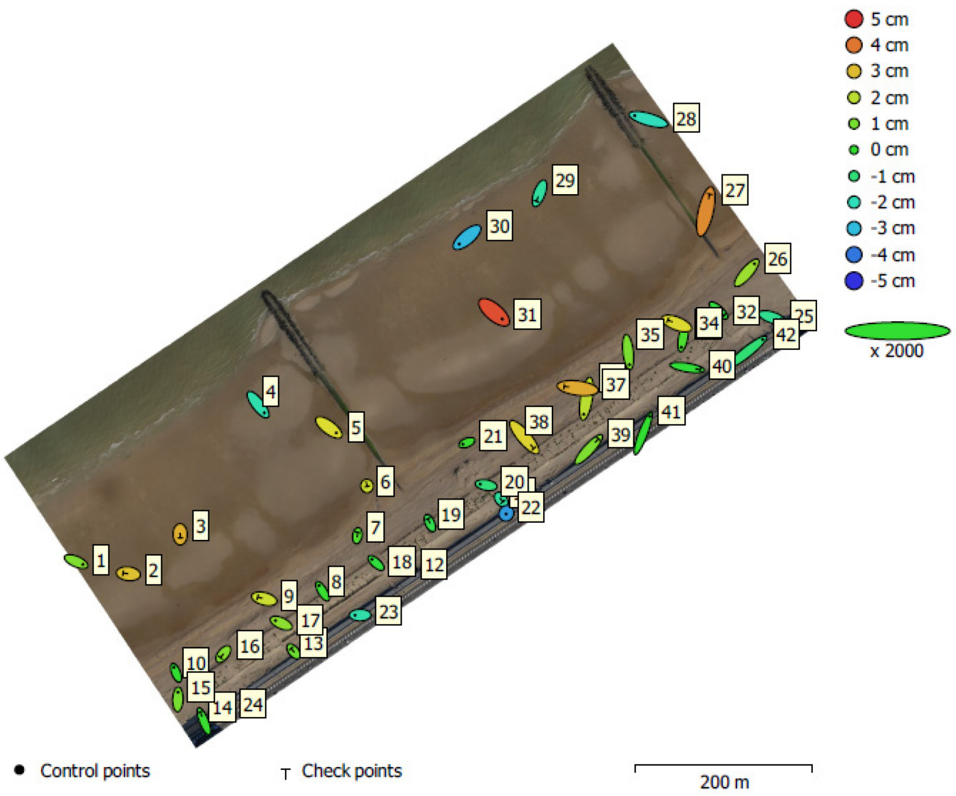


Figure 13 – Error estimation and position of the GCPs. (extracted from the report of the UAV survey on 12/09/2022 [ATO, 2022]).

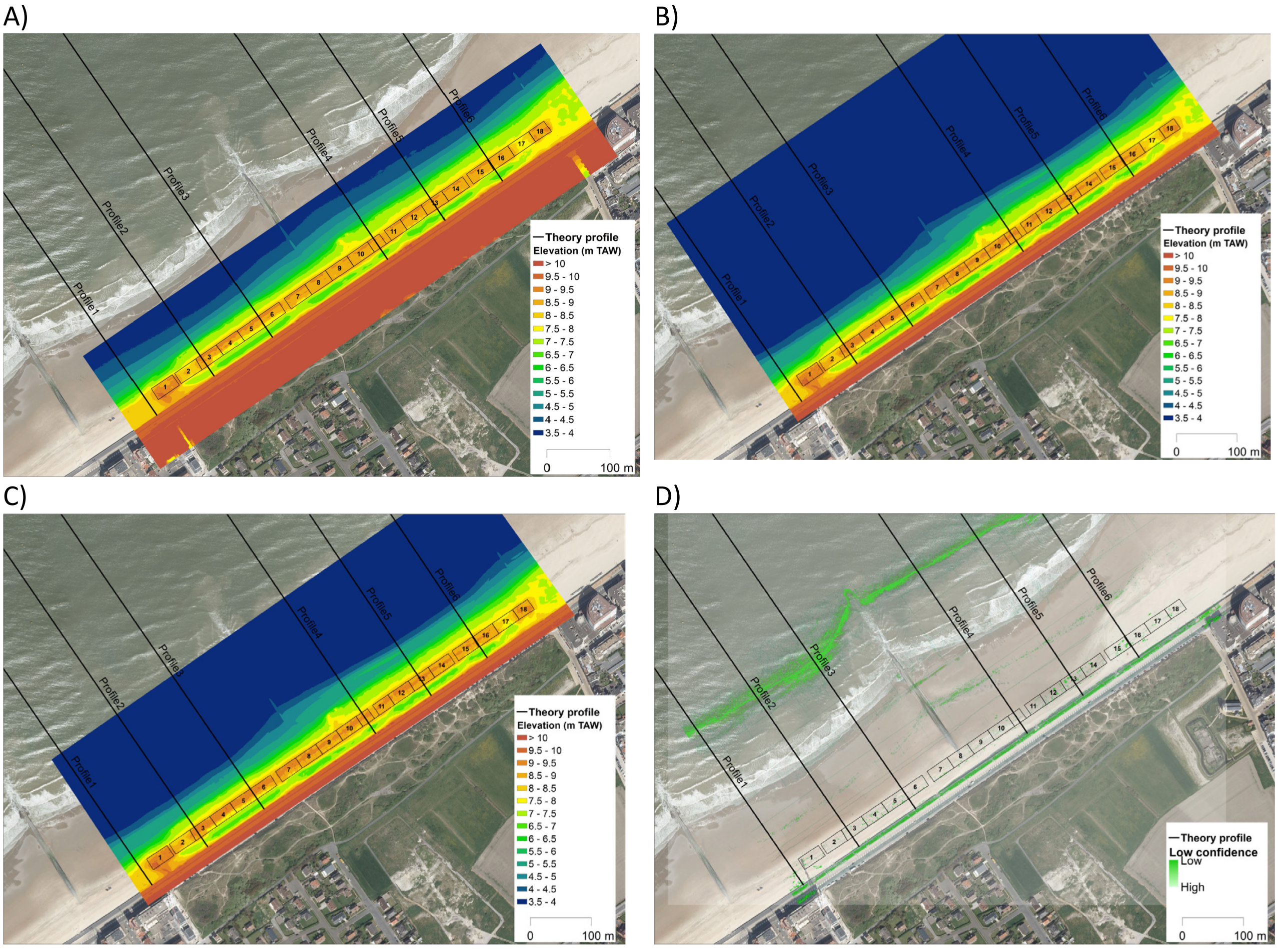
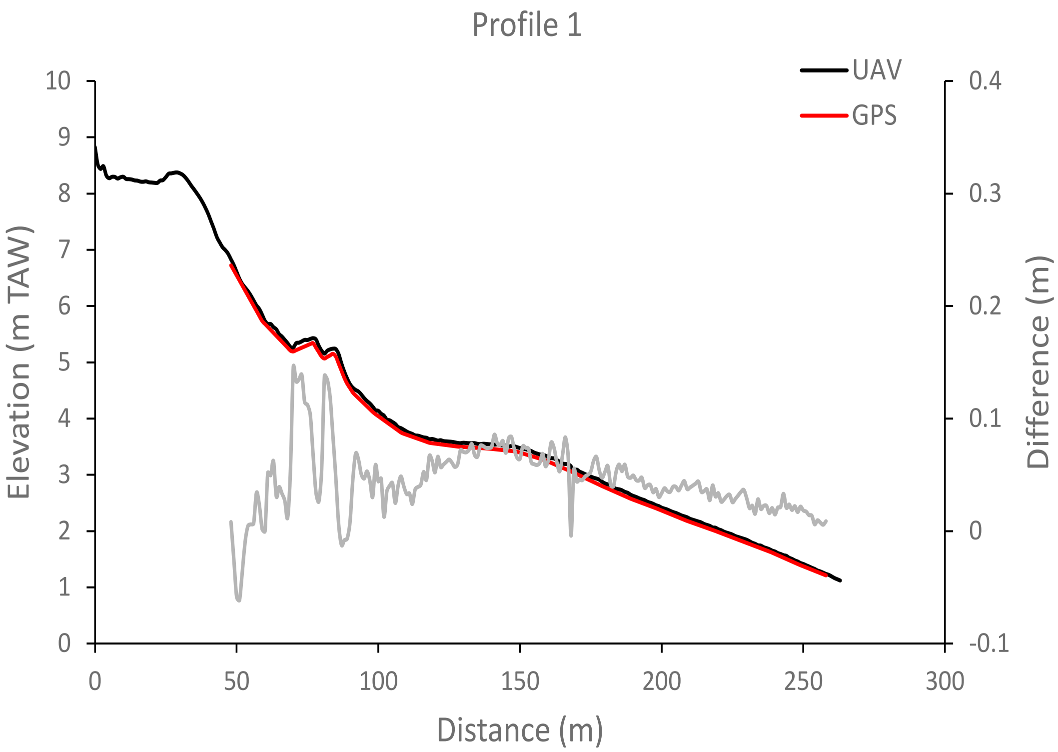
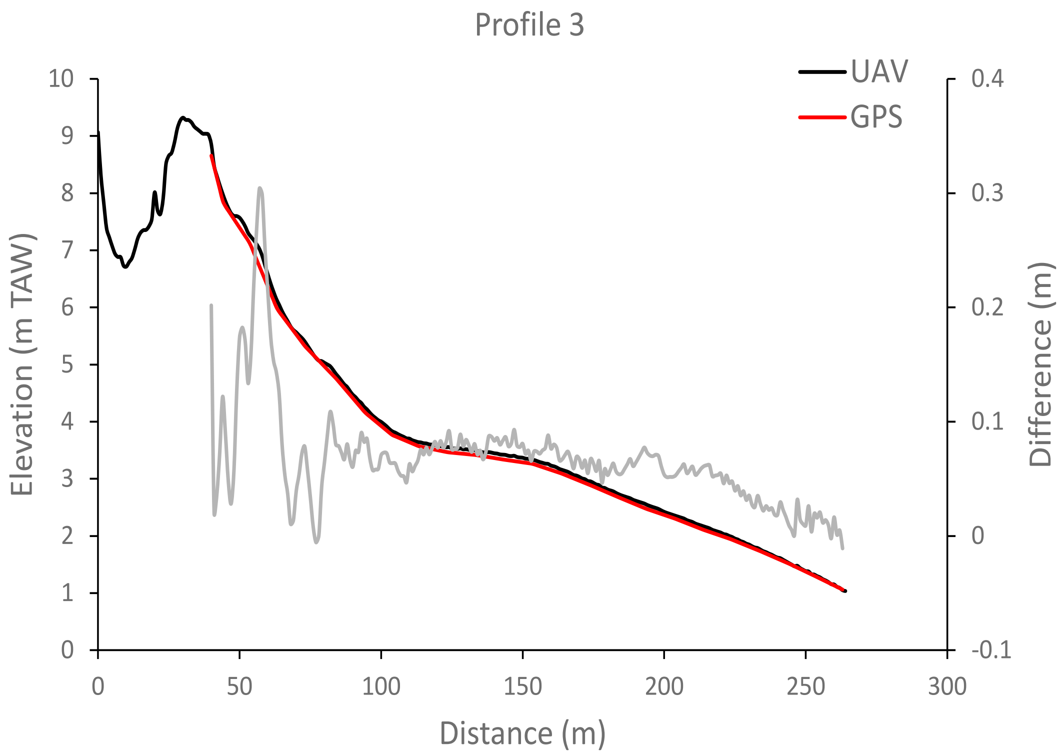


Figure 14 – Comparison of DEM coverage for A) T13 survey (previous coverage) and B) T14 survey (coverage in 09/2022) C) cut DEM in T14 and D) confidence point raster in which green colour corresponds to low confidence.


Profile 1
UAV
GPS
Elevation (m TAW)
Difference (m)
Distance (m)
0
1
2
3
4
5
6
7
8
9
10
-0.1
0
0.1
0.2
0.3
0.4
0
50
100
150
200
250
300


Profile 3
UAV
GPS
Elevation (m TAW)
Difference (m)
Distance (m)
0
1
2
3
4
5
6
7
8
9
10
-0.1
0
0.1
0.2
0.3
0.4
0
50
100
150
200
250
300

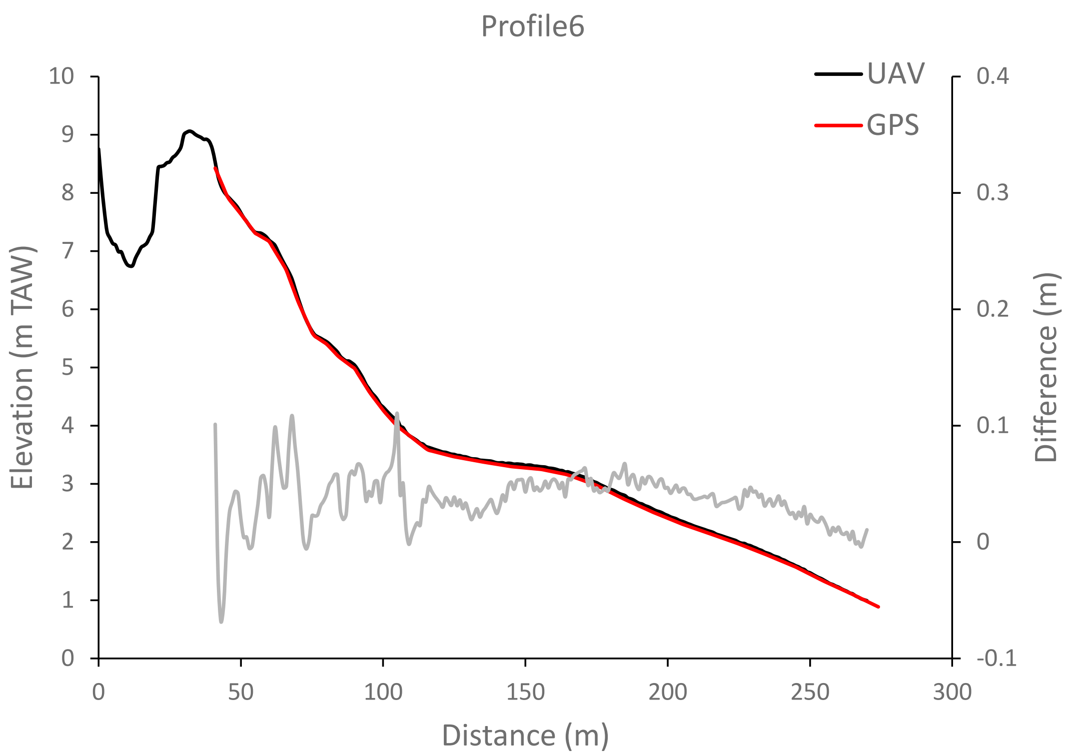


Figure 15 – Difference between the extracted UAV and RTK-GPS profiles (left column) with the confidence indication by the photogrammetric processing (right column) for Profile 1, 3 and 6 on 12/09/2022 (T14).

