Inter-comparison of wave measuring equipment

Instruments Database

PDG/REM/RDT/LHYMAR
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Date : 14/11/2023

Fiche documentaire

Titre du rapport: Inter-comparison of wave measuring equipments: Instruments Database	
Référence interne : REM/RDT/LHYMAR 23_064 **Diffusion :** ☒ libre (internet) ☐ restreinte (intranet) – date de levée d'embargo : AAA/MM/JJ ☐ interdite (confidentielle) – date de levée de confidentialité : AAA/MM/JJ	**Date de publication :** 2023/11/14 **Version :** 1.0.0 **Référence de l'illustration de couverture** Vincent Perier/Déploiement de bouée Datawell à Ste Anne du Portzic/20 octobre 2022 **Langue(s) : english**
Résumé/ Abstract : In order to accurately characterise the waves encountered in the Ifremer Brest Bay test site, a wave measurement campaign was carried out between October and April 2023 using Spotter and Datawell wave buoys, RBR pressure sensors and a Nortek Signature ADCP. The aim of this test campaign is to obtain the data required to carry out an inter-comparison of the various wave measurement instruments.	
Mots-clés/ Key words : Wave monitoring, Wave Buoy, ADCP, pressure gauge, Ifremer Brest Test Site, Saint Anne Du Portzic	
Comment citer ce document : P. Bothorel, M. Träsch, V. Perier, M. Pezerat, M. Répécaud (2023). **Inter-comparison of wave measuring equipment: Instruments Database. IFREMER REM/RDT/LHYMAR 23_064**	
Disponibilité des données de la recherche :	
DOI :	

Commanditaire du rapport :	
Nom / référence du contrat : ☐ Rapport intermédiaire ☒ Rapport définitif	
Projets dans lesquels ce rapport s'inscrit (programme européen, campagne, etc.) :	
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1 Introduction

Characterisation of a site's sea states is important in several aspects: it is essential for navigation issues and safety at sea, it is useful to improve oceano-meteorological models, and it is recquired to design offshore structures, such as marine renewable energy devices. Thus, various wave monitoring equipments have been developed for years, using different techniques to assess sea states.

A set of buoys, pressure transducers and an ADCP has been deployed in the Sainte-Anne du Portzic site for 6 months to allow for an inter-comparison of the wave parameters measured by the different instruments. This database contains the raw file of the measured displacement of the sea free surface directly exported from the sensors.

2 Experimental set-up

2.1 The Ifremer sea test site of Sainte-Anne du Portzic

The wave measurement equipment has been deployed in the Sainte-Anne du Portzic test site (Trasch M., 2023). This site is part of the TheoREM infrastructure, the Carnot MERS Institute and the Open-C Foundation. It is located in the North coast of the Brest Bay, near the Sainte-Anne du Portzic harbour, at the South-West side of a 330m long dike. The site hosts the COAST-HF Marel Iroise monitoring station, that monitors at high frequency various physicochemical properties of the seawater (Rimmelin-Maury, 2020) and the SOMLIT station, where samples are taken every other week for a physicochemical study of seawater (Rimmelin-Maury Peggy, 2022). The site is surrounded by the Pointe du Diable on the West side and the Pointe du Portzic on the East. The sea depth varies between 2m and 12m at the lowest astronomical tide and the tidal range is about 7.68m.

