AI-Driven Temporal Super-Resolution for Flooding Prediction in Norfolk, Virginia

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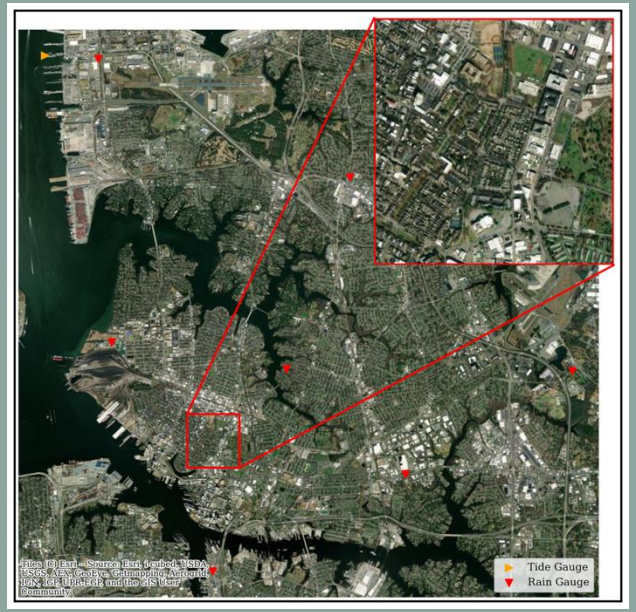
Motivation and Study Area

- The lack of fine-scale environmental inputs, such as high-resolution rainfall data, makes it difficult to predict flooding water depths at short time intervals needed for applications like transportation decision support

- We address this limitation by using the Fourier Neural Operator (FNO) to learn complex spatiotemporal flood dynamics and produce high-frequency, temporal super-resolution predictions

- We have selected Hague community in Norfolk, VA as study area for this work



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Flooding Event and Data Pre-Processing

Date (mm/dd/yyyy)	Rainfall (days)	Surge (m)	Daily Precipitation (in)	Scenario
08/29/2017	5	1.17	3.93	Compound
09/19/2020	5	1.13	3.60	Compound
11/13/2020	4	0.83	4.96	Heavy rain
01/03/2022	5	1.34	1.68	High Surge
09/30/2022	4	1.25	3.40	High surge

Inputs:

- The physics-based model TUFLOW simulated water depth
- Observed rainfall interpolation with a spatial resolution
- Digital Elevation Model (DEM)

Spatial Resolution: 10m x 10m

Target: Water depth maps with fine temporal resolution

Data Pre-processing:

- The study area consists of 125 x 125 cell grid
- The grid is divided into 50 x 50 patches
- Four events are used for training
- One event is reserved for testing

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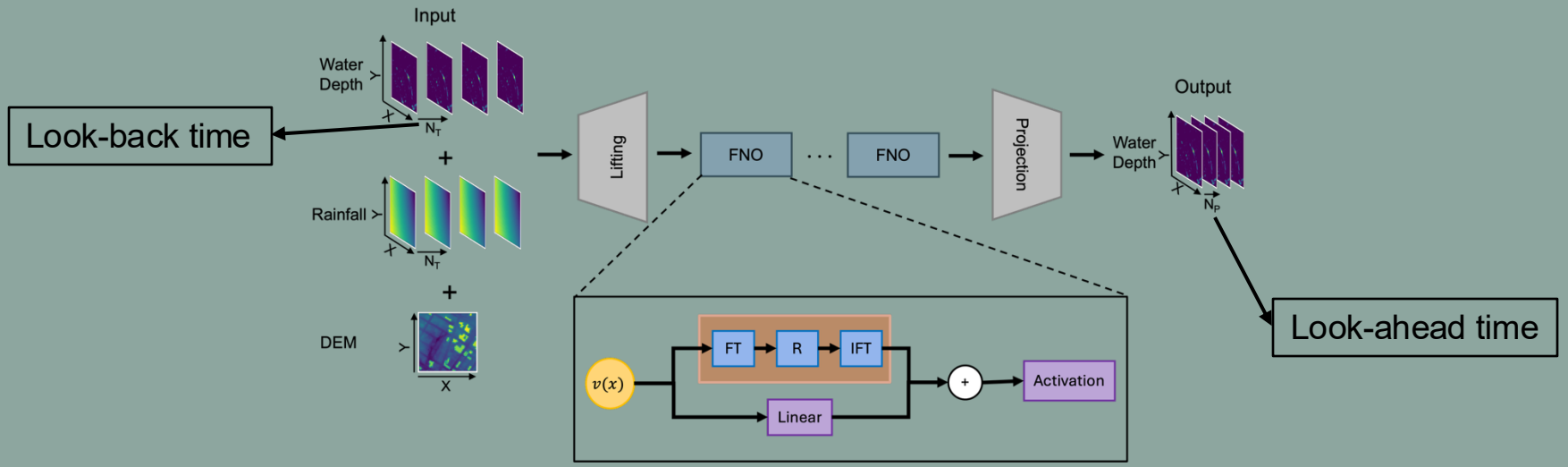
Framework