Table 3 – Statistical summary of the UAV error.

UAV error [m]		Profile1	Profile2	Profile3	Profile4	Profile5	Profile6	All
All	Avg	0.045	0.044	0.060	0.034	0.042	0.037	0.044
	Max	0.146	0.197	0.304	0.131	0.147	0.110	0.304
	SD	0.031	0.053	0.046	0.027	0.027	0.022	0.034
from top to 4.39 m TAW	Avg	0.044	-0.001	0.102	0.037	0.051	0.037	0.045
	Max	0.146	0.197	0.304	0.131	0.147	0.109	0.304
	SD	0.054	0.088	0.077	0.037	0.037	0.034	0.054
from 4.39 m TAW to 1.39 m TAW	Avg	0.047	0.064	0.061	0.037	0.045	0.041	0.049
	Max	0.086	0.104	0.093	0.077	0.090	0.110	0.110
	SD	0.018	0.016	0.019	0.020	0.021	0.014	0.018
from 1.39 m TAW to low	Avg	0.012	0.014	0.010	-0.008	0.011	0.009	0.008
	Max	0.022	0.037	0.026	-0.001	0.025	0.021	0.037
	SD	0.005	0.011	0.009	0.007	0.007	0.007	0.008

All the data and analyses can be found:

E:\RaversijdeLivingLab_21_012\Data\Topography
E:\Duin voor dijk pilots_21_014\Analyses\raversijde_mariakerke\Profiles

4 Bathy-topographic monitoring

4.1 Merging beach and shoreface surveys

Finally, DEMs merging the beach and the shoreface were generated with a cell size of 2 m and 10 m by giving the priority of the shoreface data (i.e. DEM groynes were not considered here). Table 4 and Figure 16 present the combination of the survey dates and an example of DEM. Following this, DoDs of 2 m cell size were produced in order to highlight the potential influences of the groynes on the morphology represented on the single beam DEMs.

Table 4 – Merging beach from LiDAR topographic survey and shoreface from bathymetric survey.

Name	Beach (LiDAR survey)	Shoreface (Single bathymetric survey)
2021	28/04/2021	09/06/2021
2022_1	23/02/2022	23/02/2022
2022_2	17/04/2022	19/04/2022

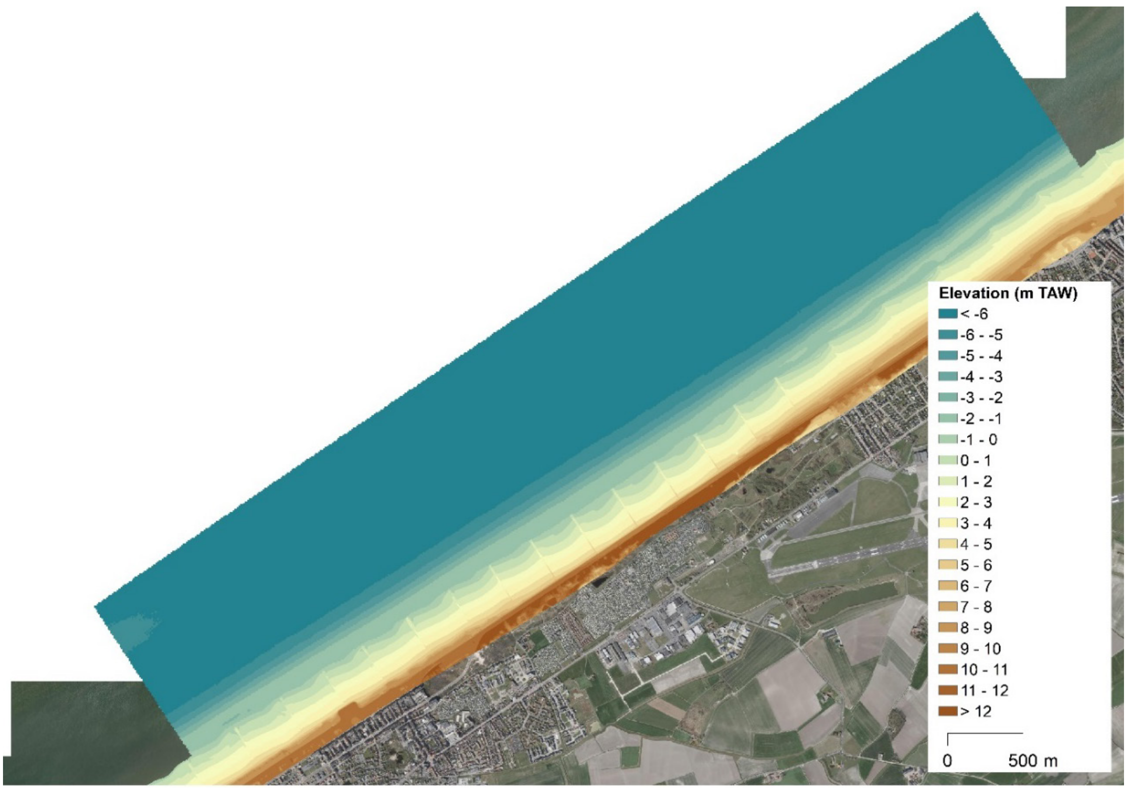


Figure 16 – Example of merging beach and shoreface DEM of 2021 with 2 m cell size.

4.2 Comparing survey techniques for the region around the low water line

The study site was surveyed on 12/09/2022 with drone, hand RTK-GPS and multibeam techniques. These give the opportunity to compare techniques for the region around the low water line (Figure 17).

In general, the width of the overlapping area is 120 m between UAV and multibeam and 25 m between hand GPS and multibeam. Figure 18 presents a difference DEM between UAV and multibeam. The average difference is -0.07 m, and thus elevation determined by the multibeam survey is lower than the UAV one. The difference gradually increases seaward. For further investigations, profiles were extracted to compare the three techniques (Figure 19). On the profiles, one can observe that the region around the low water line, which is the most difficult to monitor, can be covered by both UAV and multibeam techniques. With the multibeam ca. +1.2 m TAW was reached, which is to be related to the high water on that day of 5.04 m TAW. With the UAV ca. +0.2 m TAW was reached, which is to be related to the low water on that day of 0.13 m TAW.

Table 5 presents the differences between the survey techniques along the six profiles. In general, there is a restrained difference between UAV and multibeam. Surprisingly, UAV depicts the topography till a distance of approximately 300 m where the confidence of the survey was flagged low by the photogrammetric processing. It suggests that the area of the cut DEM T14 (cfr. 4.1) could be expanded ca. 50 m further seaward so performing a 'cutting' process based on the orthophoto and not on the low confidence parameter from the photogrammetric processing. As previously observed, UAV slightly overestimates the beach topography with an average error referenced to the hand GPS technique of 0.04 m. In general, the average of error between UAV and MB for the elevation from 1.2 m to 0.2 m TAW is only 0.01 m with a standard deviation of 0.02 m.

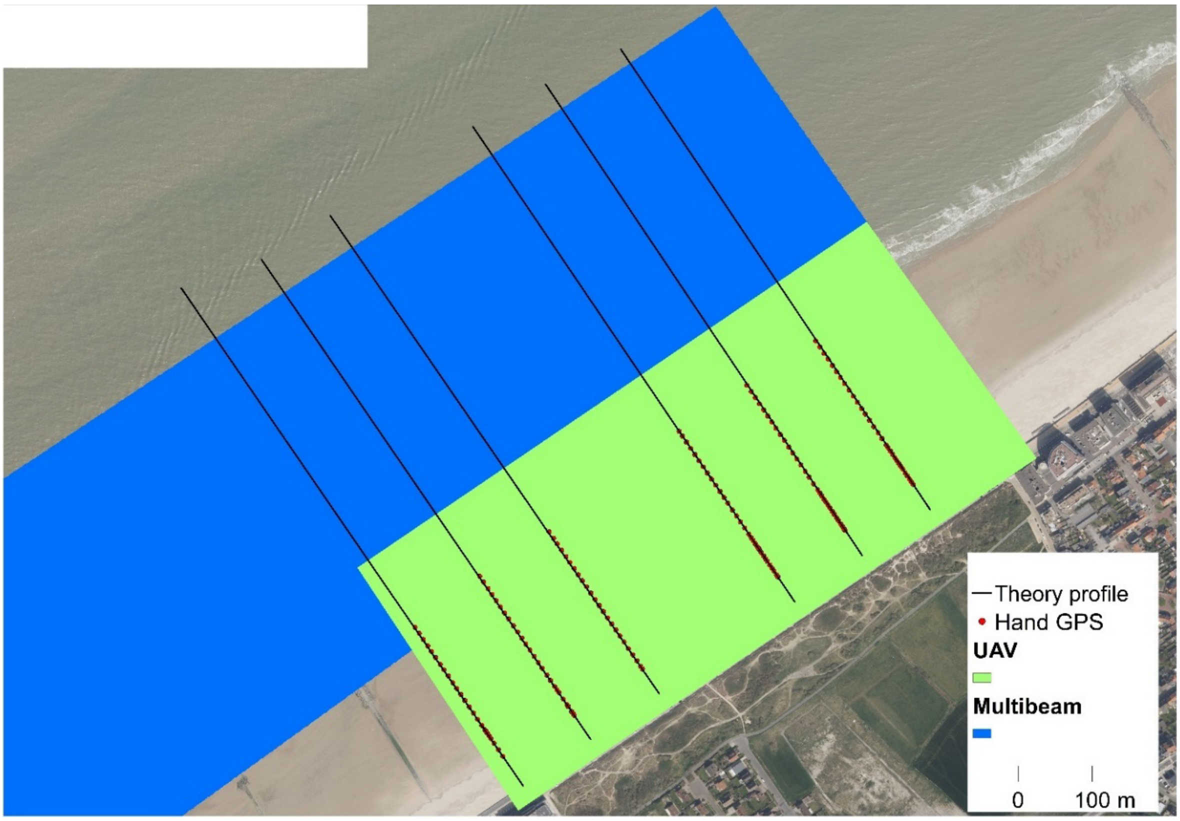


Figure 17 – Areas of the different survey techniques on 12/09/2022. Profile 1 (left) to profile 6 (right).