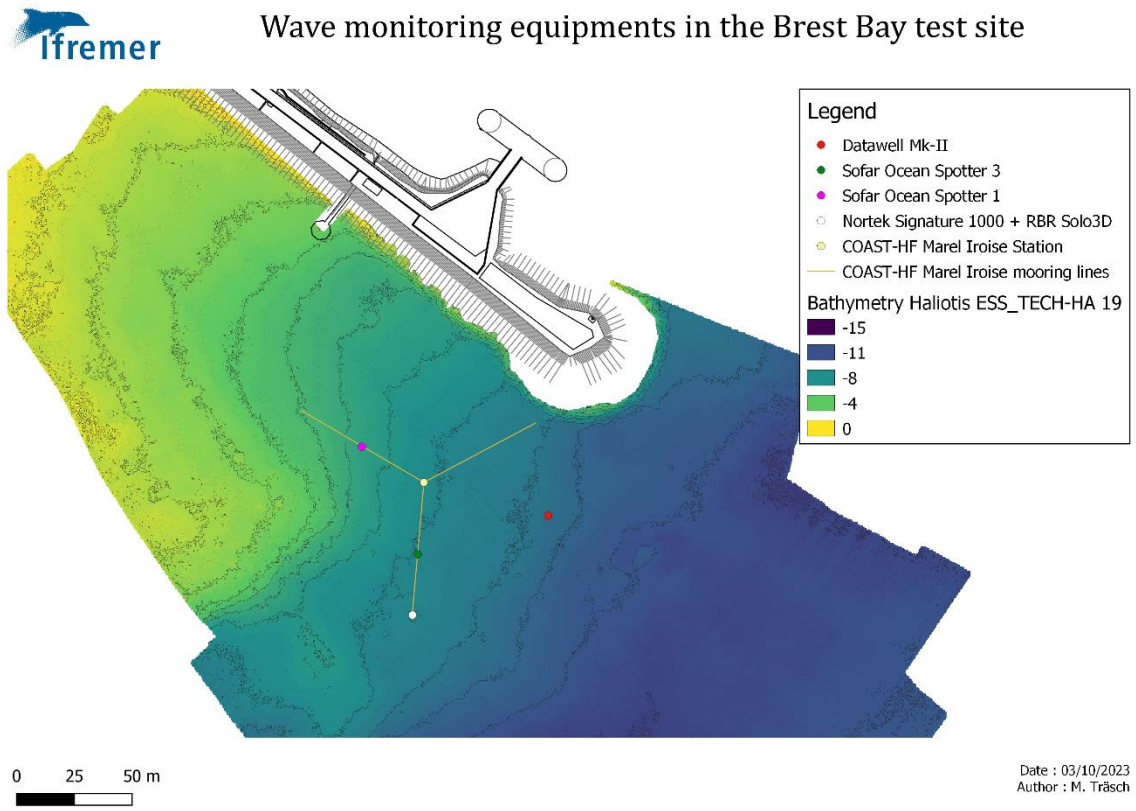

Figure 1 - Sainte Anne du Portzic site map with sensors position

2.2 Presentation of the wave monitoring sensors

2.2.1 Sofar Ocean Spotter

Spotter is a newly developed wave measurement buoy by Sofar Ocean (Raghukumar, et al., 2019). It measures the free surface displacement by using only GPS location data with a sampling frequency of 2.5Hz. It can detect waves with periods between 1s and 30s using a bandpass filter. Sofar Ocean indicates a standard uncertainty of ±2cm in favourable conditions. The buoy has a diameter of 42cm for a weight of 7.45kg.

During the campaign, two Spotters have been deployed, each using a different mooring technique. The first one is named Spotter 3 and has been moored using the recommended mooring line. The second one, identified as Spotter 1, used an innovative mooring system using elastomer.

