A Comparison Between Directional Wave Measurements from the RDI Workhorse with Waves and the Datawell Directional Waverider

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Abstract - Directional wave measurements from an RDI Workhorse with Waves are compared with those from the traditional Datawell Directional Waverider buoy. The measurements were conducted simultaneously at the same location over several months, and show good agreement. The principles of two measurement techniques are contrasted.

I. INTRODUCTION

The RDI Workhorse with Waves (WHW) has become widely used for directional wave measurements in shallow water. However, there remain relatively few published comparisons between the WHW and simultaneous measurements from the well proven Datawell Directional Waverider (DWR). This paper describes such a comparison undertaken by Fugro GEOS on behalf of Shell Global Solutions. Measurements started in July 2002 at the same site off the eastern Pacific coast and were ongoing at the time this paper was prepared. Simultaneous measurements were also made using the new Datawell GPS system but these are described elsewhere [1]. The RDI measurement principles are fundamentally different to those of the traditional Datawell buoy, so these are reviewed before the measurements are compared.

II. THE RDI METHOD OF WAVE MEASUREMENT

A. Basic Principles

The RDI Workhorse with Waves is similar to a conventional ADCP with four acoustic beams inclined at fixed angles to the vertical. When deployed on the seabed in an upward looking configuration, the Workhorse measures the component of wave velocity along each beam axis, and averages it over a depth cell. Each depth cell will therefore contribute to forming an array of virtual sensors, from which the velocity auto- cross-spectra are calculated using the RDI WAVESMON software. The cross-spectra are then used as input to the Iterative Maximum Likelihood Method (IMLM) to estimate the frequency-direction velocity spectrum. The velocity spectrum is translated to surface displacement using linear wave kinematics. This allows calculation of the wave spectrum and then derivation of the wave parameters necessary to describe the wave field [2].

This ADCP also calculates the non-directional wave height spectrum from its pressure sensor and from echo ranging the sea surface (surface tracking). Each technique has its advantages and limitations. The pressure height spectrum calculation is a familiar technique that can be used as a back up. However, it does not allow measurement of short period waves because of the attenuation of wave velocity with depth. In contrast, surface tracking allows such measurements, but cannot be used when the ocean surface is smooth and reflects the echo sent to the surface by the ADCP. It can also be contaminated by bubbles in the water column. The user selects which of the three frequency spectra (velocity, pressure or surface track) is used to scale the directional wave spectrum and derive wave parameters. The velocity spectra is usually considered the most reliable [3].

B. Contrast With Traditional Surface Following Buoys

The main difference between the RDI and Datawell measurement techniques lies in the number of independent measurements used to compute the directional spectrum. A Datawell Directional Waverider buoy offers a three-dimensional measurement of sea surface acceleration at a single location. The accelerations are digitally integrated to calculate displacement, from which the cross-spectral matrix is calculated. This information is sufficient to compute only the first two harmonics of the Fourier series that represents to full directional spectrum, which has many more degrees of freedom. It is therefore impossible to reconstruct the full directional spectrum from a surface following buoy. However the full spectra is often simulated using either the Maximum Likelihood or Maximum Entropy method [4].

In contrast, the ADCP uses each depth cell along each beam as a sensor and provides more independent measures of the wave field. It provides only one piece of information – the wave velocity – but in many different locations. Calculating the auto- and cross-spectra from all these independent measurements means that the directional solutions are better constrained and will therefore result in an improved representation of the directional distribution of wave energy. This difference between the two measurement techniques is particularly significant for occurrences of simultaneous swells coming from different directions at either the same or different frequencies. Surface following buoys can at best only partially represent the two modes because they provide only three degrees of freedeom. In contrast, because of its many degrees of freedom, the WHW can distinguish the different modes present in the sea state.

III. COMPARISON OF MEASURED WAVE PARAMETERS

The WHW was set up to record a 35 minute wave burst once every 2 hours. The data were processed using the RDI WAVESMON software, and wave parameters were derived from the velocity spectra. Directional spectra were output with 1024 frequency points, because fine resolution was required for longer wave periods. Intensive quality control was required during processing to ensure that appropriate cut-off frequencies were selected. The WAVESMON software provided time series of basic wave parameters, but more parameters were required so the full direction spectra were loaded into MATLAB for further processing. Mean wave direction and spreading were calculated as functions of frequency via the first two Fourier coefficients, following the Rijkswaterstaat standard [5]. A comprehensive set of wave parameters was calculated for the total sea state and also for separate sea and swell components.

