On the wave field as observed in the BTS (Todos Santos Bay, Ensenada, Mexico) Natural Laboratory

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I. Introduction

A natural laboratory in the coastal waters of the Pacific Ocean in the Northwest of Mexico is being implemented (Natural Laboratory in Todos Santos Bay, Mexico) since the beginning of CEMIE-Oceano in 2017.

The main objective is to provide a coastal region with specialized sensors to readily monitor the wave field and the most relevant environmental (and oceanographic) variables for future performance analysis and studies of ocean energy conversion devices. BTS coastal region was selected to build the natural laboratory, since the wave power was promising resources for future harvesting.

Some details of spatial and temporal variability of the wave field are presented in this work, taking into consideration the advantages of the various measuring systems which properly combined they certainly provide a relatively fine both, spatial and temporal resolution.

A. *In-situ sensors*

The combination of measuring systems includes in-situ sensors, such as Acoustic Doppler Current Profilers (ADCP) and oceanographic buoys (BOC –Coastal Oceanographic Buoys, and BOMM –Oceanography and Marine Meteorology Buoys, for their Spanish definition).

B. *Remote sensors*

Besides in-situ sensors, ocean surface images have been obtained from space borne synthetic aperture radars operating from ESA (Sentinel 1) and DLR (TerraSAR-X and TanDEM-X) satellites. Furthermore, remote sensors (X-band and High Frequency radars) are also deployed in the coast and results of the wave field retrieval are shown. In particular, high frequency (HF) radar is used to estimate the wave height and the description of the spatial variations are provided with maps of the significant wave height as obtained every hour.

II. Methods

The combination of sensors used to monitor the ocean surface wave field, obviously requires a proper method for the analysis of the retrieved information. While typical measurements obtained at a single point with buoys or anchored ADCPs, reasonably represent the wave phenomenon as a function of time, the most acceptable time series analysis is based in Fourier techniques. In fact, from a time series of at least three dynamical variables associated with the wave field, a good approximation can be reached for the directional spectrum, as it was shown with the original ideas by Michael Longuet-Higgins and colleagues [1]. They used a small buoy and developed the theory to estimate the directional wave spectrum from the heave, pitch and roll measurements and their spectra and co-spectra. The directional behaviour description is limited to the use of only the first five Fourier coefficients of their respective series. The method, however, can be extended to other three variables, such as p, u and v, pressure and fluid velocity components under the presence of waves as detected by an ADCP or any other similar device [2].

A fine description of the time variability of the wave field is readily obtained with this type of data processing method. From a different point of view, when the ocean surface is detected with some remote sensors, the spatial character of surface waves can be obtained and the spatial evolution and variability can be described. That is the case when an ocean surface image is obtained with a synthetic aperture radar (SAR) as it is shown in Fig. 1. Two wave field systems with very different propagation directions are readily apparent in this image acquired by TerraSAR-X, over BTS Natural Laboratory on November the 17th, 2018. The spatial resolution (pixel size) is 2.5 m by 2.5 m and the spatial variability and evolution of the wave field is clearly detected. Another type of remote sensor is also used in our Natural Laboratory. A High Frequency radar has been deployed to obtain a different perspective of the wave field over BTS area.

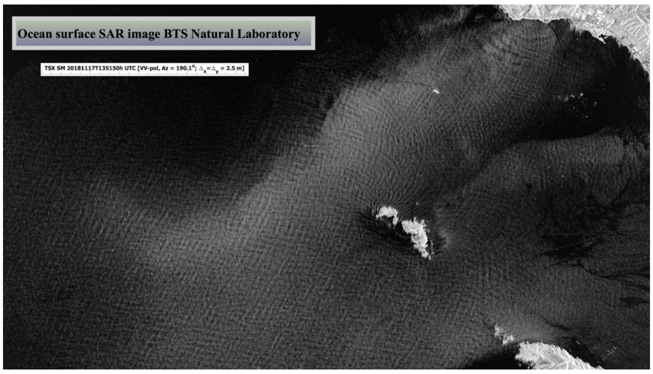

Fig. 1. Ocean surface wave field as observed with an image acquired with the synthetic aperture radar of the German satellite TerraSAR-X, on November the 17th, 2018. The area covered is practically the region of interest for Todos Santos Bay Natural Laboratory, in the coastal region of the North West of Mexico.