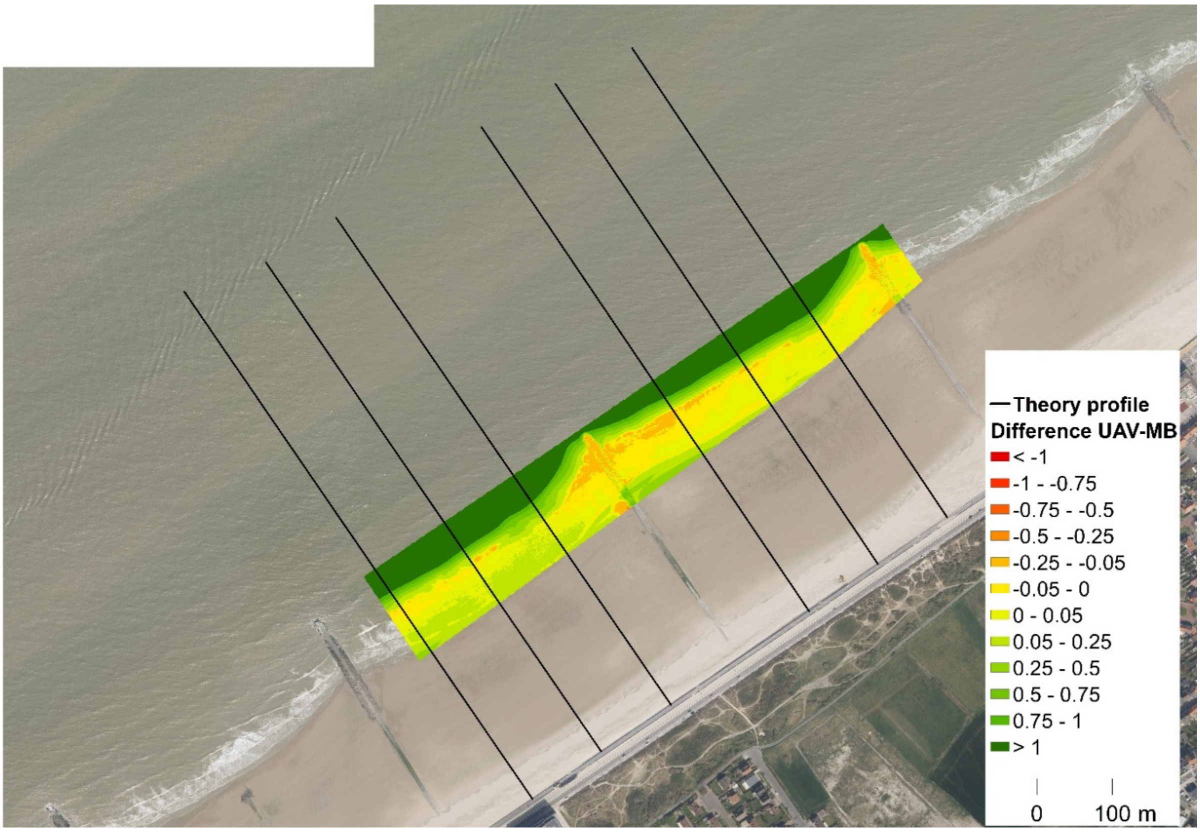
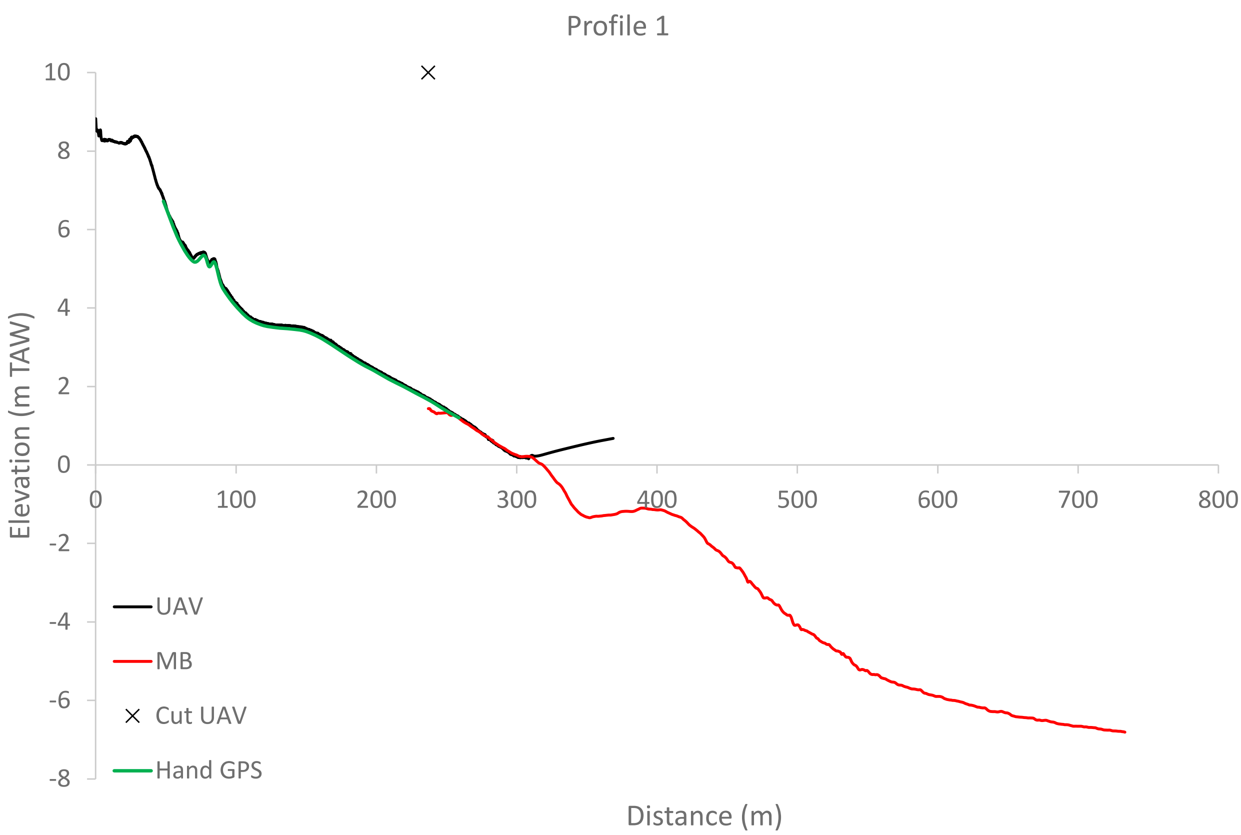
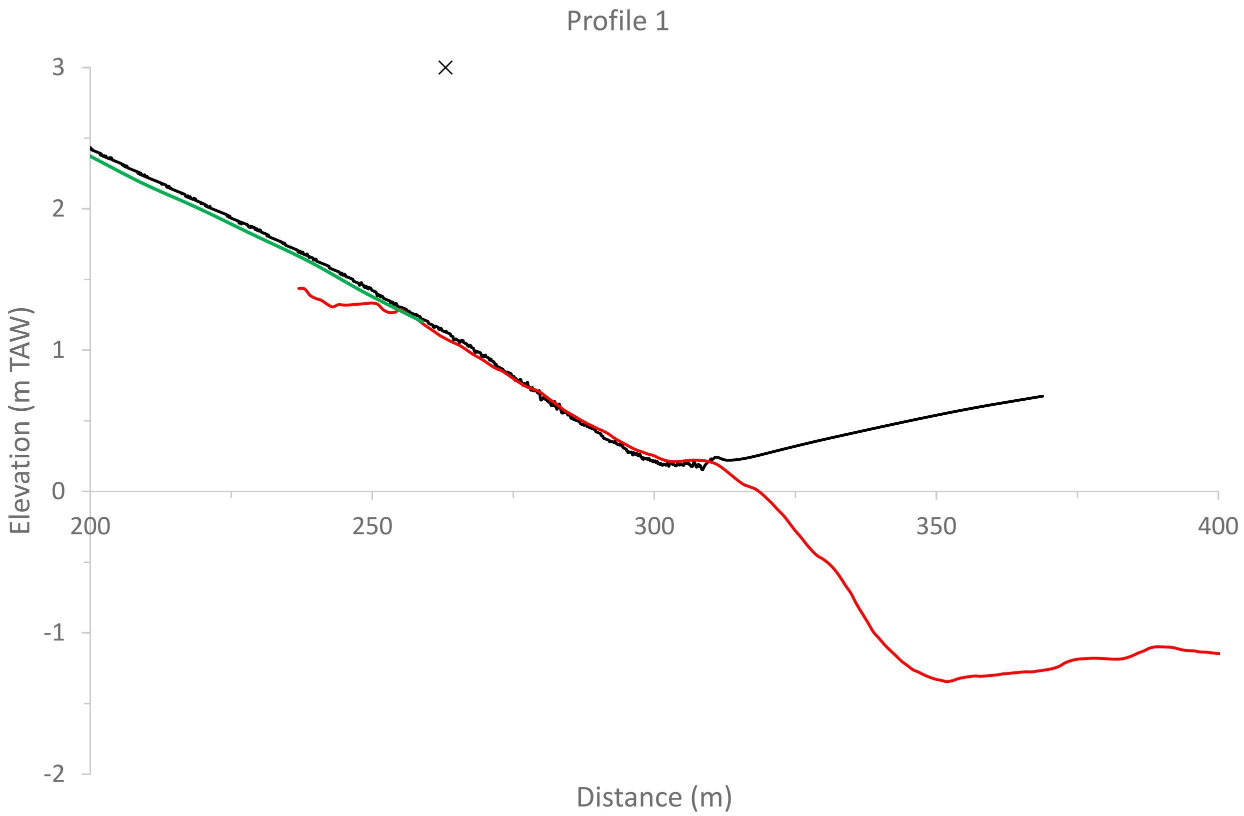
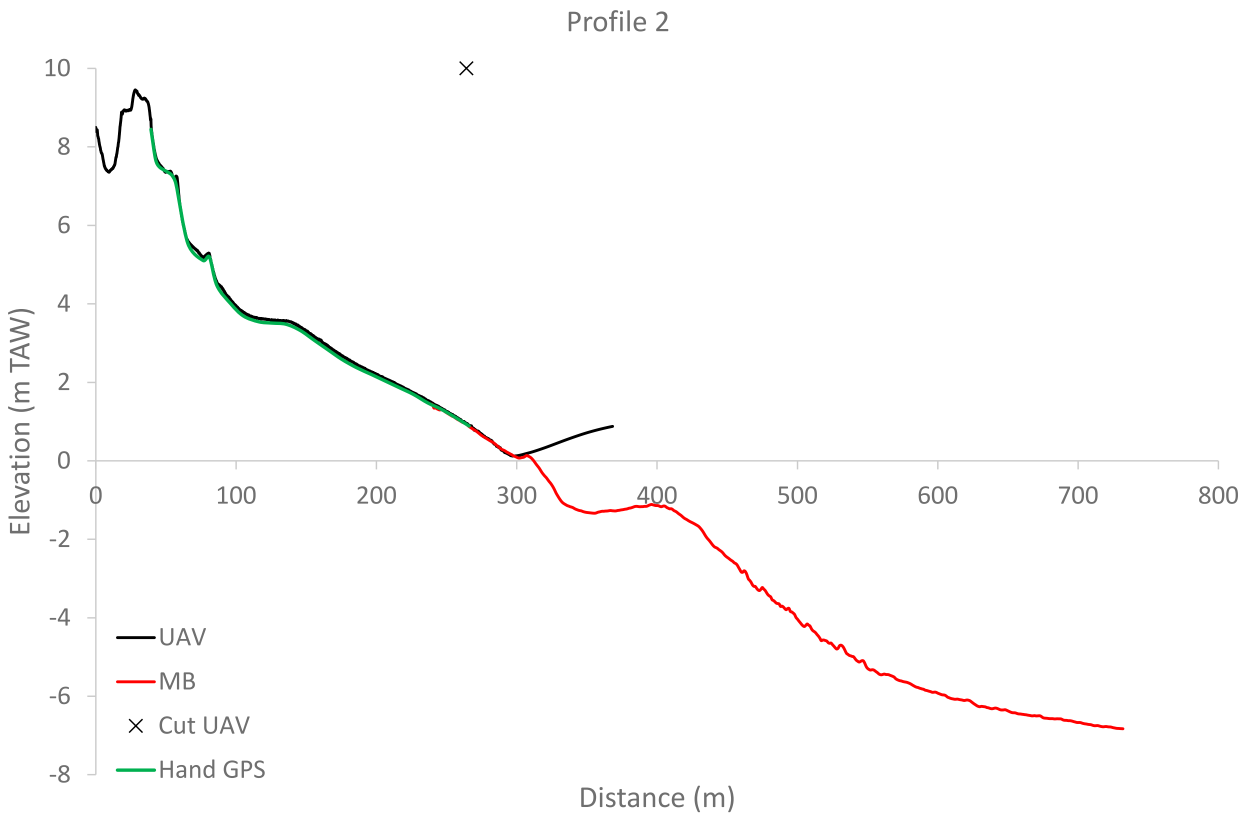
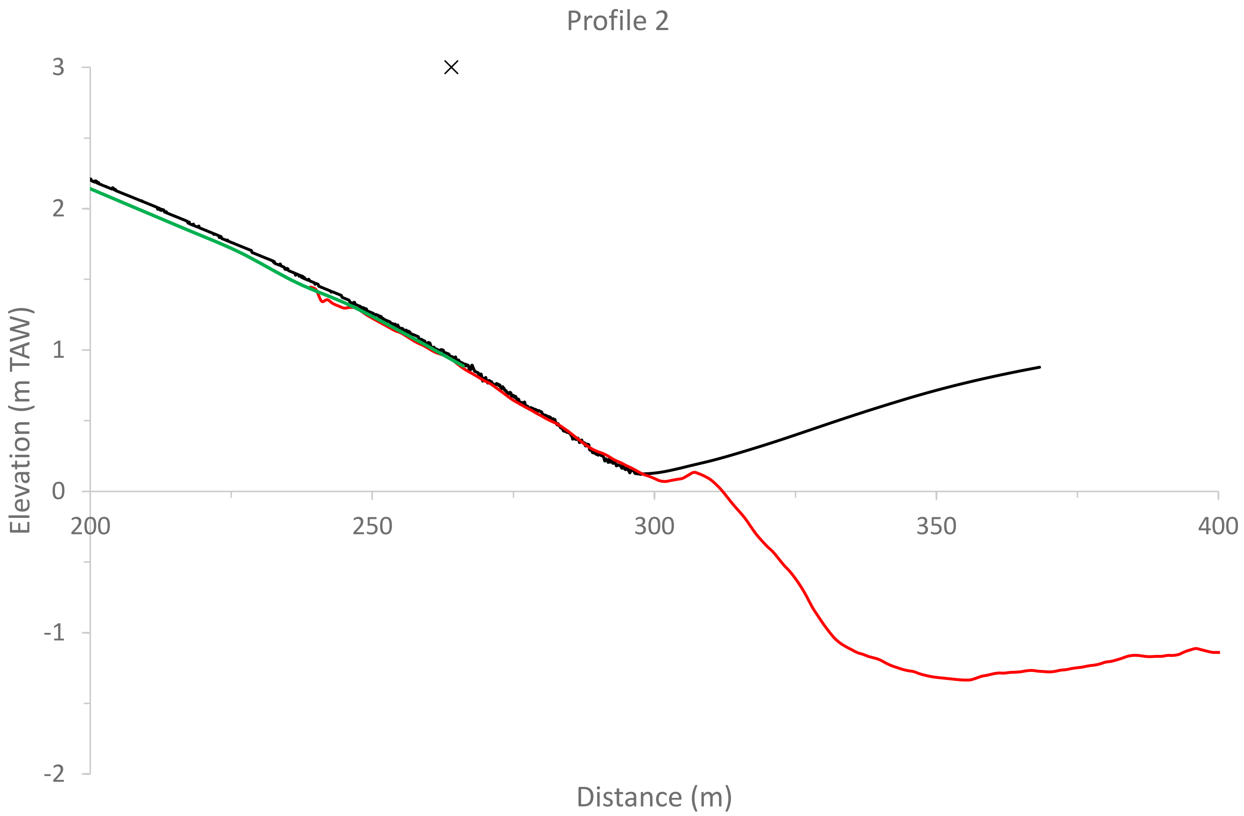


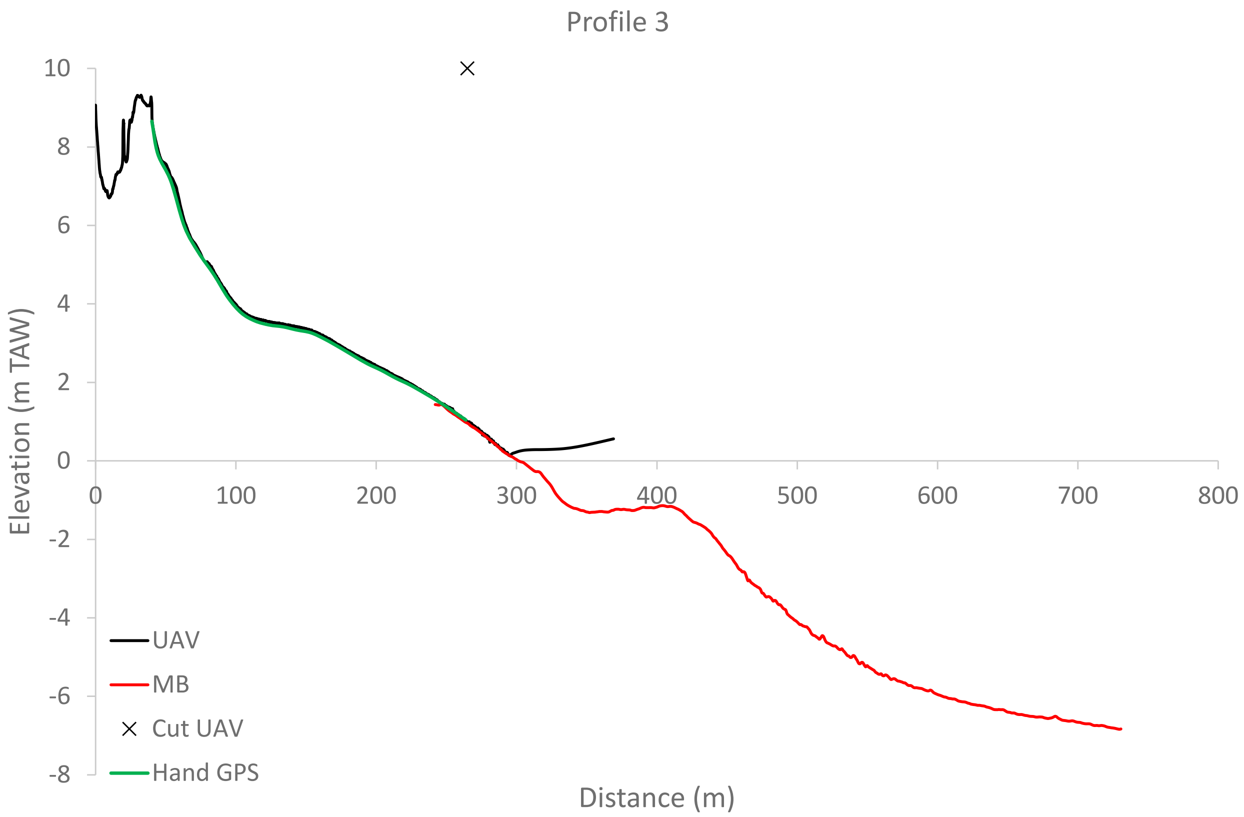
Figure 18 – Difference DEM between UAV and multibeam survey on 12/09/2022. Profile 1 (left) to profile 6 (right).