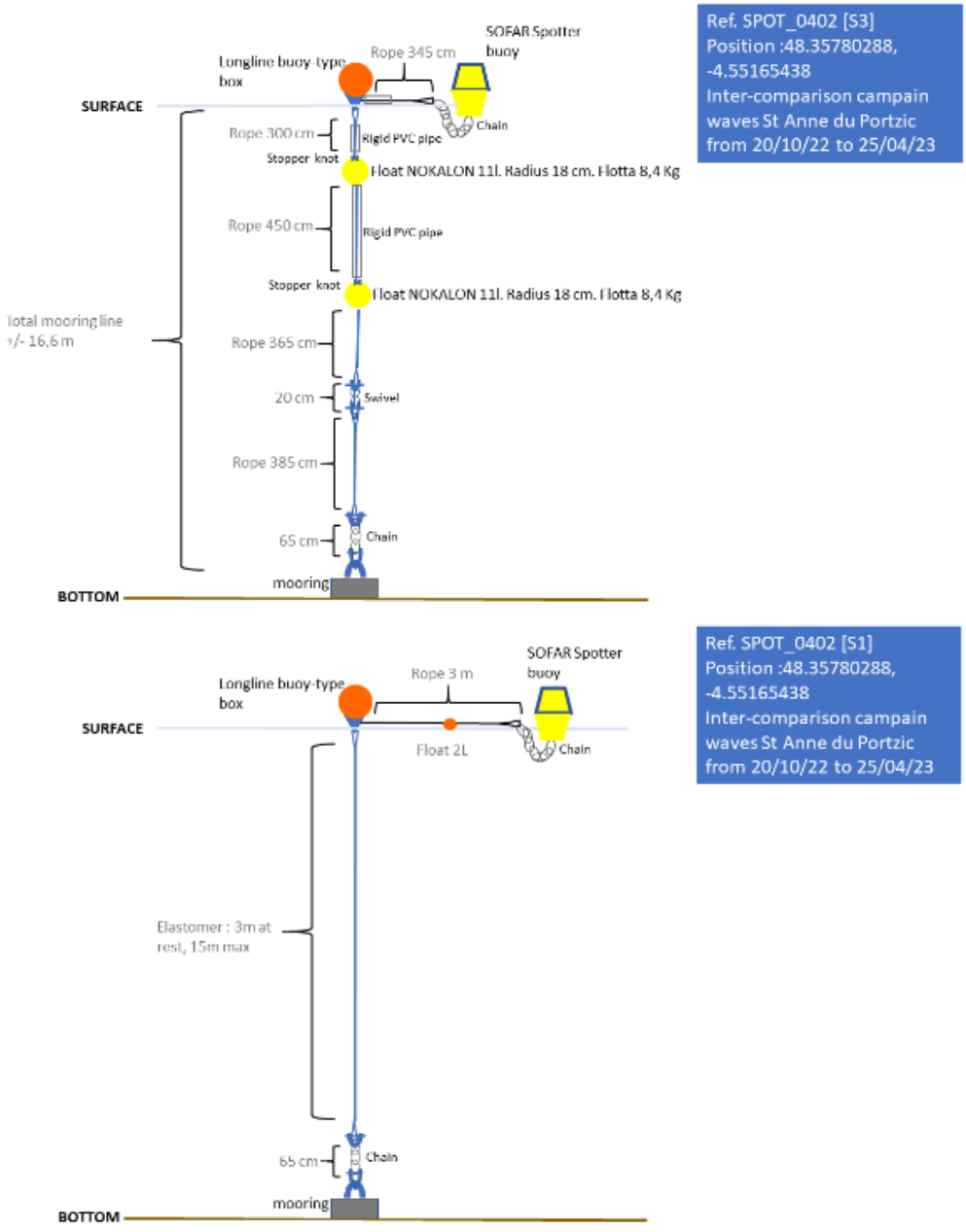

Figure 2 - Mooring lines of the Spotter buoys

2.2.2 Datawell Waverider Mk-II

The Datawell is a wave measurement buoy historically used as a reference (Herbers, et al., 2012). It uses a three-component accelerometer, a tiltmeter and a compass to retrace its displacement in three dimensions along time. Its sampling frequency is 1.28Hz. The boy can detect waves in a range of ±20m and a period between 1s and 24s, with a resolution of 1cm and an accuracy lower than 0.5%. The compass allows to detect the wave direction according to the magnetic North with a resolution of 1.5°. The system is 70cm wide and weights 90kg. The Datawell buoy that has been used during this campaign is property of SHOM, and has been deployed using a mooring line inspired by the Datawell's recommendation, except it uses only one 15m elastomers line rather than two as suggested, in order to reduce avoidance radius.