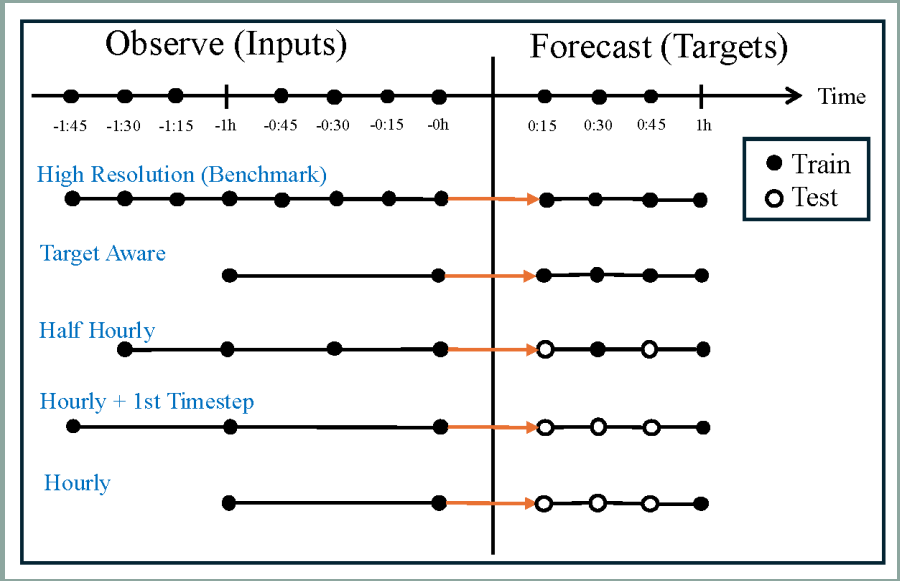


Model contains:

- Four FNO layers
- Four spatial and temporal Fourier modes

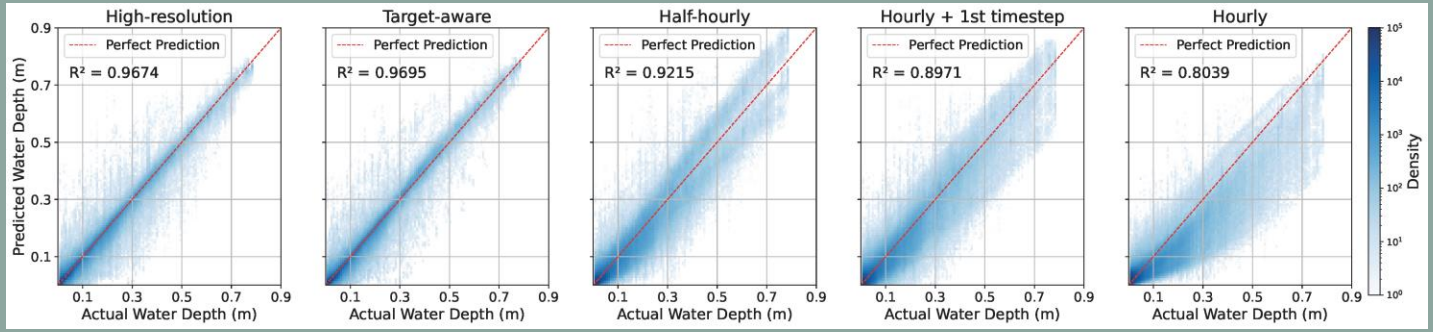
Training Approaches

- Solid circles show timesteps used in both input and target data during training
- Open circles show target timesteps used during testing



Result

Model	MAE (m)	RMSE (m)	R^2
High-resolution	0.007	0.017	0.971
Target-aware	0.008	0.017	0.971
Half Hourly	0.015	0.026	0.930
Hourly + 1st timestep	0.018	0.031	0.905
Hourly	0.028	0.046	0.791



- The fine-resolution model shows highest accuracy while accuracy decreases as training data become coarser
- Predicted and observed values align closely for all approaches
- The hourly model shows slight underprediction, but most points remain near the ideal line.

