Predicting Water Surface Elevation Based on the Turbulent Airflow Overlying the Waves: a Novel Machine Learning Approach

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The action of wind on the water creates a broad spectrum of spatiotemporally varying waves; their presence alters the adjacent air and the stresses at the water interface[1]. Accurately assessing air-sea drag is paramount in oceanography; however, it remains elusive since it depends on the complicated interaction between waves and turbulent airflow. To address this, we combine two research disciplines. We developed a novel Artificial Intelligence (AI) model to clarify the relationship between different lengths and time scales in air motion and water waves. Extensive high-resolution laboratory measurements at the Tel-Aviv University wind-wave facility[2] (figure 1a-b) provide the time series for the model induction algorithm. The two-dimensional turbulent airflow velocity (in x and y directions) and the mean airflow are measured by x-shaped hot-film and Pitot tube; the water surface elevation is obtained optically (Figure 1a). Data was recorded at three downstream distances, *x*, and four maximum wind velocities U_0; for seven minutes at a sampling rate of 200 Hz. Our novel AI model first finds the optimal description of each parameter in the system in the frequency domain and then applies advanced signal processing and machine learning algorithms that combine a genetic algorithm and deep neural networks rather than shallow networks[3]. The model finds the connection between the leading wave-wind frequency bands and predicts the instantaneous resultant surface elevation based on the turbulence properties, to our knowledge this was never performed before. The model results agree well with the actual surface records at different wind velocities; figure 1(c) demonstrates a correlation of 0.98, $R^2 = 0.97$, and RMSE=0.43 when the wave height STD is 2.95.

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[1] Pizzo et al., *Phys. Today*, **74**, 38 (2021).

[2] Geva & Shemer, *J. Fluid Mech.*, **394**, (2022).

[3] Chen et al., *IEEE 4th Int. Conf.*, 80 (2021).

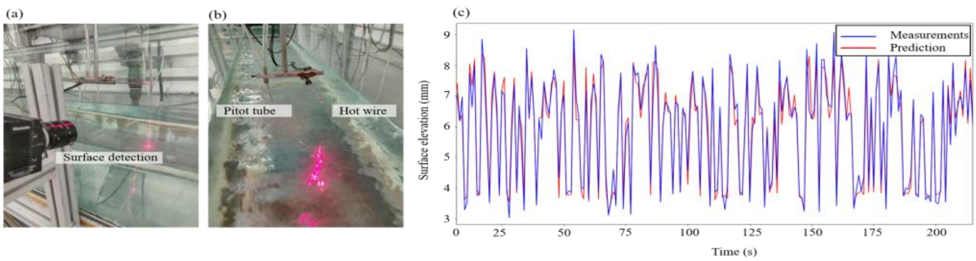

Figure 1: The wind-wave facility (a) quiescent water surface and (b) wavy water surface created by a maximum wind velocity U_0=6.6 m/s; images were taken at *x*=2.5 m. (c) The prediction of the data driven model and the actual surface measurements (more than 16000 different sequences were predicted successfully).