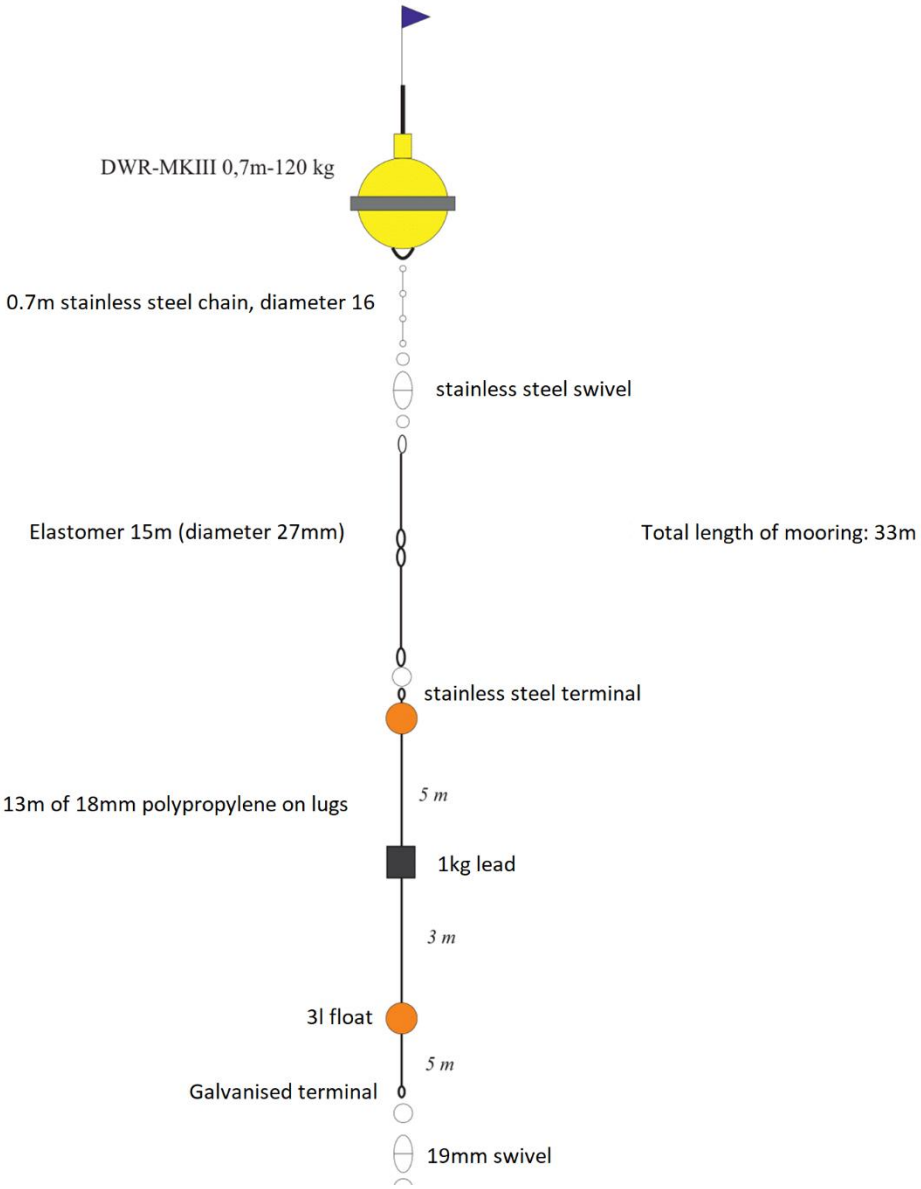

Figure 3 - Mooring line of the Datawell buoy

2.2.3 RBR solo3 D

The RBR solo3D is a pressure transducer. The pressure transducers can be used to measure waves by detecting the pressure perturbation induced by waves along the water column. During the campaign, two types of RBR have been used.

One RBR solo3 D-200m, property of SHOM, has been deployed in continuous acquisition mode at a sampling frequency of 2Hz. The sensor measured the pressure with an accuracy of 10cm and a resolution of 0.2cm[1]. The last calibration of the sensor was made on the 15th June 2021.

Additionally, two RBR solo3 D-50m have been deployed in burst configuration at a sampling frequency of 2Hz, during 30 minutes every hour. They measured pressure with an accuracy of 2.5cm and a resolution of 0.5mm[1]. They also computed statistical wave parameters that will be introduced in part 3.3.

Both sensors have been calibrated the 23th of August 2022 and checked after each deployment. These three pressure transducers were deployed fixed upside-down to an instrumented frame placed on the seabed. The sensors were 14cm from the bottom.

