A PREDICTIVE EQUATION FOR WAVE SETUP THROUGH THE USE OF GENETIC PROGRAMMING

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INTRODUCTION

As the sea level rises, coastal flooding is predicted to increase worldwide. One of the processes contributing to estimating coastal flooding is wave setup (combined with swash), which accounts for the effect of breaking waves on water levels. Defined as the superelevation of the mean water level due to breaking waves (Longuet-Higgins & Stewart, 1964), wave setup prediction has been a research topic of interest for decades. However, empirical predictors still show considerable scatter, making this component the one with the largest uncertainty when estimating flooding levels. At the same time, more data has become available, opening the possibility of using data-driven models, such as machine learning, a powerful tool that has already been applied to predict a variety of coastal processes. Our work aims to develop a new, robust and reliable wave setup predictor through the use of an evolutionary-based genetic programming technique. To develop the algorithm, we use a dataset compiled by Stockdon et al. (2006), containing 491 measurements from 10 field experiments representing different beach and wave conditions.

GENETIC PROGRAMMING MODEL

Inspired by natural selection and the "survival of the fittest" during the evolutionary process, genetic programming (GP) is a computational technique to automatically solve optimization problems (Koza & Poli, 2005). The objective of GP is to iteratively transform a set of computer programs (i.e., equations) at each generation into a new set of programs (i.e., new equations) through the application of genetic operations (i.e., crossover, mutation, reproduction). The final optimized predictor for maximum wave setup ($\bar{\eta}_M$) can be represented in mathematical form. The GP model was built using a set of independent variables (offshore significant wave height - H_{s0}, peak period - T_p, offshore wavelength - L_0, foreshore slope - β_f, surf similarity parameter - $\xi_0 = \beta_f/(H_{s0}/L_0)^{0.5}$ and median sediment diameter - D_{50}), mathematical operators (+, -, ×, ÷, x^x, √), and coefficients. Candidate solutions were tested using the training data, and the best predictor was the one capable of minimizing a fitness function (MAE). The accuracy of model results was evaluated against measured data through the use of statistical parameters (R^2, MAE, and RMSE). We also compared the GP model results with some of the most widely known predictors in the literature.

RESULTS AND CONCLUSIONS

Two predictors of wave setup were selected from the GP output. The complex predictor (Equation 1, Figure 1a) is the best predictor in terms of R^2 (0.70) and RMSE (0.14), which maintains a physical interpretability with separate terms related to wave dynamics and sediment. Alternatively, Equation 2 (Figure 1b) is presented as a simpler and dimensionally-correct predictor:

$$\bar{\eta}_M = \frac{H_{s0}}{4.08}\left(\frac{\xi_0}{3.25} + \frac{\xi_0}{\xi_0 + 0.64} + \frac{\xi_0}{1625 D_{50} + \xi_0}\right) \quad (1)$$

$$\bar{\eta}_M = 0.355 H_{s0} {\xi_0}^{0.5} \quad (2)$$

Comparisons with previous works (Figure 1c) highlight that, in general, our results (Figure 1a, 1b) show less scatter and provide a better fit for both dissipative (e.g., Agate) and reflective (e.g., San Onofre) conditions.
The results of this work prove that GP models are able not only to improve predicting capability (compared with classical predictors) but also capable of offering physically sound descriptions of the simulated process.

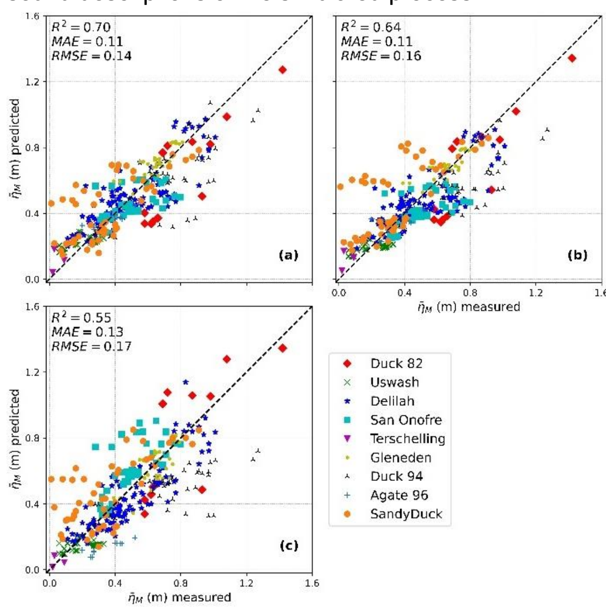

Figure 1 - Measured versus predicted $\bar{\eta}_M$ using **(a)** GP Eq. (1), **(b)** GP Eq. (2), and **(c)** Stockdon et al. (2006) Eq. ($\bar{\eta}_M = 0.35\beta_f(H_{s0}L_0)^{0.5}$) using the testing data.

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