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Verification within wave resource assessments. Part 1: Statistical analysis

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ABSTRACT

Interest in wave energy as a viable renewable energy has increased greatly in the past couple of decades. To determine the potential that a certain location has to harvest wave energy, a resource assessment must be performed for that location. As wave energy converter technologies get closer to market, it is becoming necessary to undertake more detailed resource assessments in order to determine the optimal location for deployment as well as the design and operating sea states. This study shows the level of sophistication that must be included in the verification process within a wave resource assessment. We describe the methodology in two articles. The first part shows how doing a complete statistical analysis of the fit of the model at the location of interest is essential for determining the reliability of the model data. Part 2 of this study will investigate the systematic trends of the fit of spectral values. In Part 1, it is shown that spatial analysis, the examination of distributions to reveal overall trends, and the careful choice of the appropriate statistical model to describe the fit of the wave model to buoy observations are all critical steps that must be added to verification processes. Part 2 demonstrates that looking closely at the fit of spectral values can reveal potentially vital issues for energy extraction. Better statistical validation gives the predictions of a particular resource assessment greater credibility or reveals areas where model accuracy must be improved.

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1. Introduction

Gunn and Stock-Williams [1] estimate a global wave power resource of 2.11 ± 0.05 TW. With the growing interest in this source of energy and the resulting recent increase in the level of detail required for resource assessments comes the need for a more thorough understanding within each assessment of the specific wave model used. The appeal of using wave models to predict resources is very logical; for example, a model can give a prediction over a much longer time period than buoy or satellite measurements. Wave models are extensively validated (e.g. [2–4]), but these validations are often not focused on parameters that are vital for wave energy extraction. For a resource assessment, before the wave model can be deemed reliable, a complete statistical analysis of the fit of the wave model at the location of interest must be completed, and the implications of any errors found must be thoroughly understood. To verify the fit of the model, output must be compared to *in situ* observations from a buoy or satellite.

Large-scale resource assessments have become more comprehensive in the past couple of years, but overall there is not a large emphasis in these studies on verification of the model used. Gunn and Stock-Williams [1] provide a comparison of previous global and national/regional resource assessment studies. One example, Mørk et al. [5], performs a global resource assessment study, and a global map of correlation coefficients between model and satellite significant wave height is shown by way of verification. The global assessment by Ariange and Cheung [6] includes a slightly more detailed verification process, in which the correlation coefficient, root mean square error (see Section 2.2), and 90% confidence intervals are calculated for significant wave height measured against altimetry data and for significant wave height, peak wave period and mean wave period measured against buoy data.

For national or regional studies, the degree of verification increases. For example, in ESBI's Wave Energy Resource Atlas Ireland [7] the verification process involves calculating coefficients of correlation and determination for significant wave height and wave period, and correcting the model data to align with buoy data if the values suggest this is required. In ABPmer's Atlas of UK Marine Renewable Energy Technical Report [8] significant wave height and resultant wave power model values were compared to monthly means and overall distributions of buoy observations. The authors provide hypotheses on why certain locations had better agreement than others and observations on seasonality. EquiMar (Equitable Testing and Evaluation of Marine Energy Extraction Devices) Project Deliverable D2.3 [9] proposes a standard practice for validation of numerical models, following the example of Ris et al. [4], which involves calculating bias, root mean square error, scatter index, model performance index, and operational performance index (see Section 2.2).

The main focus of Part 1 of this study is to highlight the benefits of carrying out a comprehensive statistical analysis for *localized* resource assessments. There is limited evidence of this in practice in existing literature. For example, in an assessment of the wave energy potential in El Hierro by Iglesias and Carballo [10], there was no verification and only a model was used. In a study of the U.S. Pacific Northwest by Lenee-Bluhm et al. [11], only buoy measurements were used.

Stopa et al. [12], in an assessment of the wave energy potential in Hawaii, compare model data to both satellite data and buoy data. Statistics such as bias, normalized root mean square error, correlation coefficient, and scatter index (see Section 2.2) are calculated, and time series and quantile–quantile plots are constructed. The fit of the model at different locations are compared, and a structured pattern of agreement in the model associated with buoy locations around the islands is observed. The analysis is, however, limited to significant wave height, and does not include energy period which is also influential in calculating wave energy potential.

Liberti et al. [13] compare the fit of model calculations to satellite and buoy measurements for the Mediterranean. Statistics are calculated for significant wave height, spectral period (T_{02}), and mean wave direction, including bias, root mean square error, and scatter index. This study does consider periods by examining spectral period, but analyzing energy period would lead to a more targeted validation for wave energy.

In a resource assessment for the Cornish coast (UK), van Nieuwkoop et al. [14] perform the most extensive verification analysis for a local resource assessment at present. The importance of removing outliers is stressed, relevant statistics are calculated for significant wave height, energy period and mean direction, and bias is calculated for different bins of the parameters. It is also openly stated that

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