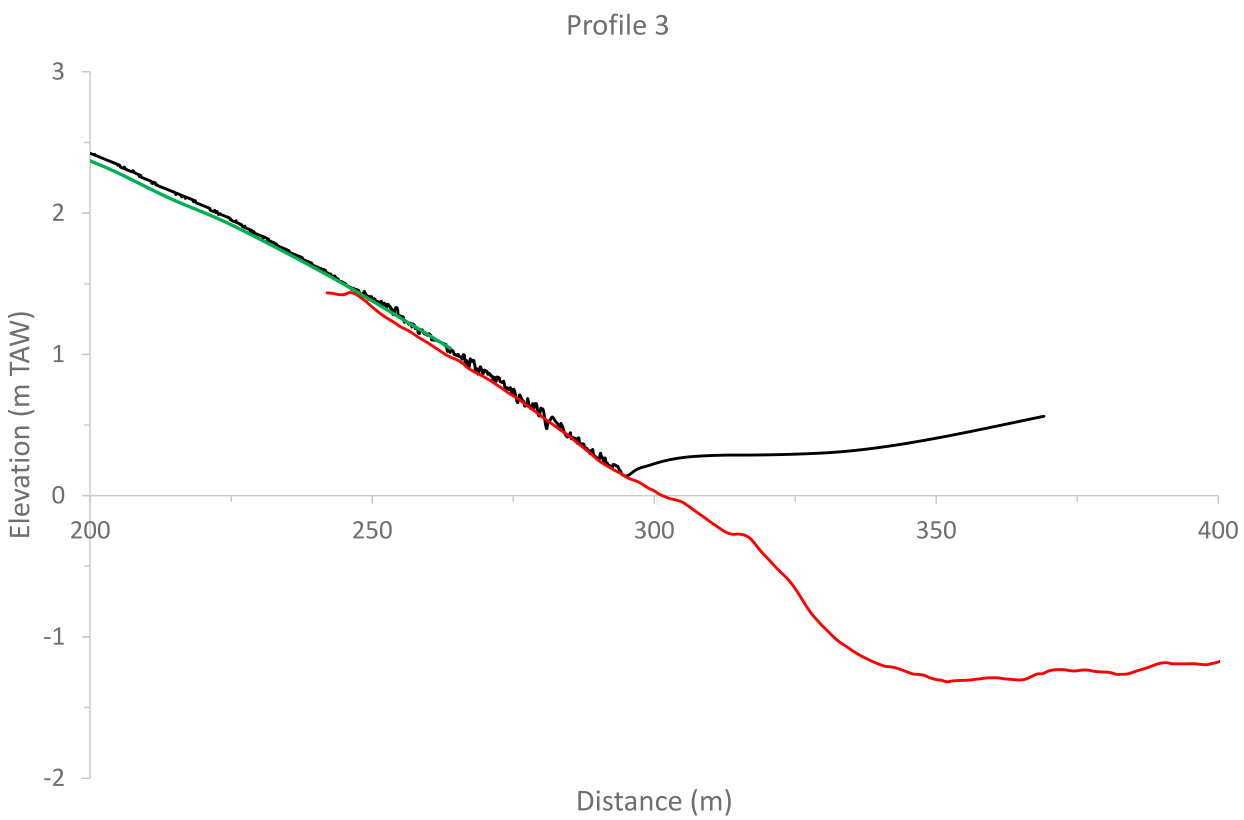


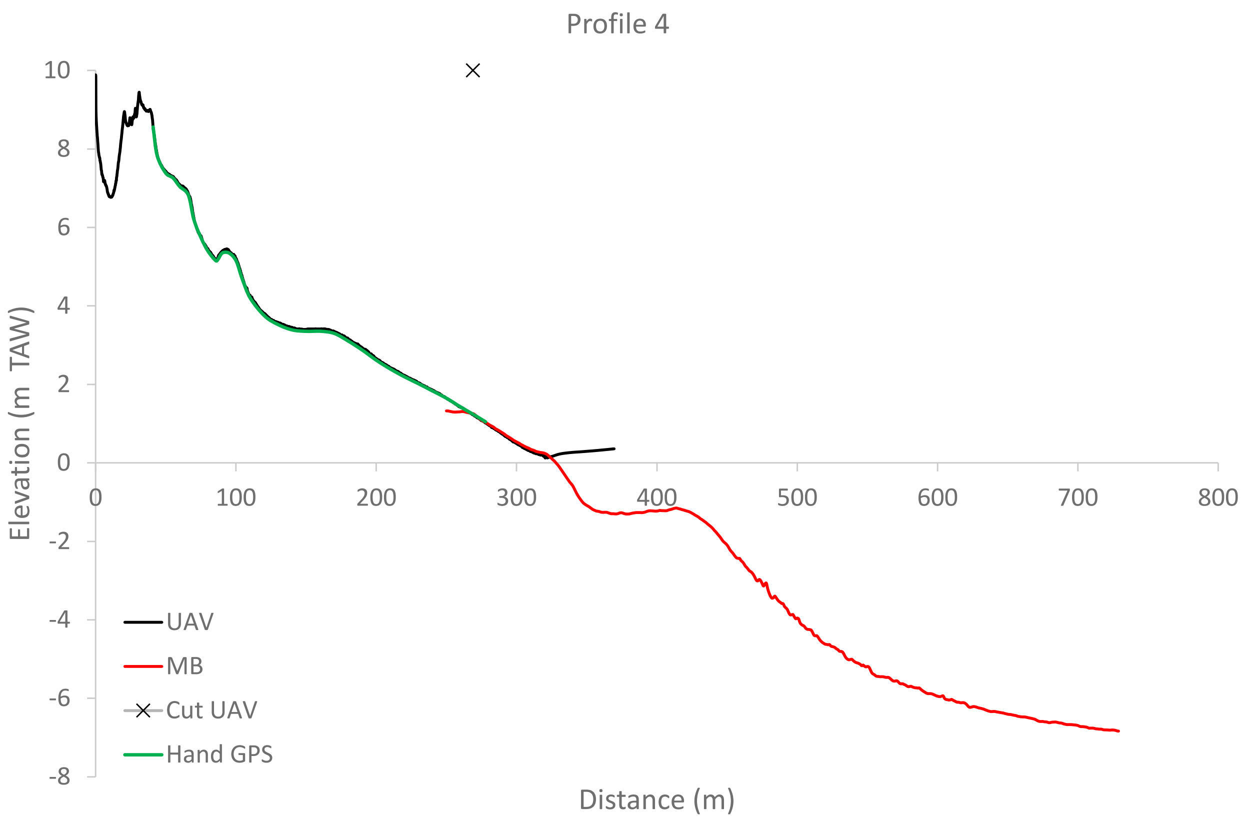

Profile 1
Elevation (m TAW)
Distance (m)
3
2
1
0
-1
-2
200
250
300
350
400

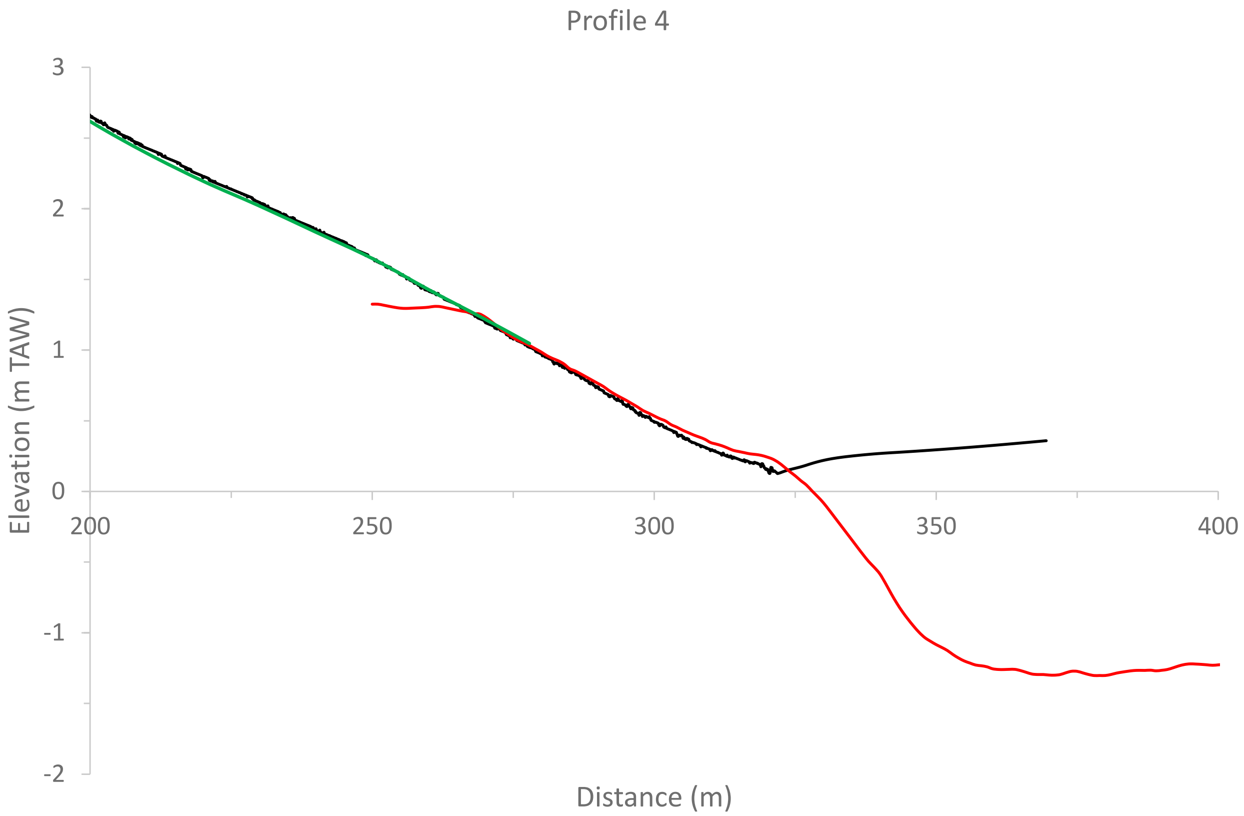

Profile 2
Elevation (m TAW)
Distance (m)
10
8
6
4
2
0
-2
-4
-6
-8
0
100
200
300
400
500
600
700
800
UAV
MB
Cut UAV
Hand GPS

