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Machine-leaning based resolution enhancement for fluvial hydrodynamics

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ABSTRACT

Hydrodynamic modeling is crucial for predicting key flow characteristics in rivers, with applications in flood impact assessment, fluvial infrastructure design, and morphological, environmental, and ecological studies. Physics-based hydrodynamic models rely on numerical techniques to solve governing equations, such as the Navier–Stokes equations (in 3D) or Saint-Venant equations (in 1D/2D depth-averaged), to simulate fluid flow in fluvial environments. Hydrodynamic predictions must often have high spatial resolution to capture fine-scale details, yet they must also be computationally affordable. This balance is particularly crucial for real-time, long-term (multi-year), or repetitive scenario-based simulations near critical locations. Despite the latest advances in high-performance computing, achieving computational affordability in physics-based models remains a significant challenge, without sacrificing accuracy through simplifications and lowering spatial resolution. This creates a crucial need for methods to enhance spatial resolution (downscale) and reduce noise in flow data. Machine learning (ML) and deep learning (DL) techniques for super-resolution (SR) have proven effective for resolution enhancement across various fields. This study introduces and evaluates DL-based techniques for enhancing the spatial resolution of computationally affordable low-resolution (LR) hydrodynamic predictions, transforming them into high-resolution (HR) outputs that would otherwise be computationally expensive. The developed model integrates deep neural networks (DNN) with convolutional and fully connected layers. Evaluations show good accuracy of the predicted HR water level and velocity for different cases, demonstrating the model's capabilities.