A Wellen Radar, also known as WERA (WavE RAdar), is a high frequency remote sensing device used to measure ocean wave characteristics and the surface current field. It transmits radio waves over the ocean surface and with the analysis of the return signals it is possible to derive some information about the waves. At least two systems are required to estimate the surface velocity field, although some wave characteristics can be retrieved from one single station.

III. RESULTS

With a combination of different sensors, the wave field characteristics can be obtained, these sensors can be operated remotely or in-situ to observe and detect the waves over and in the area of interest. Usually different points of view generate slightly different type of signals or characteristics of the observed waves. As an example, a single buoy or point measurements would provide a time series of the wave process being observed, and very limited or null spatial description. Therefore, a convenient procedure is the use of more than one type of direct or remote measurement, although each method has their own advantages and disadvantages.

From in-situ sensors, long term description of the wave field is achieved, as it is shown in Fig. 2. Significant wave time series as obtained from an ADCP deployed near Todos Santos Island are presented for the period of time between 2010 and 2019 [3]. Relatively high waves are readily apparent during the winter months, and the lack of continuity of the records is also clearly visible, mainly due to limitations on operation funds. From this time series, a probability distribution can be obtained and described as a function of the several years of the measurements, as it is shown in Fig. 3.

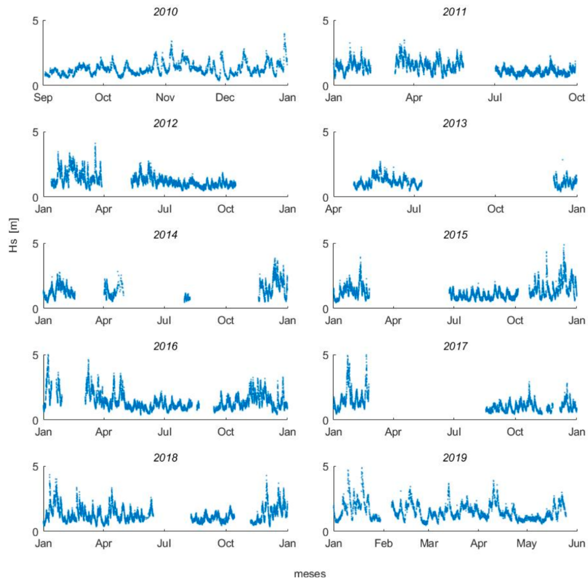

Fig. 2. Time series of significant wave height (*Hs*) as measured with an ADCP nearshore Todos Santos Bay, in BTS Natural Laboratory. The sensor is an Aquadopp (Nortek), operated by The Waves Group (CICESE-UABC). From [3].

Besides the time series of wave heights, from the coincident measurements of pressure, and the orbital velocities induced by the waves, some information about the directionality and in fact, an estimation of the directional wave spectrum can be achieved. Directional information is rather important regarding the wave power resource estimations, and also very relevant for future performance studies of wave energy converters.