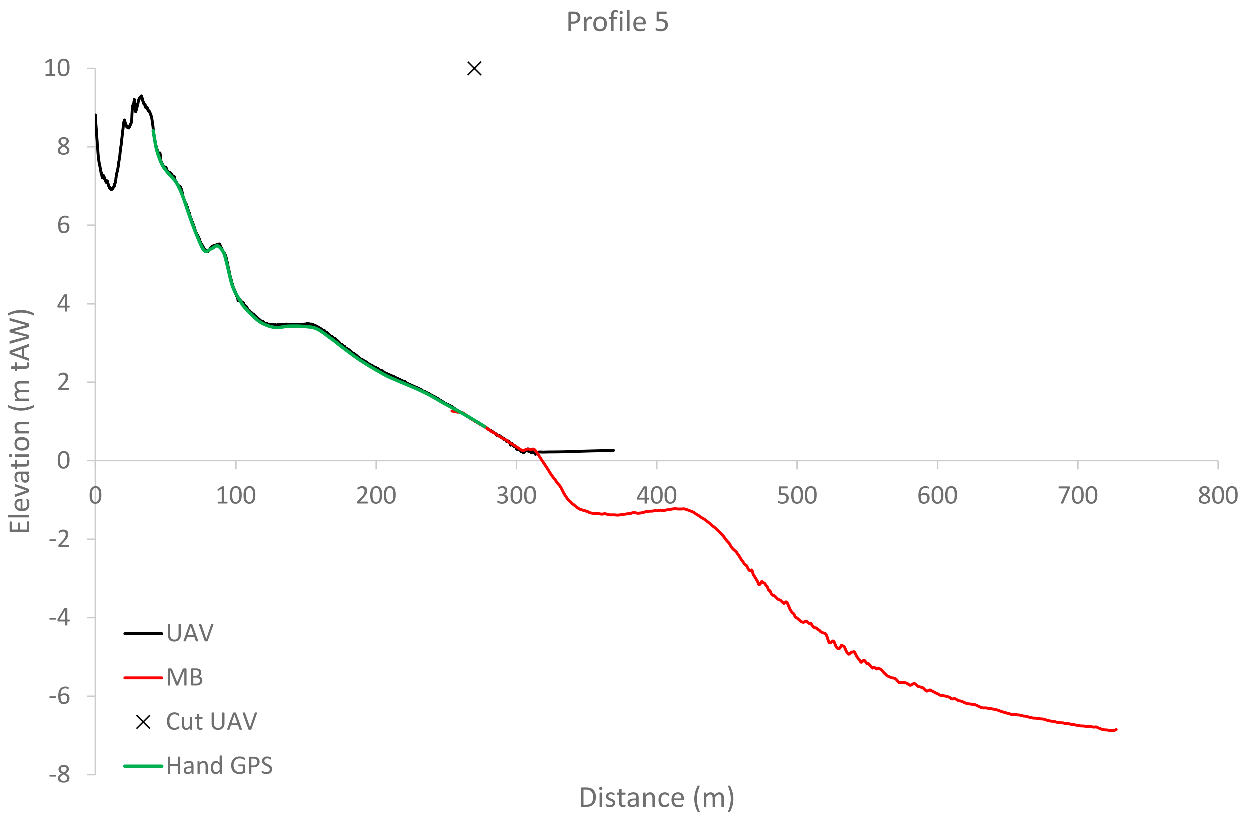

Profile 2
Elevation (m TAW)
Distance (m)
3
2
1
0
-1
-2
200
250
300
350
400

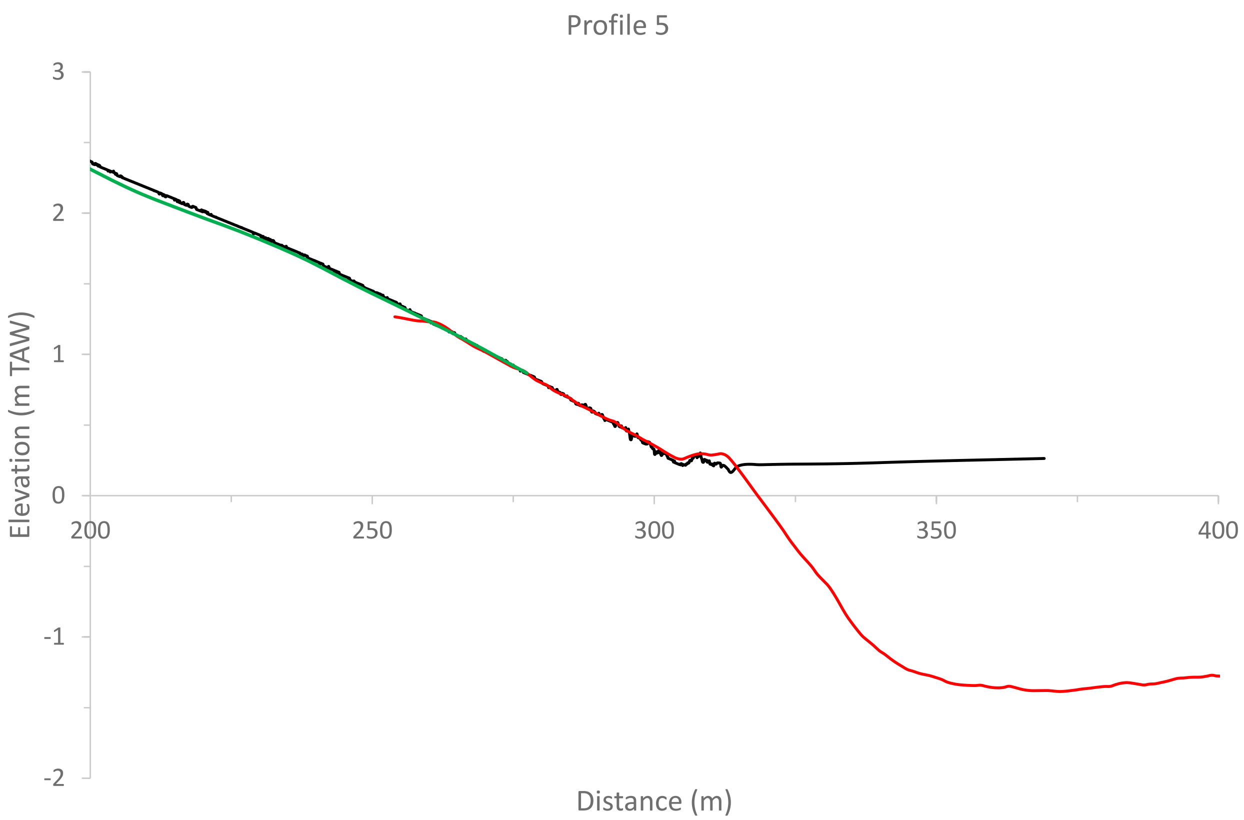

Profile 3
Elevation (m TAW)
Distance (m)
10
8
6
4
2
0
-2
-4
-6
-8
0
100
200
300
400
500
600
700
800
UAV
MB
Cut UAV
Hand GPS

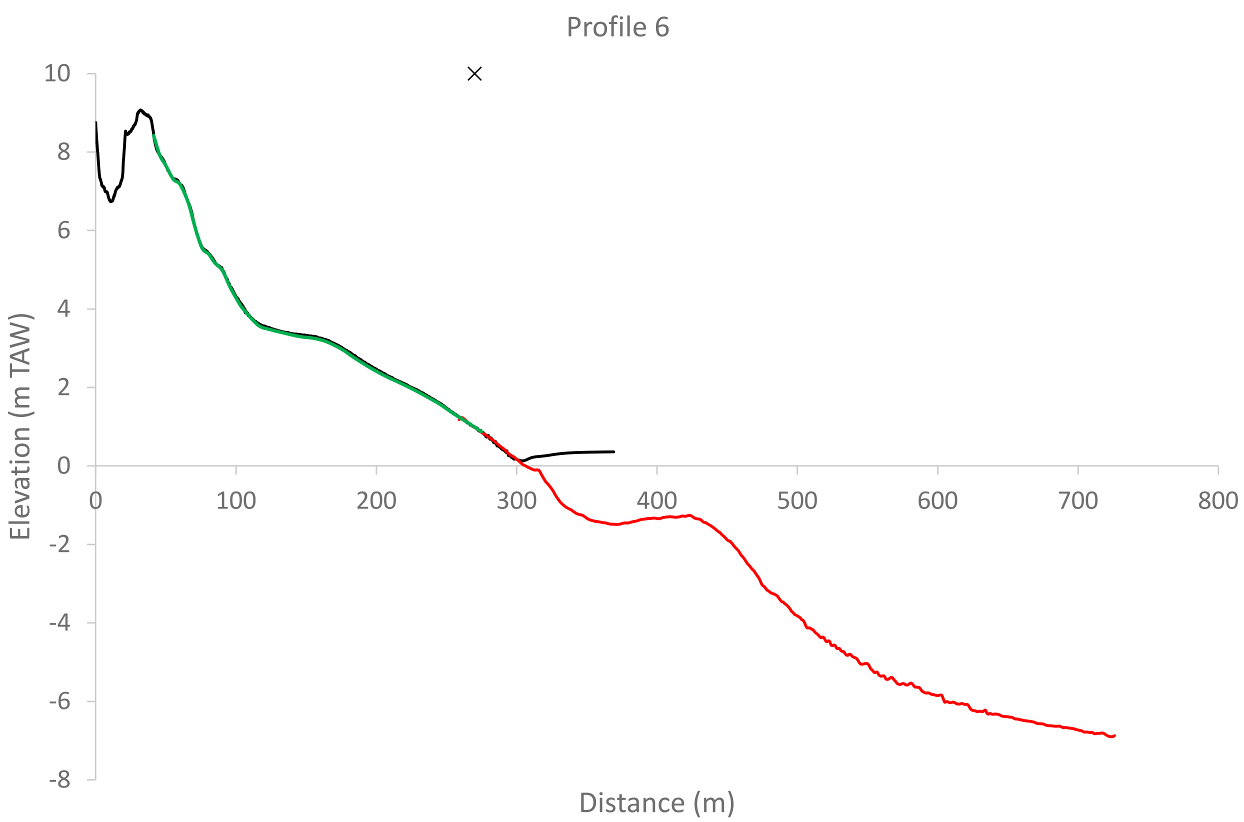

Profile 3
Elevation (m TAW)
Distance (m)
3
2
1
0
-1
-2
200
250
300
350
400


Profile 4
Elevation (m TAW)
Distance (m)
10
8
6
4
2
0
-2
-4
-6
-8
0
100
200
300
400
500
600
700
800
UAV
MB
Cut UAV
Hand GPS


Profile 4
3
2
1
0
-1
-2
Elevation (m TAW)
200
250
300
350
400
Distance (m)


Profile 5
10
8
6
4
2
0
-2
-4
-6
-8
Elevation (m tAW)
0
100
200
300
400
500
600
700
800
Distance (m)
UAV
MB
Cut UAV
Hand GPS


Profile 5
Elevation (m TAW)
3
2
1
0
-1
-2
200
250
300
350
400
Distance (m)


Profile 6
Elevation (m TAW)
10
8
6
4
2
0
-2
-4
-6
-8
0
100
200
300
400
500
600
700
800
Distance (m)

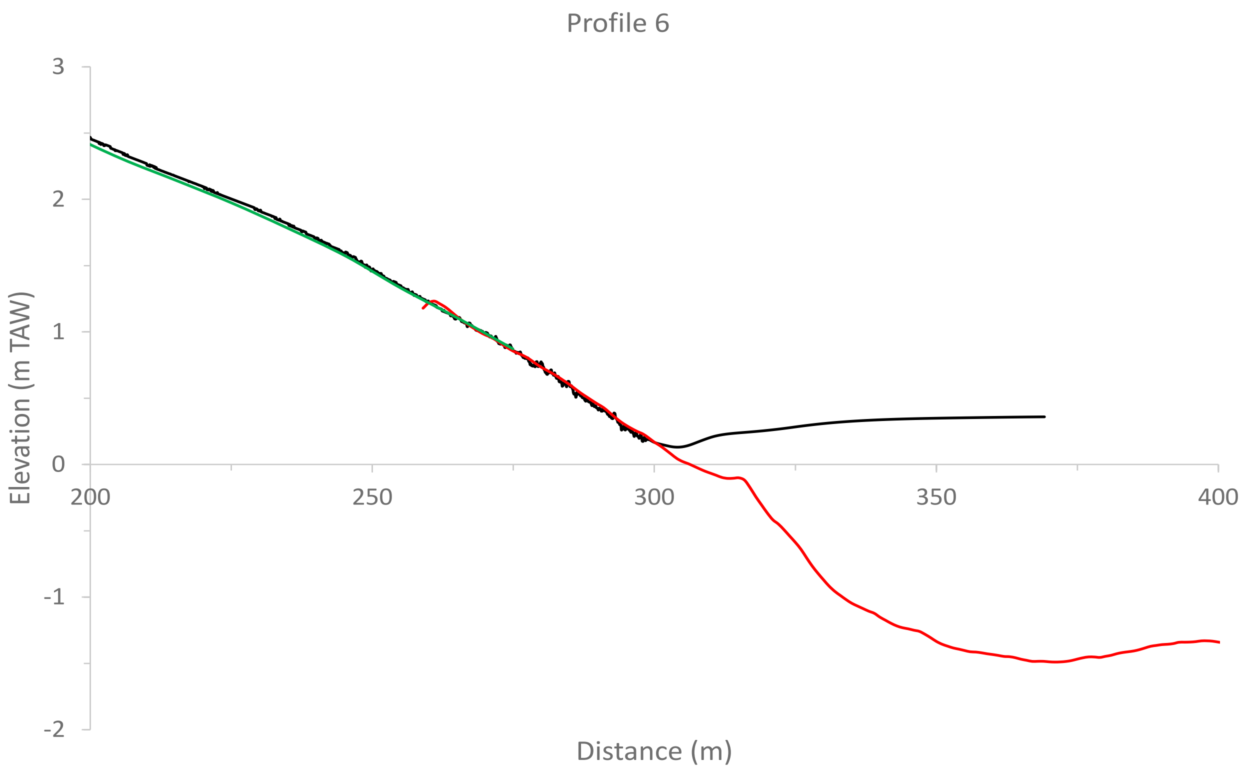


Figure 19 – Extracted profiles from UAV and multibeam DEMs with the reprojected hand GPS points.

Table 5 – Summary statistics of the difference between survey techniques along the profiles

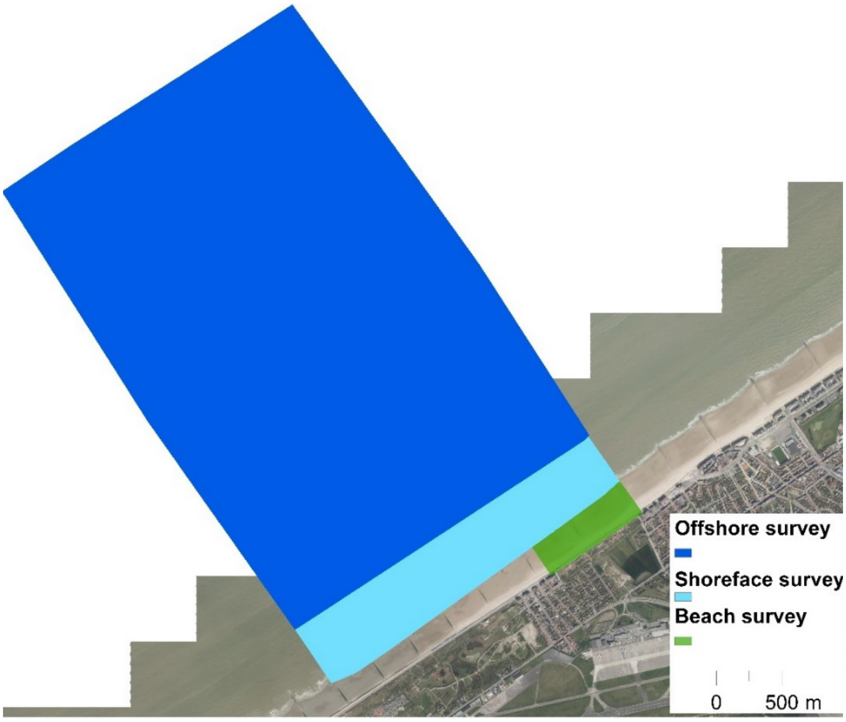
Diff UAV-MB [m]		Profile1	Profile2	Profile3	Profile4	Profile5	Profile6	Profile 1-6
All	Avg	0.566	0.702	0.721	0.402	0.536	0.691	0.603
	Max	1.940	2.148	2.158	1.649	1.642	1.844	1.897
	Min	-0.052	-0.026	-0.106	-0.087	-0.087	-0.054	-0.069
	SD	0.747	0.856	0.861	0.605	0.672	0.738	0.747
from 1.2 to 0.2 m TAW	Avg	-0.004	0.018	-0.020	-0.037	-0.011	-0.011	-0.011
	Max	0.050	0.046	0.024	-0.004	0.031	0.033	0.030
	Min	-0.052	-0.026	-0.050	-0.087	-0.087	-0.054	-0.059
	SD	0.031	0.021	0.018	0.021	0.026	0.020	0.023
Diff MB-HandGPS [m]								
All	Avg	-0.116	-0.013	-0.060	-0.106	-0.016	0.000	0.046
	Max	1.940	0.010	-0.020	0.017	0.020	0.037	0.718
	Min	-0.052	-0.056	-0.126	-0.323	-0.087	-0.063	0.095
	SD	0.747	0.015	0.024	0.111	0.027	0.024	0.265
Diff UAV-HandGPS [m]								
All	Avg	0.065	0.066	-0.043	0.034	0.037	0.028	0.037
	Max	0.127	0.312	0.606	0.129	0.151	0.085	0.181
	Min	-0.002	-0.114	-0.395	-0.046	-0.044	-0.092	0.130
	SD	0.022	0.038	0.147	0.028	0.026	0.023	0.045

All the data can be found here:
E:\RaversijdeLivingLab_21_012\Data\TritonBathyData\MB_20220912\AvgDepth

4.3 Combining beach and shoreface

An offshore survey carried out by multibeam occurred from 13/09/2022 to 11/10/2022 (Figure 20A). It was combined to the beach and shoreface survey measured by UAV and multibeam techniques respectively on 12/09/2022. DEM of 1 m cell size was generated (Figure 20B).

