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A Powerful Method of Measuring Sea Wave Spectra and their Direction

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Besides the need of precise measurements of water levels of the sea, there is an increasing demand for assessing waves in height and direction for different purposes like sea-wave modelling and coastal engineering. The design of coastal structures such as piles, breakwaters, and offshore structures like wind farms must take account of the direction of the impacting waves. To date, records of wave directions are scarce. The reason for this might be the high costs of purchasing and operating such measuring devices. These are usually buoys, which require regular maintenance. Against this background, the German Federal Institute of Hydrology (BfG) developed a low-cost directional sea-wave monitoring system that is based on commercially available liquid-level radar sensors. These sensors have the advantage that they have no contact to the fluid, i.e. the corrosive sea water. The newly developed device was tested on two sites. One is the tide gauge 'Borkum Südstrand' that is located in the southern North Sea off the island of Borkum. The other one is the 'Research Platform FINO1' approximately 45 km north of the island of Borkum. The main focus of these tests is the comparison of the data measured by the radar-based system with those of a conventional Directional Wave Rider Buoy.
The general conditions at the testing sites are good for the tests. At the tide gauge 'Borkum Südstrand' waves propagate in different directions, strongly influenced by the morphological conditions like shallow waters of the Wadden Seas and the coast of the island of Borkum. Whereas on the open sea, at the site FINO1, the full physical conditions of the sea state, like heavy storms etc. play an important role.
To determine and measure the direction of waves, the device has to be able to assess the wave movements in two dimensions. Therefore, an array of several radar sensors is required. Radar sensors are widely used and well established in measuring water levels, e.g. in tanks and basins. They operate by emitting a chain of electromagnetic pulses at a frequency of 26 GHz twice per second and, in turn, detect the backscatter information from the water surface. As the travelling time of each pulse is proportional to the distance between water surface and sensor, the height of the water surface can be easily calculated. To obtain the directional information of the sea state, all four radar sensors in the array have to collect simultaneously the wave profiles at fixed points.
The Wave Rider Buoy works in a completely different way. Here, the wave height is calculated by the double integration of the measured vertical acceleration. By correlating the three-dimensional motion data, which are gained from gravity-stabilized vertical and horizontal accelerometers, the directional wave spectrum can be derived. Data of both devices were collected and analysed.
During the hurricane Xaver, extreme water levels and heavy sea hit the North Sea coast on 5 and 6 December 2013. The radar array at the testing site FINO1 measured wave heights in the order of 15.5 meters. Furthermore, it was possible to detect significant wave heights, the mean wave direction, and the spread of the sea state. For the first time the accuracy of the wave height distribution could be determined as well.