The DWR recorded data continuously at a rate of 2Hz throughout the deployment periods. This sampling regime differs from that in a standard Datawell Directional Waverider buoy because it was designed to enable comparison with Datawell's new GPS system which records GPS measurements at 2Hz [1]. The DWR data were split into a set of 20 minute duration wave bursts and processed using a combination of software provided by Datawell and developed in-house by Fugro GEOS. The Rijkswaterstaat SWAP program was used to derive basic wave parameters. The results from two months of measurement are compared in Fig. 1 to Fig. 3. Wave directions indicate the direction from which the waves arrived.

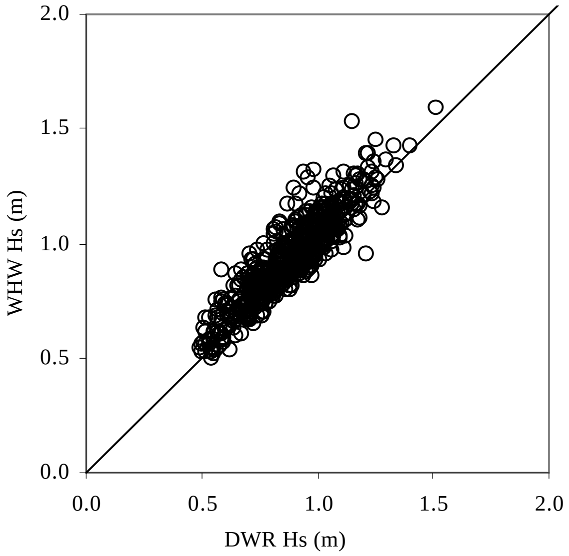

Fig. 1. Comparison of Significant Wave Height

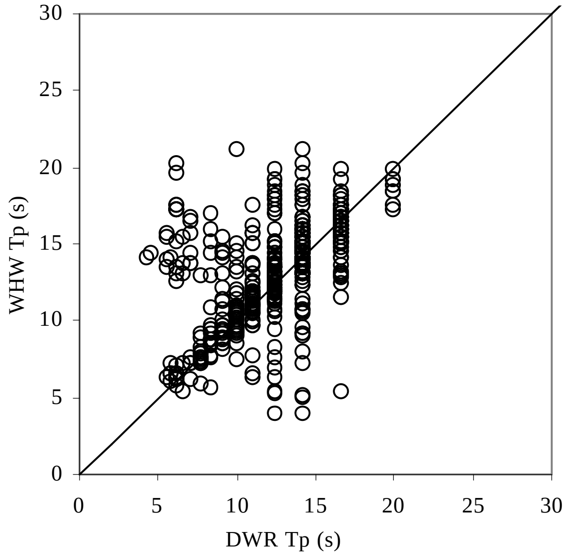

Fig. 2. Comparison of Peak Wave Period

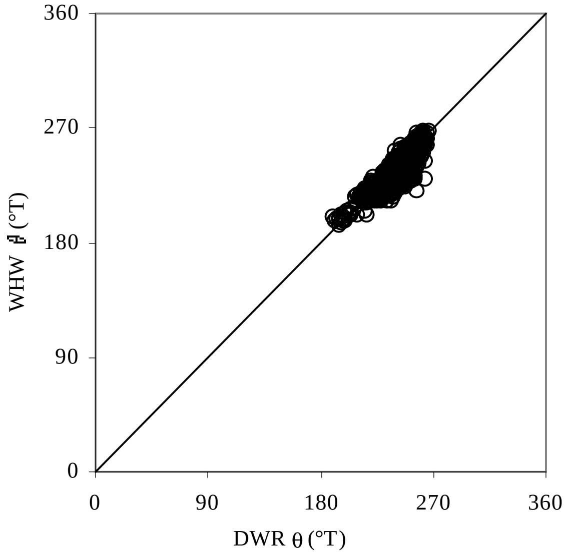

Fig. 3. Comparison of Mean Wave Direction

The WHW appears to give slightly higher wave heights compared to the DWR. It should be noted that the DWR results presented in this paper were derived from the complete spectra, while the WHW results were derived from only the part of the spectra between the cut-off frequencies selected in the WAVESMON software. To perform a direct comparison, a selection of DWR spectra were cut off at the same frequency thresholds as the WHW spectra. This led to smaller wave heights from the DWR and an even greater difference from the WHW than indicated in Fig. 1.

