Driving Wave Models from Sensor Data: How Much Information do we Need?

David Christie*†, James Morrison*‡, Arne Vögler*§
*Lews Castle College, University of the Highlands and Islands, Stornoway, Scotland HS2 0XR
† david.christie@uhi.ac.uk (Corresponding Author) ‡ james.morrison@uhi.ac.uk § arne.vogler@uhi.ac.uk

I. Keywords

Directional spectrum, DHI Mike 21 Spectral Wave Model, Preprocessing, Maximum Entropy Method, Maximum Likelihood Method, directional distributions

II. Abstract

During the planning and financing phase of wave energy developments, spectral wave software such as DHI Mike 21 and SWAN is used to determine local spatial and temporal variation of the wave resource. It is often advantageous to drive these local models directly from metocean data physically measured at the boundary location by devices such as Waverider buoys. Sensor data can offer a higher temporal resolution than global models, and nearshore model domains do not need to be extended to offshore global datapoints. This paper compares various approaches to converting raw buoy data to the directional spectra required to drive a resource model.

Buoy displacements in three dimensions can be post-processed to yield a non-directional energy spectrum, plus the first four Fourier coefficients of the directional distribution for each frequency bin (equivalent to the directional mean, spread, skew and kurtosis). This is the maximum amount of information available from a point measurement without making further assumptions [1]. To obtain a full directional spectrum, one must either choose a standard parametrised distribution to match the first two moments for each frequency, or else attempt iteratively to fit all four moments by appealing to a principle of maximum entropy or likelihood.

Commonly used standard formulae include the wrapped normal (Gaussian), $\cos 2s$ and von Mises distributions. These symmetric, unimodal distributions match the directional means and spreads at each frequency, but take no account of skew or kurtosis. Maximum Entropy and Maximum Likelihood distributions are calculated using software such as WAFO [2] and DIWASP [3], while Datawell's W@ves21 has its own estimation algorithm. While more computationally demanding, this approach uses more of the available information from the buoy, and can handle asymmetry or bimodality.

While the various choices of directional distribution share at least some trigonometric moments, they can differ noticeably from each other. This paper seeks to address the resulting question: what is the best method to construct the boundary conditions for resource models?

Fig. 1. Location of the offshore buoys and nearshore AWACs

Long term datasets have been obtained from the Datawell Waverider buoys and Nortek AWACs deployed west of Lewis in Scotland as shown in Figure 1. Wave transformations from the offshore buoys to the nearshore AWACs are simulated in a DHI Mike 21 Spectral Wave model, calibrated by comparison with one of the AWACs for a subset of the time period, and validated at the other sensor. This modelling exercise is repeated for different methods of preparing the boundary data (including a purely parametric representation, as well as fitting to standard directional distributions, plus the maximum entropy and likelihood iterative spectra calculated in WAFO, W@ves21 and DIWASP). By systematically comparing models driven by each boundary formulation, and determining how closely output parameters match the AWAC measurements, the performance of each representation is evaluated. Is the increased computational effort of an iterative statistical estimation rewarded by an improvement in model accuracy?

References

[1] M. S. Longuet-Higgins, D. E. Cartwright, and N. D. Smith, "Observations of the directional spectrum of sea waves using the motions of a floating buoy," in *Ocean Wave Spectra, proceedings of a conference, Easton, Maryland*, National Academy of Sciences. Prentice-Hall, 1963, pp. 111–136.

[2] P. Brodtkorb, P. Johannesson, G. Lindgren, I. Rychlik, J. Rydén, and E. Sjö, "WAFO - a Matlab toolbox for the analysis of random waves and loads," in *Proc. 10'th Int. Offshore and Polar Eng. Conf., ISOPE, Seattle, USA*, vol. 3, 2000, pp. 343–350.

[3] D. Johnson, *DIrectional WAve SPectra Toolbox Version 1.4*, MetOcean Solutions Ltd.