A)



B)

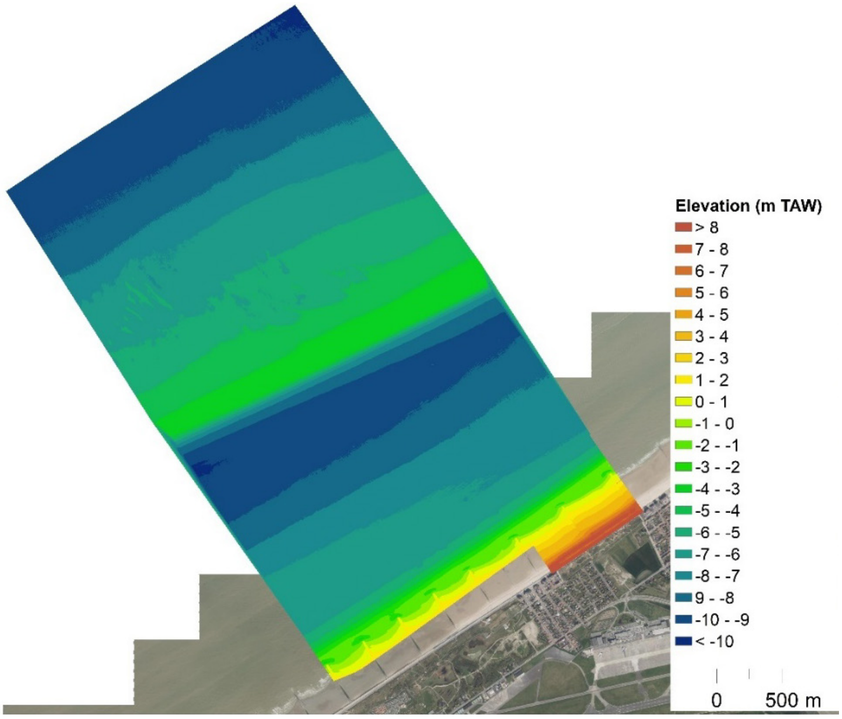


Figure 20 – A) Area of the surveys, B) combined DEM of the beach, shoreface and offshore area.

All the data and analyses can be found:
E:\RaversijdeLivingLab_21_012\Data\Topography\MergedBeachShoreface\202209

5 Hydrodynamics monitoring

5.1 Meetnet Vlaamse Banken measurements

Water level and waves are continuously measured at Oostende tide gauge and the wave buoys at Raversijde 1 and Raversijde 2, all the recorded data being available on the Meetnet Vlaamse Banken platform (Figure 21, Table 6). In addition, in-situ wave and currents were measured from Acoustic Doppler Current Profiler (ADCP) sensors from Nortek Signature 1000 located on two frames (Table 7, Figure 22). The sensors were set-up on a customized closed frame based on a Nortek design with a gimbal ensuring stability. A file contains 43 200 records, equivalent to 3 hours. Figure 23 displays time series of measured meteo and marine parameters. Time series of measurements of an energetic day event from the Meetnet Vlaamse Banken platform and in-situ ADCP sensors are displayed in Figure 24. Station 1 (Rav1 and ADCP1) and station 2 (Rav2 and ADCP2) are located at -5.7 m and -9.2 m TAW respectively. Appendix B presents the time series for ADCP sensor at Raversijde 2. Appendix C compares the motion of the sensors during energetic and calm conditions for both ADCPs.

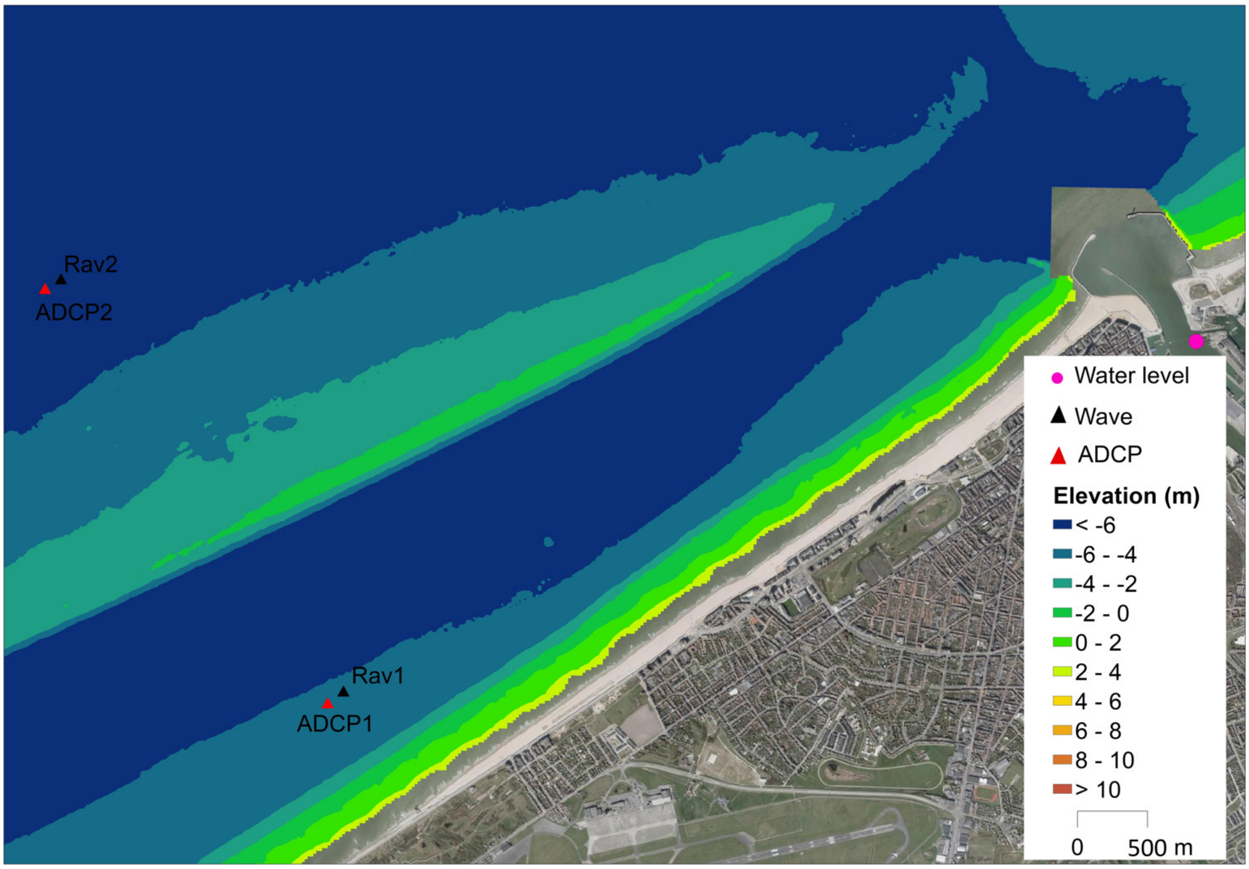


Figure 21 – Map of the hydrodynamic measurement at the study site

Table 6 – Description of the hydrodynamics measurements

	Measure ment	Location	Coordinates	Sensor	Start of the continuous measurement	Description	Resolution
Meet Net Vlaamse Banken	Water level	Oostende tide gauge	2° 55' 36"E, 51° 14' 03"N [Lambert72: 49283, 214780]	Tide gauge	1990's		5 min
	Wave	Raversijde 1 wave buoy	2° 50' 31"E, 51° 12' 40"N; -6 m TAW [Lambert72: 43314, 212334]	Directional Waverider	24/11/2021	Average wave height (H), 10% significant wave height (H10), Average period (Tavg) Wave direction (Dir)	30 min
		Raversijde 2 wave buoy	2° 48' 46"E, 51° 14' 12"N; -10 m TAW [Lambert72: 41336, 215219]	Directional Waverider	01/08/2021		30 min
	Wind	Zeebrugge Weather Station	3° 13' 09"E, 51° 19' 59"N [Lambert72: 69879, 225425]	Obsermet OMC170	1990's	Average wind speed at 10 m Wind direction (Dir)	10 min
In-situ	Current, pressure	Study site Raversijde 1	2°48.673 E, 51°14.162 N [Lambert72: 41225, 215151] -5.7 m	ADCP Nortek Signature 1000	28/03/2022 14:12:55 to 17/06/2022 10:12:55	Current speed (U) Current direction (UDir) Pressure (P)	0.250 s (4 Hz)
	Current, pressure	Study site Raversijde2	2°50.423 E, 51°12.621 N [Lambert72: 43203, 212252] -9.2 m TAW	ADCP Nortek Signature 1000	28/03/2022 13:46:20 to 17/6/2022 05:46:20	Current speed (U) Current direction (UDir) Pressure (P)	0.250 s (4 Hz)

A)

B)

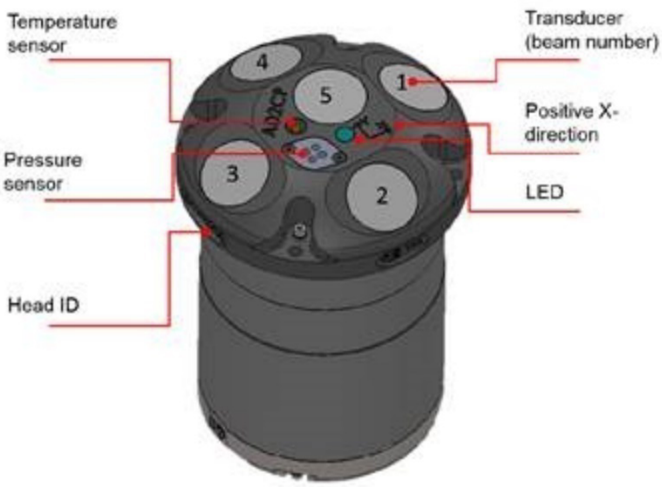


Figure 22 – A) Example of frame used for the campaign, B) Sketch of the ADCP Nortek Signature 1000

Table 7 – Description of the ADCP sensor

Sensor	Raversijde 1	Raversijde 2
Frequency	4 kHz	4 kHz
Cell size	0.5 m	0.5 m
Blanking	0.1 m	3.1 m
Nb beam	4	4
Nb cell	35	35
Distance of the ADCP from the bottom of the frame	105 cm	100 cm

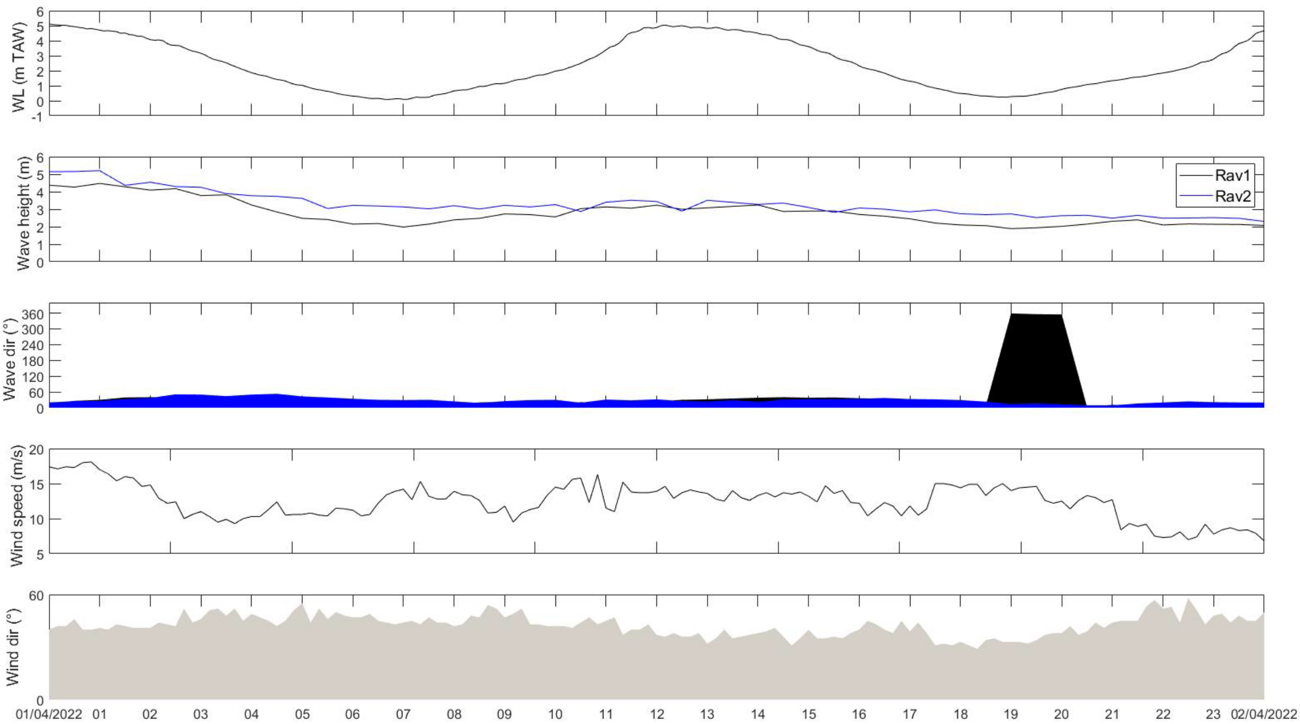
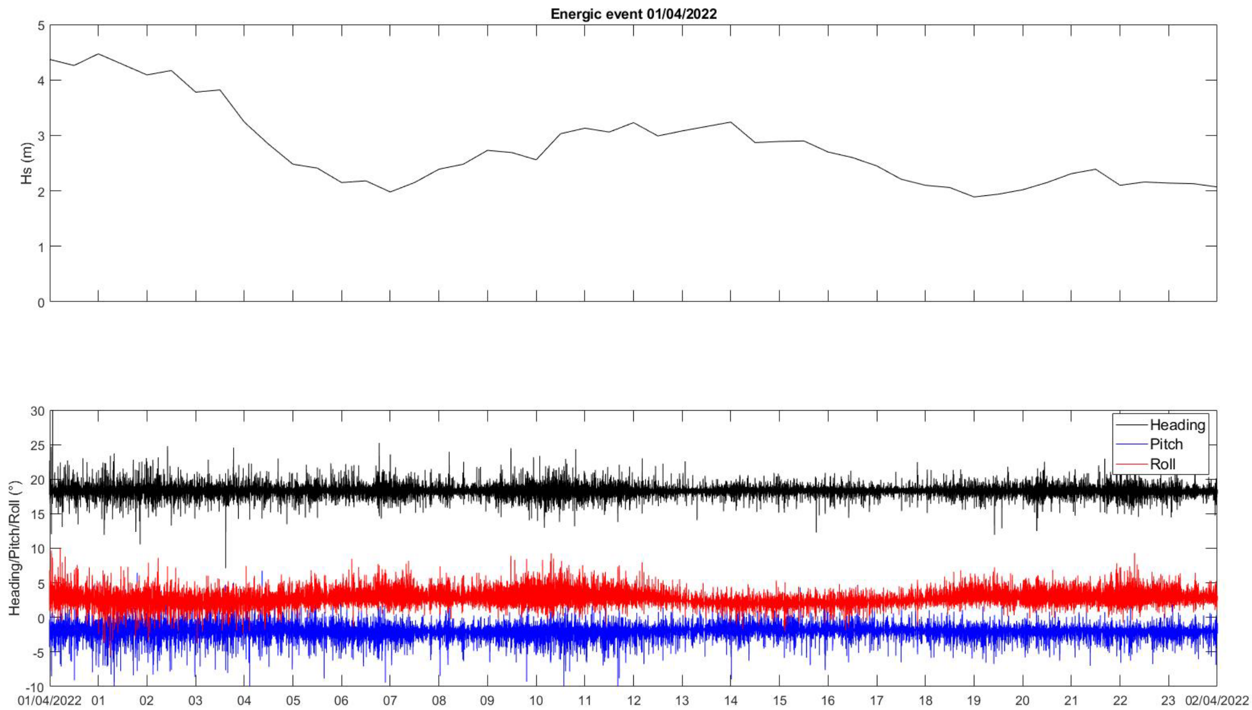


Figure 23 – Time series of water level, wave and wind measurements on 01/04/2022 from the Meetnet platform

The motion of both ADCPs is significant: often > 5°, up to more than 10° during energetic condition (energetic event with Hs of 2.8 m (wave buoy Rav 1) (Figure 24). While it is considered reasonable around 1° during calm condition (Hs: 0.3 m) (Appencix C). The causes of the motion of the instruments during energetic conditions should be investigated since variation on pitch, heading and roll of the instruments larger than 5° can cause significant error in the collected data.