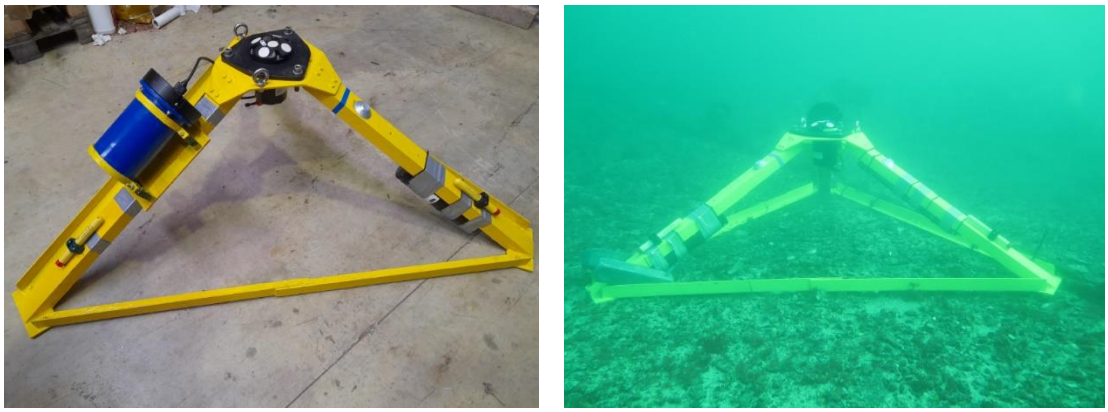

Figure 4 - Instrumented frame before deployment (left) and on the seabed (right). The pressure sensors can be seen on the sides of the frame and the ADCP at the top.

2.2.4 ADCP Nortek Signature1000

The last equipment used is an ADCP (Acoustic Doppler Current Profiler) with a transducer acoustic frequency of 1 Mhz. This device is generally used to measure flow velocity along a water column. It uses acoustic pulses and is able to measure current velocity by Doppler effect through the frequency variation of an acoustic signal reflected by suspended particles in water. The transmission frequency and broadband signal technology enable a minimum accuracy of 0.3% of the measured value ±0.3cm/s and a resolution of 0.1 cm/s of the velocity[1]. During the campaign, a current profile across the entire water column (0.3m cell height, blanking 0.1 m) was measured every half-hour for 2 minutes at a frequency of 2Hz. Once averaged, the velocity precision is better than 1 cm/s[1]. Moreover, the ADCP is also equipped with an acoustic altimeter. Thus, if placed upward at the bottom of the sea, it can measure the vertical displacement of the surface. It can then detect waves in a range of ±15m and a period between 0.5s and 50s, with an accuracy lower than 1% of measured value and a resolution of 2cm of the significant wave height (Hs)[1].

[1] Values communicated by the manufacturer

The ADCP has been deployed on the top of the instrumented frame, faced upward, 60cm from the seabed. It was used in two configurations for waves measurements: the first one had a continuous sampling frequency of 8Hz (altimeter and four lateral transducers slanted at 25 degrees from vertical) and recorded 20 minutes samples every hour. The second one a continuous 4Hz (all transducers) frequency recording for 20 minutes every half-hour. The 22th October 2021, ADCP have been checked by manufacturer (beam, TILT, compass) but no calibrated. However, compas was not calibrated before deployment.

	Weight	Size	Distance from the bottom	Sampling frequency	Height resolution	Height Accuracy	Period range
Datawell	90kg	70cm	Surface	1.28Hz	1cm	< 0.5%	1-24s
Spotter	7.45kg	42cm	Surface	2.5Hz	2cm		1-30s
RBR	130g	21cm	14cm	2Hz	0.2cm/0.05cm	10 cm/2.5 cm	Depends on the depth
ADCP	2.21kg	15.1cm	60cm	4Hz/8Hz	2cm	< 1%	0.5-50s

Table 1 : Instruments' characteristics[1]

2.3 Instruments deployment

The measurement campaign was performed between October 20th 2022 and April 25th 2023. The deployment was divided into 4 legs. The main purpose of these separated legs was to reload the batteries and download the data from the pressure transducers and ADCP. The instrumented cage was, thus, deployed during each leg. The Datawell buoy was moored from 20/10/2022 to 17/04/2023. The Spotter 3 was deployed during the entire campaign, while the Spotter 1 was only used during the third leg. The position of each instrument is provided in figure 4. The ADCP was programmed with the 8Hz configuration for the first set and the 4Hz configuration for the others.

	Leg 1	Leg 2	Leg 3	Leg 4
Start	20/10/2022	16/12/2022	02/02/2023	15/03/2023
End	09/12/2022	01/02/2023	13/03/2023	25/04/2023

Table 2 - Dates of the sets

3 Database nomenclature

The Database provided is composed of the raw data files imported from the different wave measurement instruments used during the campaign. As a consequence, each instrument uses a different file format and nomenclature. They will be exposed so that one can easily use them for analysis.

3.1 Datawell raw file

From the Datawell buoy, *.raw* files can be exported. They contain the raw displacement data of the buoys for a window of 30 minutes at 1.28Hz frequency. The last row contains the date and hour of the measurement, the name of the buoy and the number of samples. For all the others rows, there are four columns. The first one represents the status. In this database, it is always 00, which means the embedded system reported no error. Then, the three last columns contain the displacement values respectively heading Up, North and West, in cm. It should be noted that

Datawell provides a free software named Waves5 which enables to compute wave parameters out of these raw files.

