Advancing Bathymetric Reconstruction and Forecasting Using Deep Learning

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Abstract

Bathymetric evolution in coastal environments is driven by complex interactions between hydrodynamics, sediment transport, and morphodynamics. Traditional morphodynamic models often face challenges in capturing these dynamics, particularly in regions like the Wadden Sea, where the feedback mechanisms between physical processes and seabed changes are highly intricate. In this study, we explore the potential of deep learning techniques to address these limitations, using convolutional neural networks (CNN) for bathymetric reconstruction and convolutional long short-term memory (ConvLSTM) networks for forecasting. We applied these models to a dataset of bathymetric observations from the German Bight, which provides detailed coverage of the seabed from 1983 to 2012. First, we demonstrated that CNN effectively reconstructs spatial bathymetric patterns based on incomplete data inputs, achieving accurate reproductions of observed bathymetry with minimal reconstruction error, particularly in regions with active dynamics like tidal channels. Second, we used ConvLSTM for forecasting, training the model with past observations to predict bathymetry. The ConvLSTM model performed well, with an average root mean square error of 0.139 m across all tiles. Our results indicate that deep learning techniques offer promising alternatives to traditional methods for both spatial reconstruction and forecasting of bathymetric changes. These models can improve predictions of seabed dynamics, which are critical for effective coastal management, navigation, and environmental protection.