The need for a means of measuring the conditions of the test environment has been identified. This chapter of the report focuses on the design, build and testing of a suitable device. Although the wave buoy was not finalized in time to be used in parallel with the model ship, the buoy has been tested independently. This chapter begins with an introduction to the methodology; followed by the design and build of the buoys and their hardware; the data processing of the collected sensor values; and finally the results - compared against a fixed wave probe and against specialist software.

## 0.1 Introduction

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The requirement and ability to measure ocean conditions around the world is used in a wide range of applications such as global sea forecasts, engineering design of ships and structures and coastal management. As a result, gaining knowledge of the constantly shifting sea states has led to the growing commercial demand for various methods to be deployed for measuring these ocean waves. According to Stewart [2009] the more commonly used techniques include observations made at sea, satellite altimeters, accelerometers mounted on buoys, wave gauge spatial arrays and synthetic aperture radars (SAR) on satellites. Other techniques include the use of seismometers, upward facing acoustic Doppler current profilers (ADCP) [Terray et al., 1999], pressure transducers Bishop and M.A.Donelan [1987] and various radars such as wave radars on ships and structures, and scanning-beam microwave radars on aircraft and satellites [P.L.Baker, 1985].

Wind-generated ocean waves consist of wave contributions spreading in different directions with varying wavelengths, and are described using directional wave spectra. An example of a directional spectrum is presented in Figure 0.1.1. These spectra are the key to wave modelling, allowing the consequences of interactions between the waves and other structures to be calculated, be it the response of a ship or forces on an offshore structure [Hauser et al., 2003]. During open water model tests, the ability to measure and scale the waves interacting with the model is important for determining the full-scale responses of the ship during various manoeuvres or conditions. With the emphasis placed on the importance of being able to scale the environment in open water model tests, it was decided that possibilities for measuring these small-scale waves were to be explored.

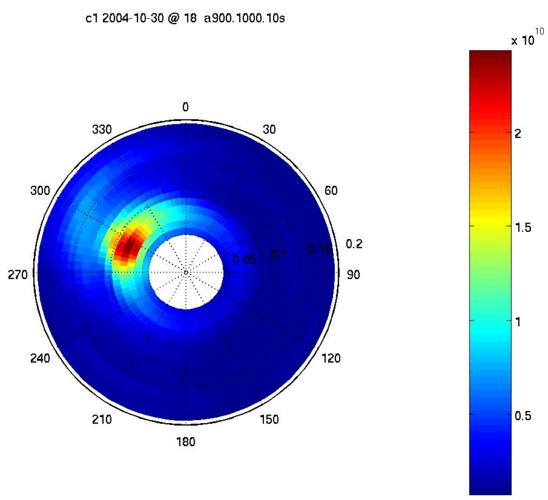


Figure 0.1.1: Example directional wave spectrum [Argus Beach Monitoring Stations].

This project models a full scale ship that operates the majority of its time in the North Atlantic during Beaufort scale 4-6 conditions. Table 0.1.1 MET Office [2013] shows the full scale wave conditions with the corresponding scaled-down waves that the model should be tested in. Data for mean zero crossing periods measured by the North Atlantic weather station *India* was used from Draper [1986] to determine the desired model scale periods. Mean zero crossing periods of 5.5-13.5 seconds were measured, pertaining to model scale wave periods of 0.71-1.74 seconds, based on Froude scaling [Lloyd, 1998]. As a result, the ability to accurately measure waves in the range of 1-10 cm height and frequency of 0.5-1.7 Hz is necessary, based on a 1/60 scale.

Table 0.1.1: Desired wave heights for model-scale testing based on the Beaufort scale.

| Beaufort Number | Wind Speed $ms^{-1}$ | Probable Wave Height m | Max Wave Height m | Model Prob. Wave Height cm | Model Max. Wave Height cm |
|---|---|---|---|---|---|
| 4 | 5.5-7.9 | 1.0 | 1.5 | 1.67 | 2.50 |
| 5 | 8.0-10.7 | 2.0 | 2.5 | 3.33 | 4.17 |
| 6 | 10.8-13.8 | 3.0 | 4.0 | 5.00 | 6.67 |
| 7 | 13.9-17.1 | 4.0 | 5.5 | 6.67 | 9.17 |

Limited by a relatively small budget and time-frame, and after assessing different methods (Section **??**), the most feasible method for measuring waves on this scale in various open water environments would be to implement a surface contouring wave buoy. Mounted with a 9 degree of freedom (DOF) sensor pack, the buoy would be capable of measuring heave, pitch and roll responses to determine the directional wave spectrum.

By developing a system that uses small, surface-contouring wave buoys it allows for easy set-up in almost every location, with the only varying factor being the mooring length (if used). Alternatively, the buoy could be launched upwind of the test site, and allowed to drift freely downwind. It would be a small, lightweight and easily transportable solution that could acquire and transmit data simultaneously to the shore for real-time analysis.

A number of commercially offered wave buoy solutions were discussed in Section **??**, such as the Wavetector, Triaxys and Datawell. However, a major limiting factor of these was the price, which greatly exceeded the available budget. It was apparent that none of the existing commercial wave buoys would be suitable to measure the small-scale waves needed during model test runs, as all are designed to be deployed in the open ocean. With these factors in mind, it was clear that there was a need to develop a wave buoy with the capability of measuring the small-scale sea states during the open water experiments.

Initial plans were to develop and test a suitable wave buoy design, then produce a number of them (approximately 4) in order to set up a grid in which the ship's tests would be conducted. It became clear, however, that this was not actually necessary and would introduce further complications when analysing the wave data, as well as greater costs. By developing a single wave buoy, focus could be aimed on improving the quality and accuracy of data acquired by spending more time and money on the construction and sensors used.

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