3.2 Spotter files

The Spotter SD card contains different type of files. They will be described successively:

FLT files are .csv files that contain the raw displacement information for a day. It has six columns. The first one named « millis » contains the elapsed time in milliseconds since the last system boot. The second one, « GPS_Epoch_Time (s) » is the UNIX Epoch time in seconds derived from GPS time for each sample. The three following columns « outx (mm) », « outy (mm) » and « outz (mm) » are the displacement respectively Easting, Northing and Vertical displacement from a mean location in mm (Sofar Ocean Technologies, s.d.). The last column « outn (mm) » is the norm of the horizontal displacement (x and y) in mm. The Sofar Ocean website provides a free python parser which can compute several wave parameters from the FLT files.

LOC files contain the GPS coordinates of the buoy for each minute. The first column is the GPS_EPOCH_Time (s), as earlier. Then, the latitude coordinate in degrees and 100 000th minutes of arc for the two following columns. The two last are the longitude coordinate in degrees and 100 000th minutes of arc.

SPC files contain the variance spectra and cospectra of the waves directly computed by the buoy. It indicates first, the « type » of spectra. Here, it is always SPECA, which indicates spectra computed from a wave statistics observation window per the Spotter's sampling configuration. Then, the « millis » section similar to that of the FLT files. « t0 » and « tN » in GPS_EPOCH_Time specifying the beginning and ending date of the sample of data used to compute the spectra. Then, « ens_data » is the system metadata for internal use. Finally, the real part of the different spectra values are stored, followed by their imaginary part, in the following order: Sxx, Syy, Szz, Sxy, Szx, Szy.

SYS files are log file containing system errors and information. They start with the usual « milis » columns. Then, they provide the type of message, namely: DEBUG, INFO, WARN and ERROR and finally the message.

3.3 RBRsolo files

Burst mode. Two RBR solo pressure transducers were deployed in burst mode. In this configuration, the RBR measures the pressure and compute some statistical wave parameters. This data is stored in an excel file for each transducer and each deployment. The first sheet « Metadata » contains the calibration and configuration data, such as the start and end time of measurement, the data's units, atmospheric pressure and water physicochemical parameters. The « Event » sheet lists the starting date of each wave burst. Then, the « Data » sheet contains for each hour: the time, the total pressure called « Pressure » in dbar, the « Tidal Slope » in m/hour, the relative pressure (= total pressure - atmospheric pressure) called « Sea Pressure » in dbar and finally the « Depth » in m. The Depth is computed using the hydrostatic pressure formula from the Sea Pressure. Then, we can find several « burst » sheets. They contain for every 0.5 seconds: the time, burst label, pressure in dbar and « Wave ». This last parameter is the relative distance in m of the water surface from its mean position with the tidal slope considered. It is the equivalent of the z displacement in the buoys data logs. Finally, there is a « Wave » sheet. It contains for each burst the time, burst label and mean depth and the following wave parameters: Significant wave height, Significant wave period, 1/10 wave height, 1/10 wave period, maximum wave height, maximum wave period, average wave height, average wave period and wave energy.

Continuous mode. The third RBRsolo was deployed in continuous mode. The file contains the same « Metadata » and « Event » sheets. There are in addition « Data » and « Raw Data » sheets. The « Data » sheets are the same as for the burst mode, without the « Tidal Slope » column. The RBR data can also be analysed through the RBR Ruskin software.

3.4 ADCP csv files :

As explained before, the ADCP has been deployed in two configurations. The configuration with a sampling rate of 4Hz is labelled 0 and the other one is labelled 1. The ADCP's data are stored in 3 types of CSV file : Ai_n, Bi_n and RABi_n, with i the label of the configuration and n, the index of the file. The A files contain the mean current along each cell of the water columns every 10 minutes for an hour. The B files also contain the current data for each cell along the water columns but for each measurement sample. Moreover, the altimeter data can also be found. For wave measurement, the AST Altimeter is to be preferred. The column « AltimeterDistanceAST » indicates the distance between the surface and the ADCP in m, and thus can be used to measure waves. Finally, the RAB files contain the Altimeter data at the beginning and ending of each measurement cycle.
The Ocean Contour software from Nortek can be used to analyse the data.

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