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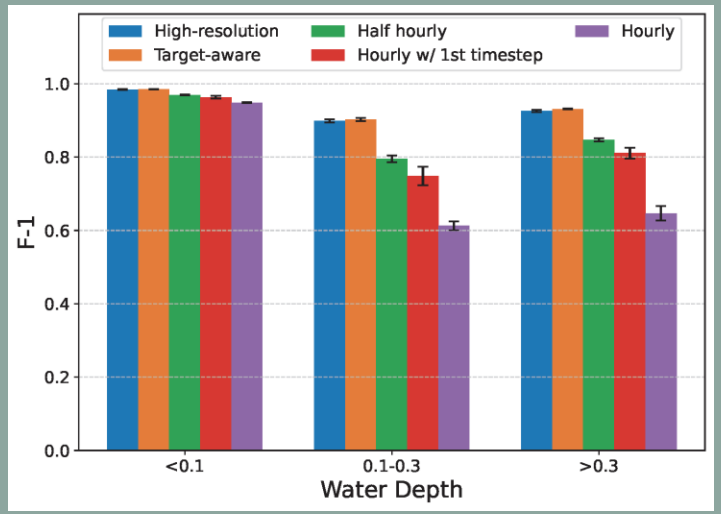
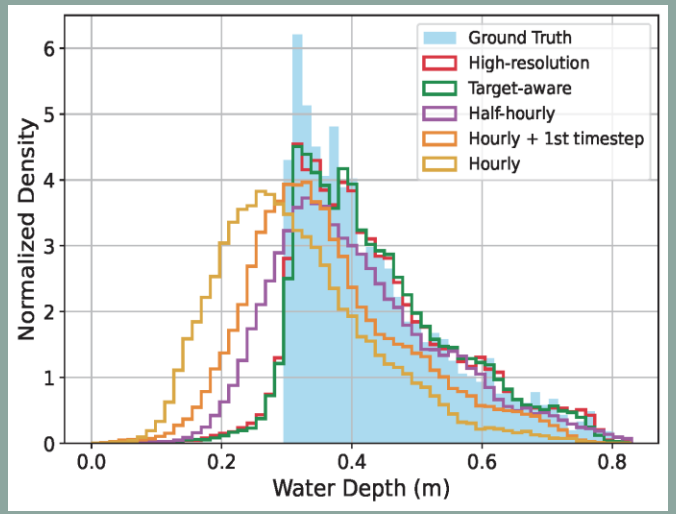
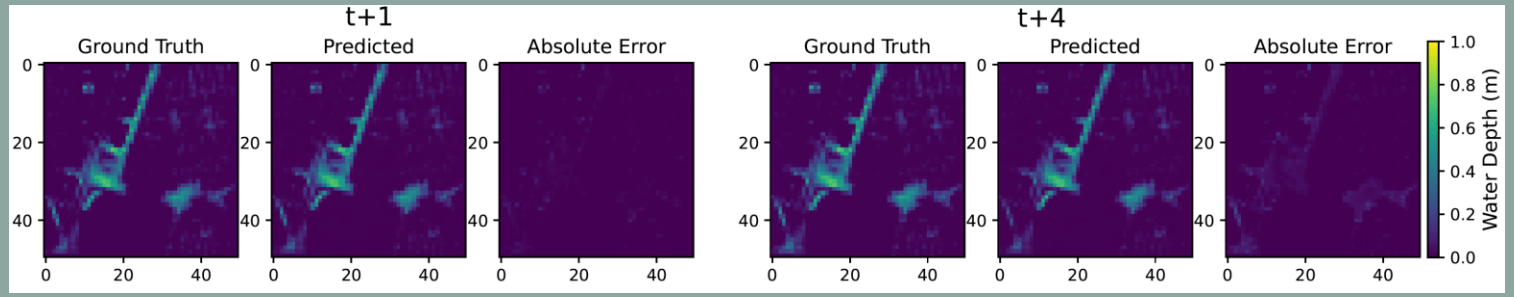
Categorical and High-Water Depth Performance



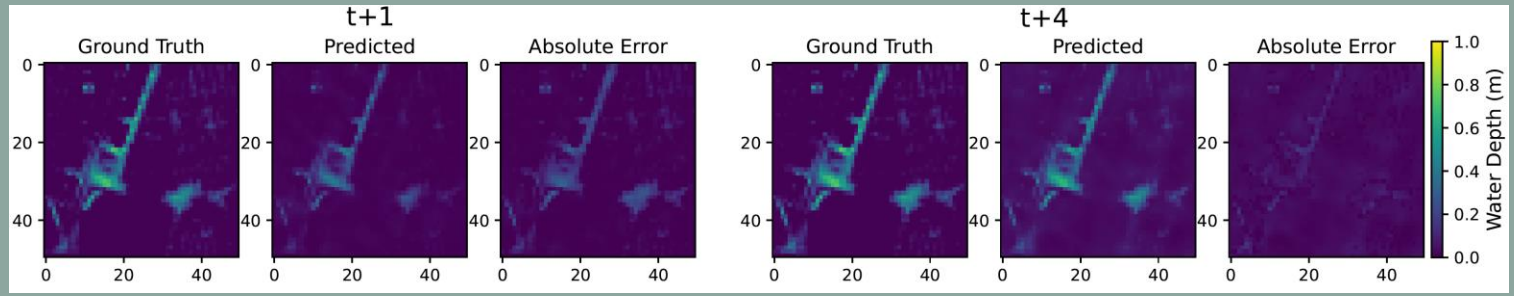


- Performance is evaluated for three different water depth categories: shallow (<0.1m), moderate (0.1-0.3m) and high water depth (>0.3m)

Qualitative Performance



(a) High-resolution



(b) Hourly

Visual results show consistent performance between predictions and ground truth across all training approaches.

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Conclusion and Future Work

- Developed a temporal super-resolution flood prediction model using an FNO with rainfall, water depth, and DEM inputs, evaluated across multiple input and output temporal resolutions
- The FNO generates 15-minute predictions from coarse-resolution inputs, greatly improving temporal resolution

Future work

- Leverage high-dimensional datasets and improve robustness and accuracy under varied conditions
- Add uncertainty quantification, especially when inputs differ from those seen during training

Thank You
Q & A