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Multi-scale hydraulic-based graph neural networks: generalizing spatial flood mapping to irregular meshes and time-varying boundary condition

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Deep learning models emerged as viable alternatives to rapid and accurate flood mapping, overcoming the computational burden of numerical methods. In particular, hydraulic-based graph neural networks present a promising avenue, offering enhanced transferability to domains not used for the model training. These models exploit the analogy between finite-volume methods and graph neural networks to describe how water moves in space and time across neighbouring cells. However, existing models face limitations, having been exclusively tested on regular meshes and necessitating initial conditions from numerical solvers. This study proposes an extension of hydraulic-based graph neural networks to accommodate time-varying boundary conditions, showcasing its efficacy on irregular meshes. For this, we employ multi-scale methods that jointly model the flood at different scales. To remove the necessity of initial conditions, we leverage ghost cells that enforce the solutions at the boundaries. Our approach is validated on a dataset featuring irregular meshes, diverse topographies, and varying input hydrograph discharges. Results highlight the model's capacity to replicate flood dynamics across unseen scenarios, without any input from the numerical model, emphasizing its potential for realistic case studies.