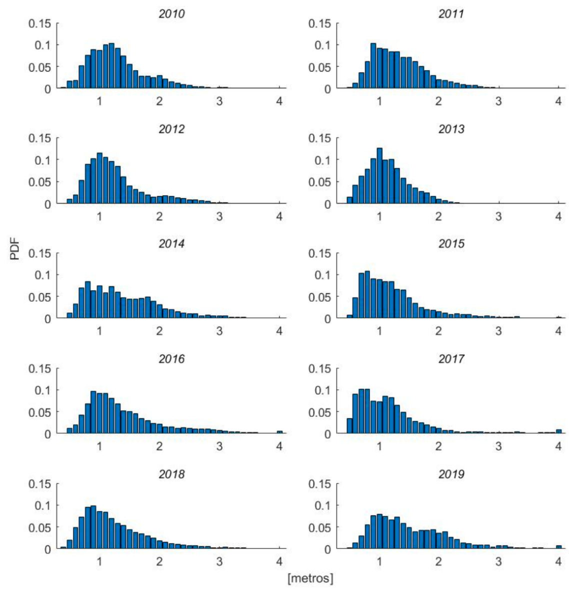

Fig. 3. Probability distribution of the significant wave height as detected in front of Todos Santos Island, in BTS Natural Laboratory. Measurements are shown in Fig. 2. From B.Sc. From [3].

Another example of the wave field information over the area of interest is achieved with the use of the measurements obtained with a High Frequency radar. A WERA systems has been deployed at a sand bar in the Southern region of Todos Santos Bay. As it was already mention, with two WERA sites it can be possible to retrieve the full map of surface currents over the coverage area. With a single station, an estimate of the wave height of surface waves con also be obtained. Therefore, the sequence of the wave field significant wave height can be estimated in principle, with one map every hour (according to pre-established data gathering program). In Fig. 4, the estimated significant wave field is shown it has been obtained for a particular time, in this case at 01:30 UTC of June the 17th, 2022.

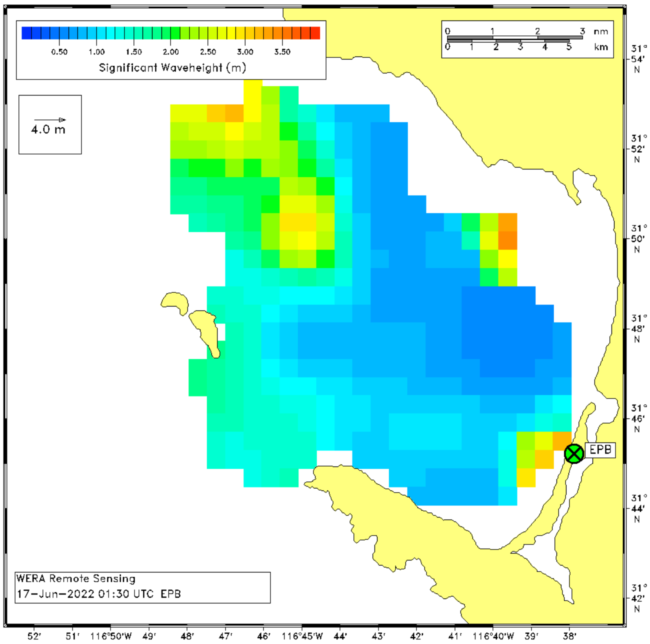

Fig. 4. Map of significant wave height (*Hs*) retrieved from data of the HF radar site at a Southern site in Todos Santos Bay. The area covered is correspondent with the BTS Natural Laboratory, as observed from the EPB station.

The spatial variation of the wave field is clearly noticed, and a region in the Northwest of the bay shows relatively higher wave heights. It is important to mention that the evolution of the wave field can be achieved as this information is obtained regularly and in a continuous fashion.

IV. Discussion & Conclusions

From different perspectives, a rather complete description of the wave field is achieved in a region where natural conditions might be of significant value for wave power harvesting. Although the wave field might be the most important oceanographic variable to be studied and recorded, various other environmental variables are being observed in the Natural Laboratory. Nevertheless, regarding the wave phenomenon, it is now recognised that a full description is only achieved by making use of complementary observing systems, functioning both in-situ and remotely. It is of course, the acquisition of information about the waves as being obtained from different perspectives, that this will result in a well required and rather comprehensive description.

Some achievements in the implementation of the BTS Natural Laboratory are very fruitful, though various interesting challenges still pending and are to be addressed.

References

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