A)



B)

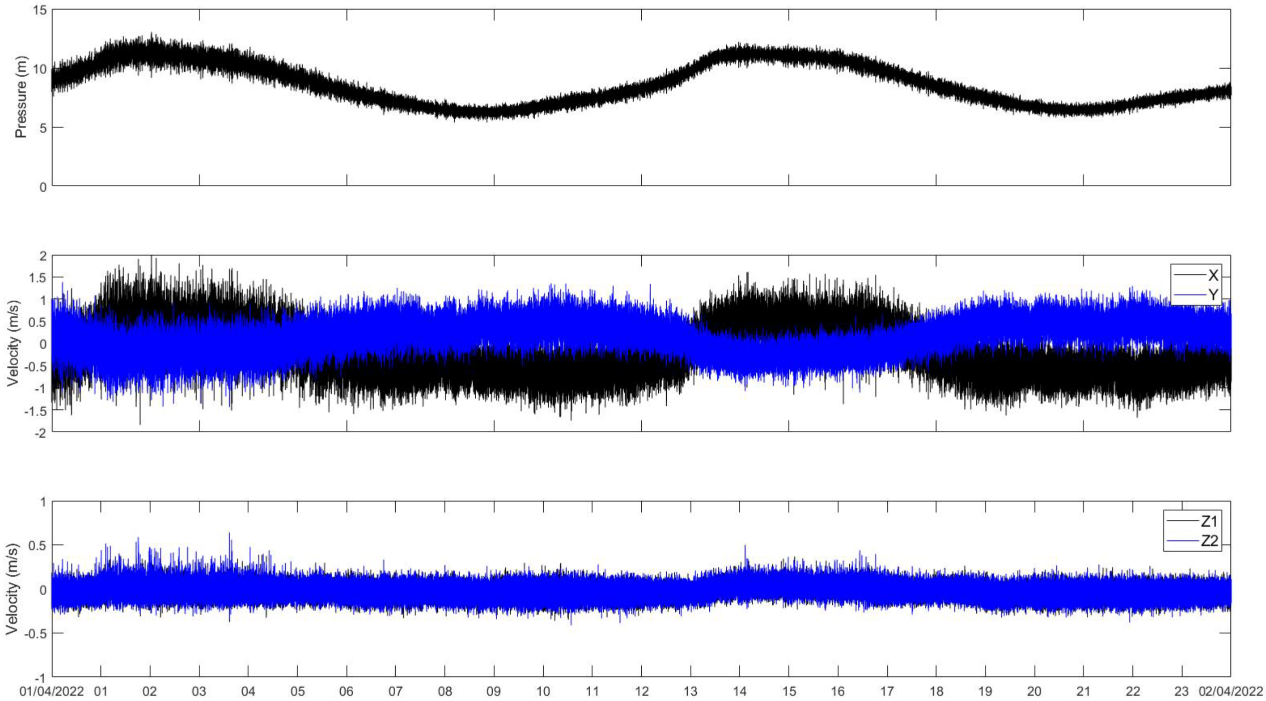


Figure 24 – Time series of A) Hs from wave buoy and sensor orientation, B) pressure, current velocities (cell 1 close to the sensor) from in-situ ADCP sensor at Raversijde 1 for an energetic event on 01/04/2022

All the data and analyses can be found:
E:\RaversijdeLivingLab_21_012\Data\Hydrodynamics

6 Conclusions

- DEMs generated from single beam profile surveys are representative of the morphology of the shoreface. However, the detail of the area near the groynes is missed and this area must be interpreted with care.

- It is suggested to carry on the beach topographic profiles using the handheld RTK-GPS system instead of the quad vehicle mounted system.

- Combining the extraction of profiles from UAV surveys with the hand RTK-GPS surveys allows to cover the entire beach from the dike to the low water line. UAV and RTK-GPS survey must be carried out as closely as possible in time.

- The lower part of the beach is accurately surveyed by the UAV method with a systematic error of 0.04 m plus a standard deviation of 0.03 m compared to the hand RTK-GPS. More comparative monitoring is needed to be able to take into account effects of variable weather conditions.

- Combining multibeam and UAV can result in a good representation of both the wet and the dry part of the active profile if both techniques are pushed to their limit in the area of the low water line. In general, the elevation determined by the multibeam method is lower than the one surveyed with the UAV. The average of difference between UAV and MB for the elevation for the overlapping zone from 1.2 m to 0.2 m TAW is only 0.01 m with a standard deviation of 0.02 m. More comparative monitoring is needed to conclude on reliable estimates of errors. Hand RTK-GPS carried out at low water is very important for this.

- The first hydrodynamics campaign using 2 ADCP frames was carried out in the period from 28/03 to 17/06/2022 during which a storm on 1/4/2022 was captured with energetic wave and current conditions. Further investigation of the sensor motion should be done before the second campaign in 11/2022.

7 References

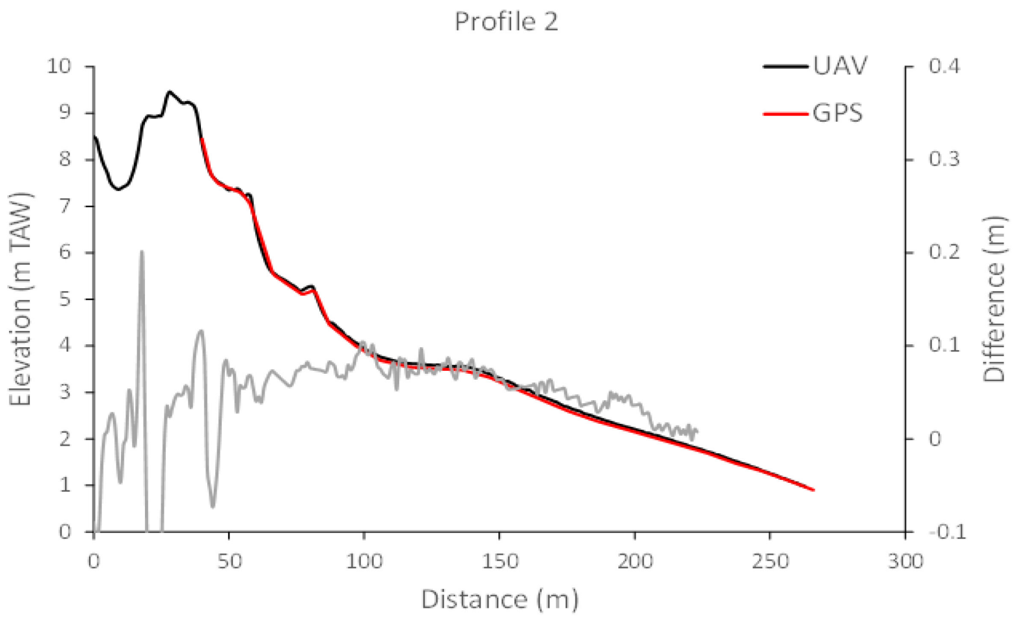
ATO (2022) Strandmeting Raversijde, Rapport_20220912_DUDE_Raversijde_T14, 6pp.

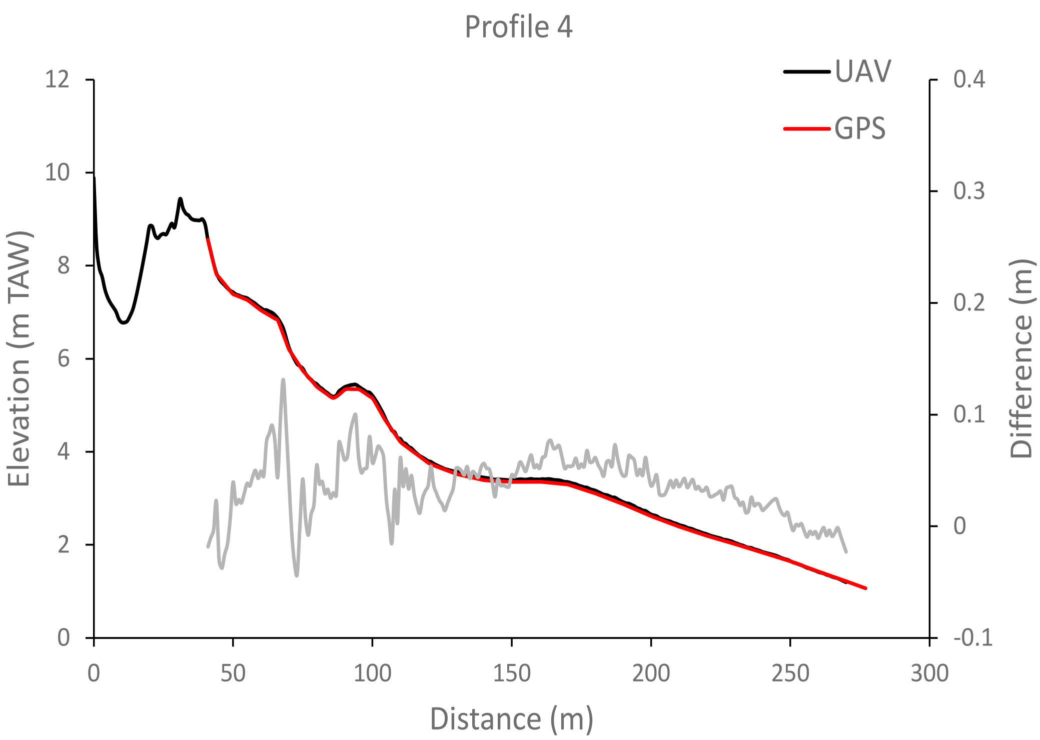
Verwaest, T.; Willems, M., Living Lab Raversijde, monitoringplan jaar 1. 2021-2022.

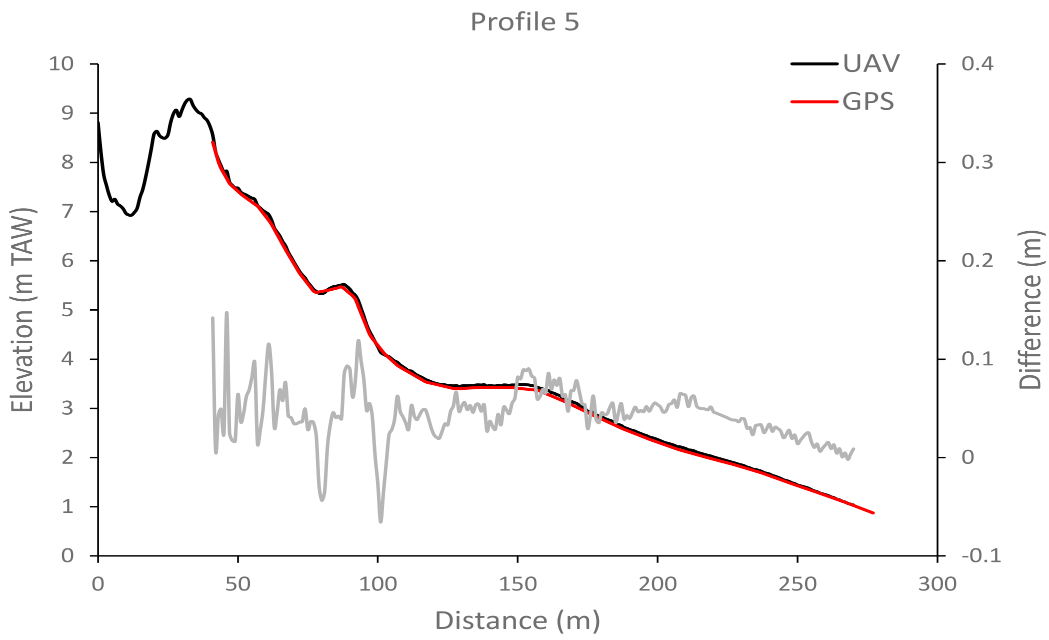
Verwaest, T.; Montreuil, A.-L.; Dan, S. (2022). Oostende-Middelkerke, Monitoring duin voor dijk pilots: Evolutie gedurende het 1e jaar. Versie 2.0. WL Rapporten, 21_014_1. Waterbouwkundig Laboratorium: Antwerpen.

Appendix A

Difference between extracted UAV profiles and RTK-GPS for Profile 2, 4 and 5 with the confidence indicator from the photogrammetric processing.

