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# Multivariate Phase Space Reconstruction and Chaos Model Prediction for Water Level and Surge Dynamics

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The methods of nonlinear dynamics and chaos theory are used in this research with the main objectives to delineate and quantify the underlying dynamics of the sea water levels and surges, and to further classify the variability and predictability of the coastal dynamics of time series of observables along several locations at the Dutch coast. Phase space reconstruction, based on time-delayed embedding method, together with Poincare surface of sections and estimation of several geometric and dynamic invariants, such as dimensions, entropies and Lyapunov exponents, and are used to study the water level and surge dynamics. Furthermore, the chaos model predictions of the coastal dynamics were developed using adaptive univariate and multivariate local models in the reconstructed phase space. In this research, the use of a mixture of multivariate local models shows reliable and high short-term forecasting performance for water level and surge dynamics - compared to the standard and chaotic neural networks. These models used air pressure, wind speed and direction, and water level and surge data (also include water level and surge data from neighboring station) as inputs, and the surge and water level as the outputs (up to 10 hours ahead). In practice, these data-driven modelling approaches elaborated in this work can serve as a basis to improve the operational forecasting for ship guidance and navigation processes in the approach channel at Hoek van Holland as an entrance to the port of Rotterdam.