Floodcast: A large-scale flood modeling using geometry-adaptive physics-informed neural solver and Earth observation data

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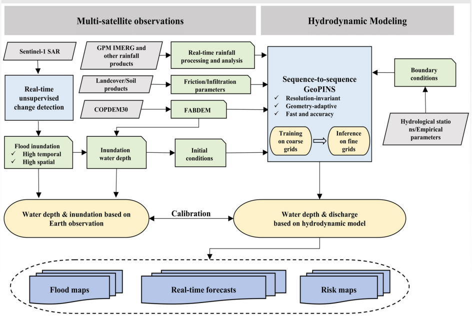
Introduction

- ☐ Traditional hydrodynamic methods (e.g. finite difference) are highly dependent on the resolution: **coarse grids are fast but low accurate; fine grids are accurate but slow.** For example, a global flood solver based on FD has a resolution of up to 1 km, but this requires a dramatic increase in computational resources.
- ✓ A "good" PDE solver for real-world simulations should satisfy the following basic conditions: **i) Fast and accurate.** Stable and accurate approximation schemes can be obtained with minimal computational overhead; ii) **Resolution-invariant.** The solver can efficiently represent dynamic processes at different spatial and temporal resolutions; iii) **Geometry-adaptive.** The solver can be adapted to general scientific problems that exist in the real world, where the geometry is often complex and irregular.

- ☐ **Hydrodynamics model has conventionally relied on surveyed bathymetric data** (e.g., river bed elevation, channel geometry). However, river bathymetry data is not available in most parts of the world. Furthermore, ground surveys are very expensive and time consuming at catchment scale.
- ✓ **Using satellite observations can help better constrain model parameters and reduce model uncertainty** because satellite observations (i.e. precipitation, land use land cover, etc.) have higher spatial coverage and contain information on land-surface processes that cannot be inferred from discharge.

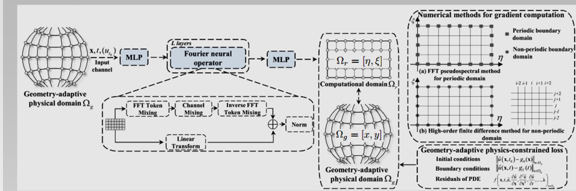
- ☐ Can we build a forecasting framework **for large-scale real flood applications**?
- ✓ The experimental results for the **Pakistan flood in 2022** indicate that the proposed method can maintain high-precision large-scale flood dynamics solutions (**more than 80% accuracy**) at different resolutions and flood hazards can be forecast in real-time with the aid of reliable precipitation data.

Overview of Floodcast



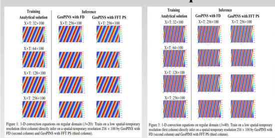
Geometry-adaptive Physics-informed Neural Solver (GeoPINS)

A machine learning alternative to traditional hydrodynamics
Unsupervised solver, Resolution-invariant solver, Geometry-adaptive solver

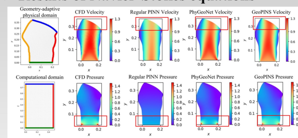


GeoPINS for Simulated Cases

➢ Results of Convection equations.

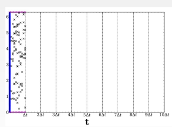


➢ Results of Navier-Stokes equations



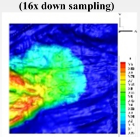
➢ GeoPINS for large-scale flood modeling and forecast

✓ Sequence-to-sequence learning: long sequence time problem

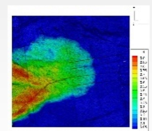


✓ Downsampling GeoPINS : large-scale spatial problem

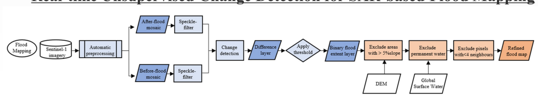
Training on coarse grids (16x down sampling)



Inference on fine grids

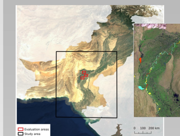


Real-time Unsupervised Change Detection for SAR-based Flood Mapping



Pakistan Flood in 2022

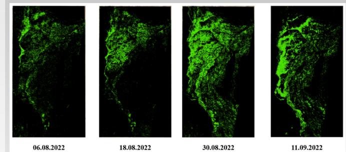
➢ Study area and Input data



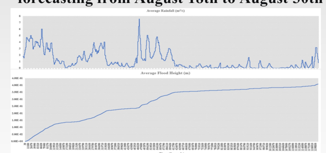
- ✓ DEM (30 m from FABDEM)
- ✓ Land Use and Land Cover from
- ✓ Precipitation data are from GPM IMERG
- ✓ Land use and land cover are from Sentinel-2 10m Land Use/Land Cover Time Series
- ✓ Initial flood extent from SAR-based flood mapping
- ✓ Boundary Conditions from FFC's Daily Flood Situation Resports

An area of 30,492 km², August 18 to August 30

➢ Time-seris SAR-based flood mapping



➢ GeoPINS-based flood simulation and forecasting from August 18th to August 30th



We compare our GeoPINS results with a 30 m resolution, SAR-based flood record, obtaining a good agreement.

Abstract info.

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