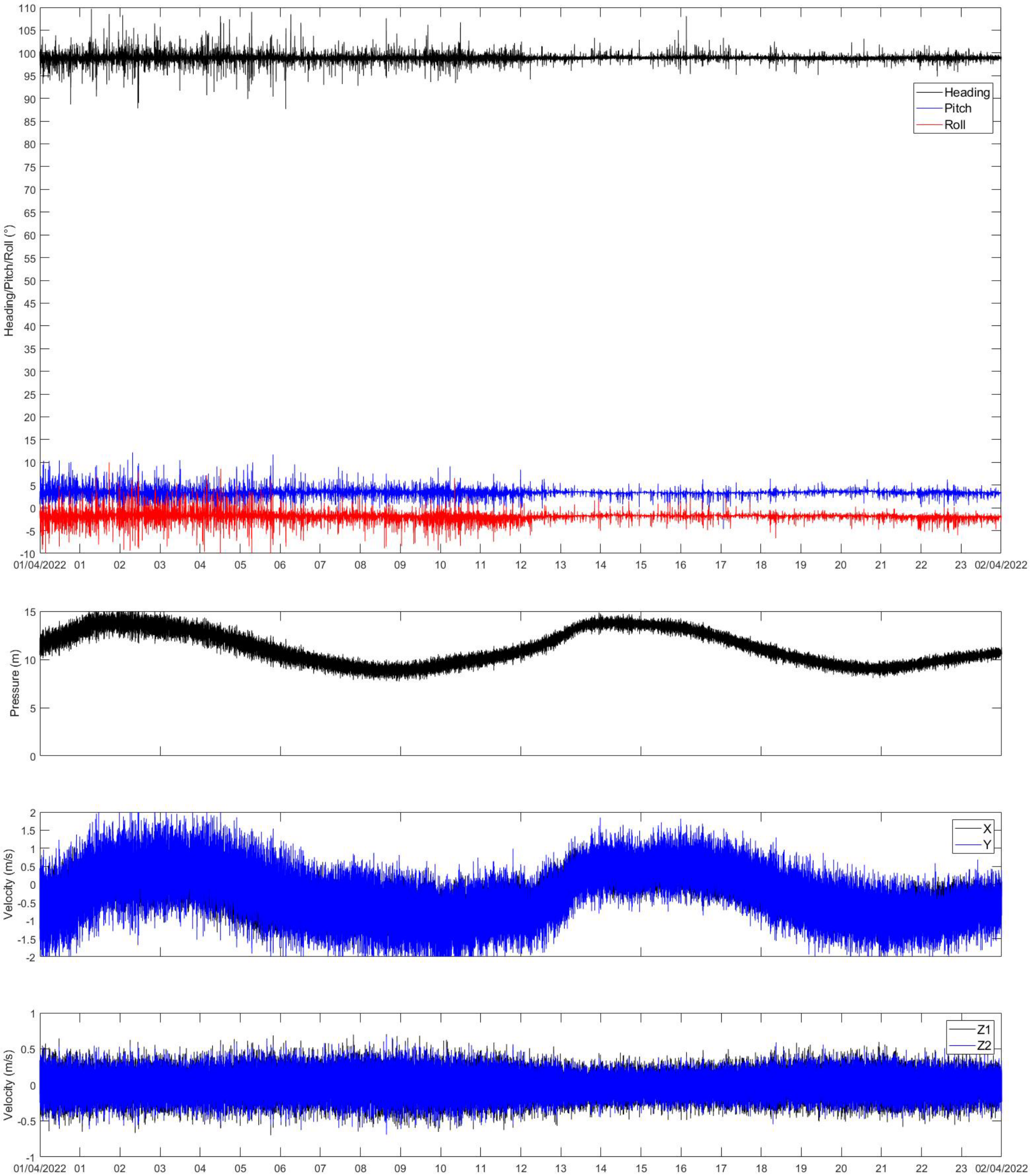





Profile 5
UAV
GPS
Elevation (m TAW)
Difference (m)
Distance (m)
10
9
8
7
6
5
4
3
2
1
0
0.4
0.3
0.2
0.1
0
-0.1
0
50
100
150
200
250
300

Appendix B

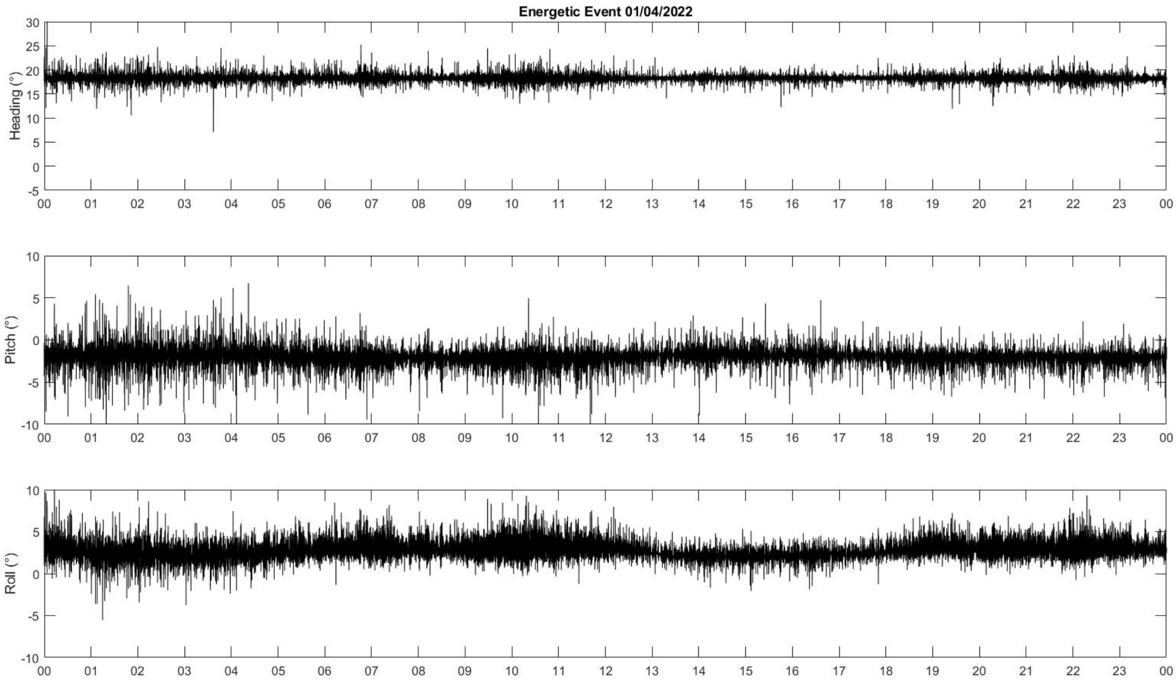
Time series of ADCP sensor at Raversijde 2 for an energetic day event. Velocities from cell 1 ca. 1 m above the bottom.



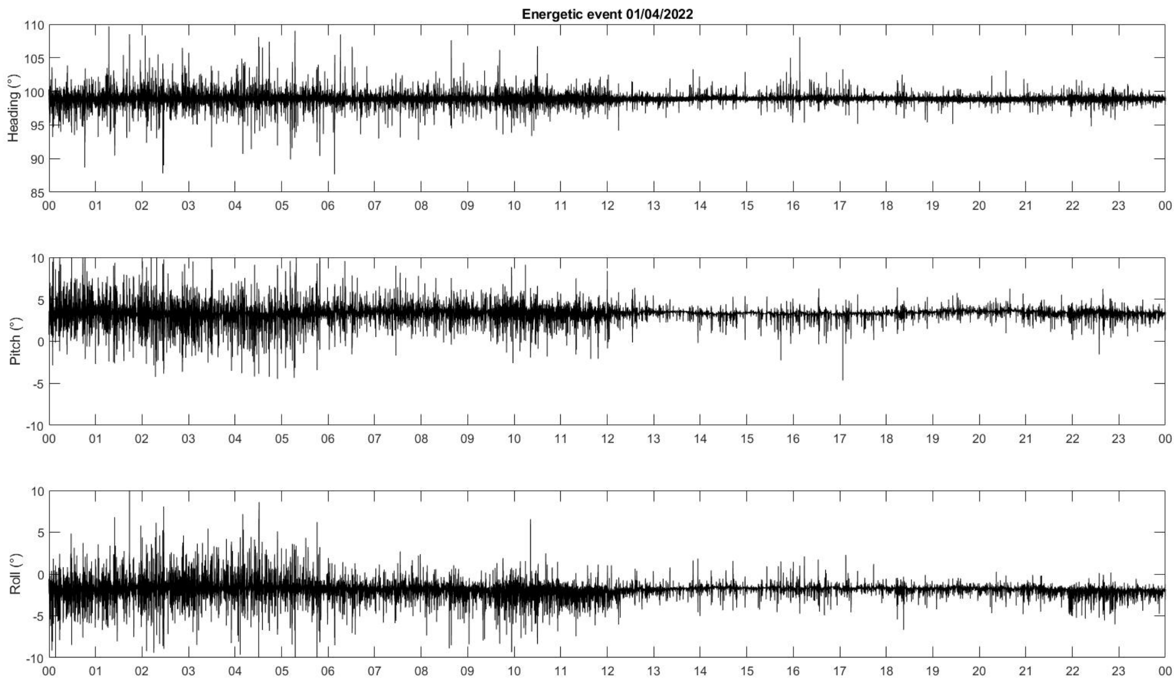
Appendix C

Motion of the ADCPs at Rav1 and Rav2 during energetic condition (storm on 1/4/2022) and calm condition (14/4/2022).

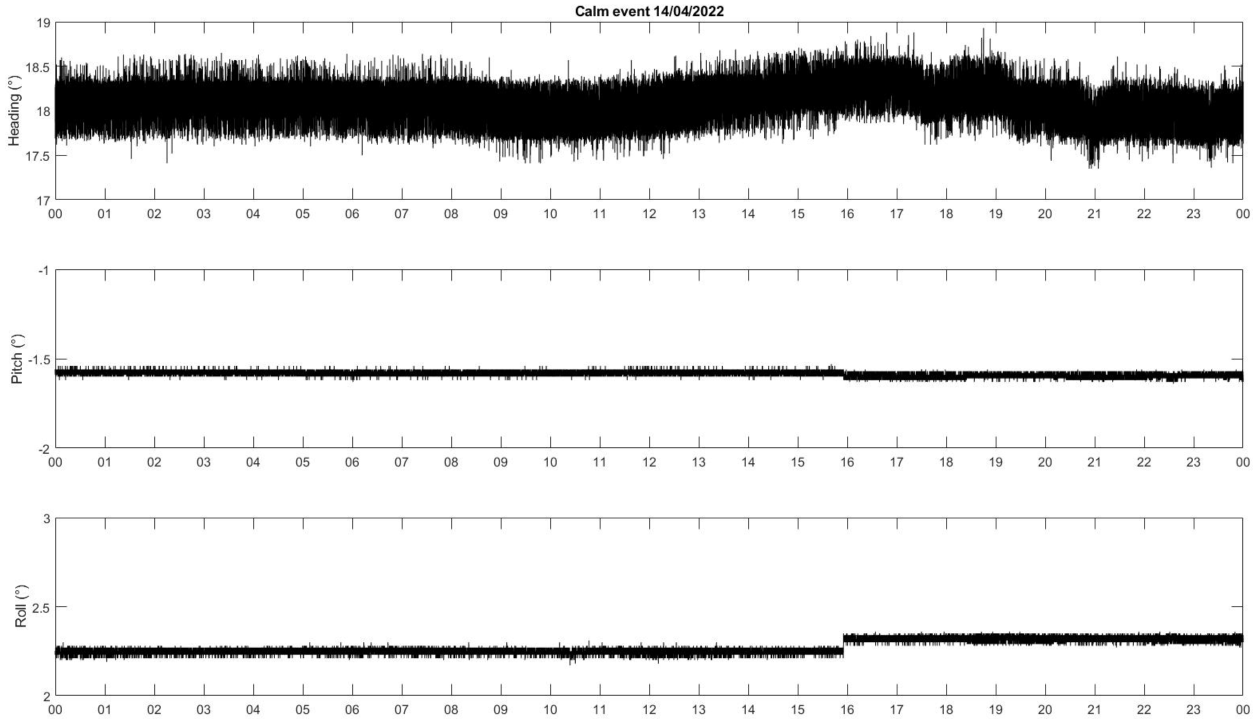
Rav 1 Energetic event (avg Hs: 2.80 m measured by the wave buoy at Rav 1)



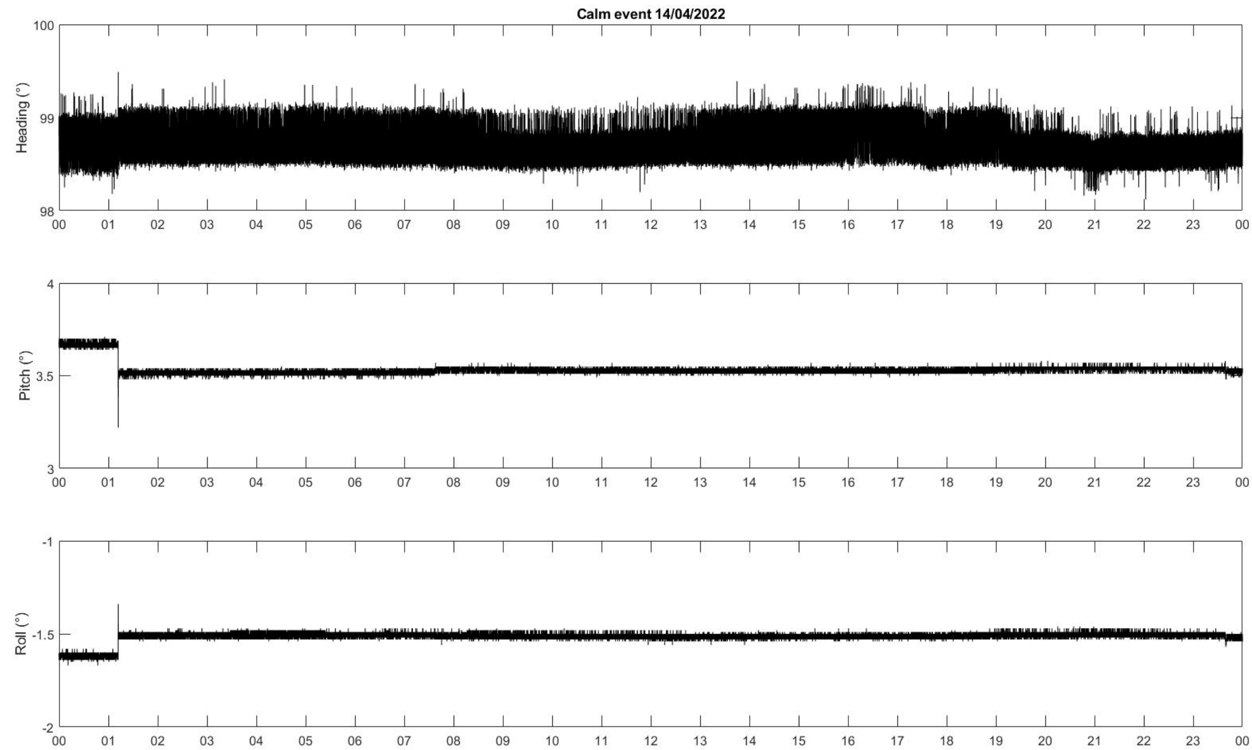
Rav2



Rav 1 Calm event (avg Hs: 0.3 m measured by the wave buoy at Rav 1)



Rav 2



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