The wave period comparison in Fig. 2 does not appear favorable. It is impossible to tell how many observations each circle corresponds to so the number of occurrences for each pair of Tp values is given in Table I. This clearly shows that whilst most of the observations agree, there are a significant number of differences. These differences are due to the presence of multiple peaks in the spectra, associated with separate wind-sea and swell components. Tp can only represent the single largest peak in the spectra, and on occasions when two peaks were of approximately equal magnitude, small differences between the WHW and DWR spectra could lead to very different values of Tp. The Tp comparison would show much better agreement after the spectra were partitioned into separate wind-sea and swell components, but this is not possible at the time of writing this paper. The good agreement between the two instruments is better illustrated by the time series in Fig. 4. This clearly shows the improved Tp resolution associated with using 1024 points in the WHW spectra, compared to the 5mHz resolution of the DWR spectra. The different spectral resolutions are clearly responsible for some of the smaller differences in Tp.

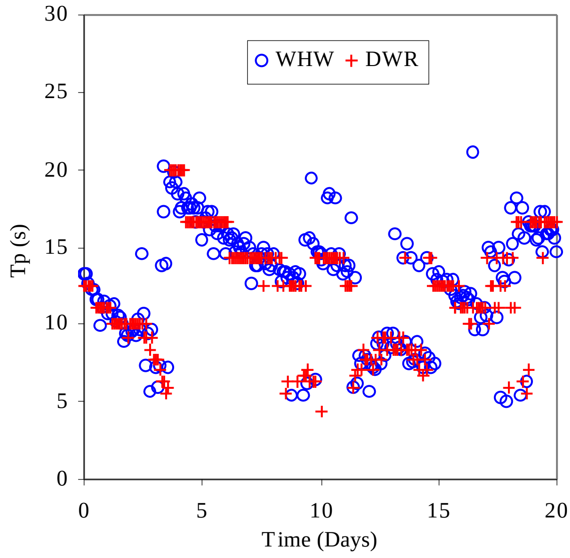

Fig. 4. Comparison of Peak Wave Period Time Series

IV. CONCLUSIONS

The agreement between the WHW and DWR measurements is good, considering the very different measurement principles. The WHW may slightly over estimate wave height, probably due to noise in the acoustic current measurements. All other wave parameters were in good agreement except directional spreading. The spreading differences are still under investigation, but may be an unavoidable result of the different measurement principles and methods of computing the directional distribution.

TABLE I
NUMBER OF OCCURRENCES OF PEAK WAVE PERIOD (Tp)

WHW Tp	DWR Tp (s)										
(s)	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22
20-22				1		1		2			
18-20				1			7	6	6		6
16-18				8	1	2	7	12	48		2
14-16			5	4	7	7	13	122	39		
12-14			2	8	3	9	74	65	6		
10-12					4	39	26	6	1		
8-10				3	24	11	2	4			
6-8			4	20	2	4	3	2			
4-6			1	3	1		2	2	1		
2-4							1	1			
0-2											

The different resolutions of the WHW and DWR spectra resulted from the selected analysis methods, not the different measurement principles. It would be preferable to use the same spectral resolution for direct comparisons between the spectra from both instruments, but this is not necessary for the comparison of wave parameters in this paper. The WHW spectra contained more peaks than the DWR spectra, and it is probably desirable to use fewer points in the WHW spectra for applications such as spectral fitting. However this could compromise the fine resolution required in Tp at longer wave periods.

The traditional Datawell buoy cannot measure waves with periods longer than 30 seconds (although their new GPS system should measure up to 100 seconds period [1]). While the full directional spectra from the WHW velocity measurements also have to be cut off at periods close to 30 seconds, it should be possible to detect long period waves using either the surface track or pressure measurements. However these may not be accurate enough to quantify waves with heights as low as 10cm, which can be critical for the response of large vessels. The detection of long period waves from the WHW data described in this paper remains under investigation.

V. ACKNOWLEDGEMENTS

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