

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

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Motivation

- 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.

Study Area

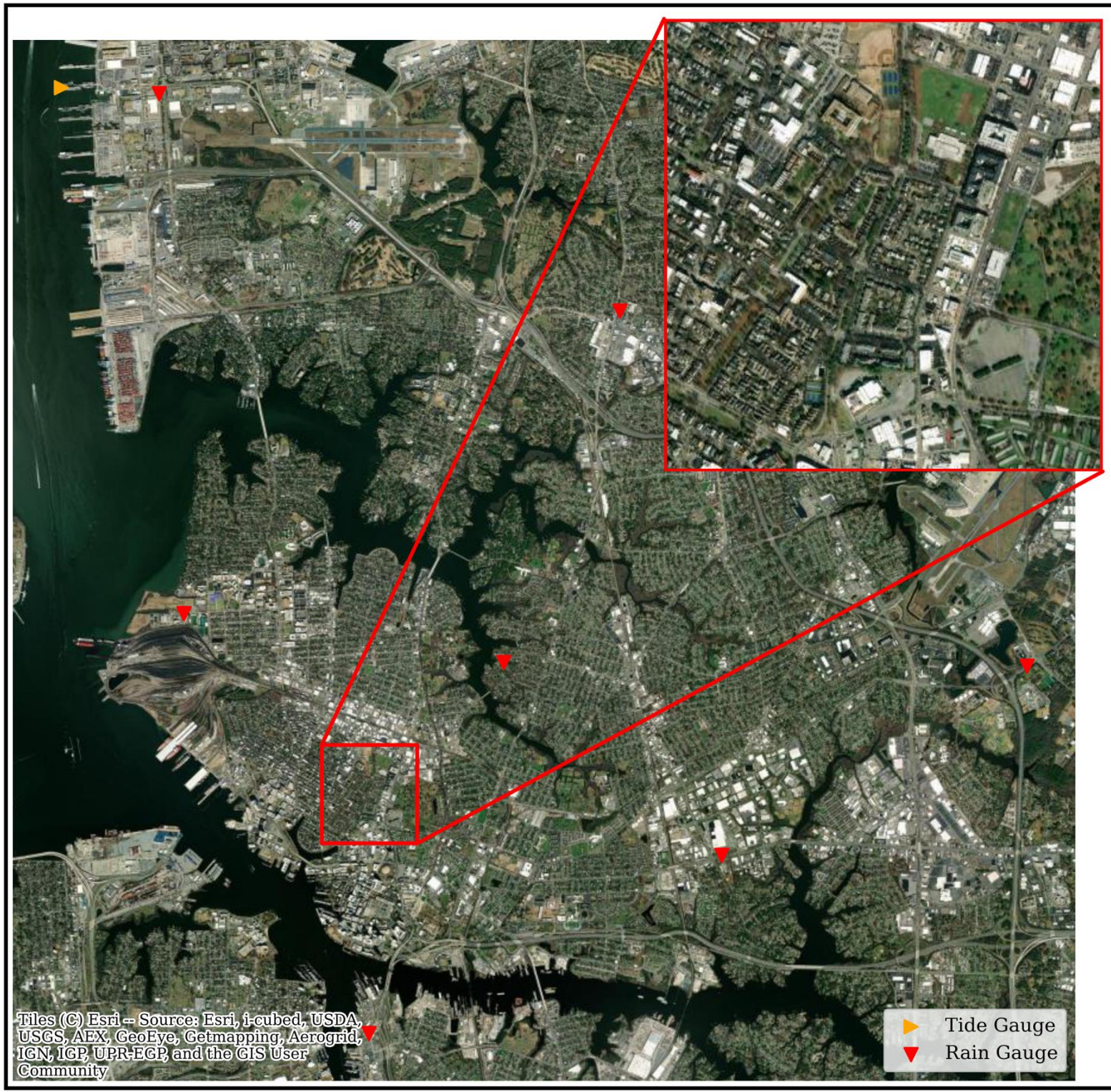


Figure 1: The map displays Norfolk, Virginia and the selected study area within the Hague community which is highlighted by the red box in the upper right.

Data

- The physics-based model TUFLOW simulated water depth and observed rainfall interpolation with a spatial resolution of 10m x 10m and 15 minutes temporal resolution
- Digital Elevation Model (DEM) with a 10m x 10m spatial resolution

Target: Water depth maps with fine temporal resolution

Table I: Rainfall events and their duration in days.

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

Data Pre-processing:

- The study area consists of 125 x 125 cell grid
- The grid is divided into 50 x 50 patches using a sliding window of 25 cells in both directions, resulting in 16 patches per flood event
- Five flood events are used: four for training and validation with k-fold cross-validation and fifth event is reserved for testing

Framework

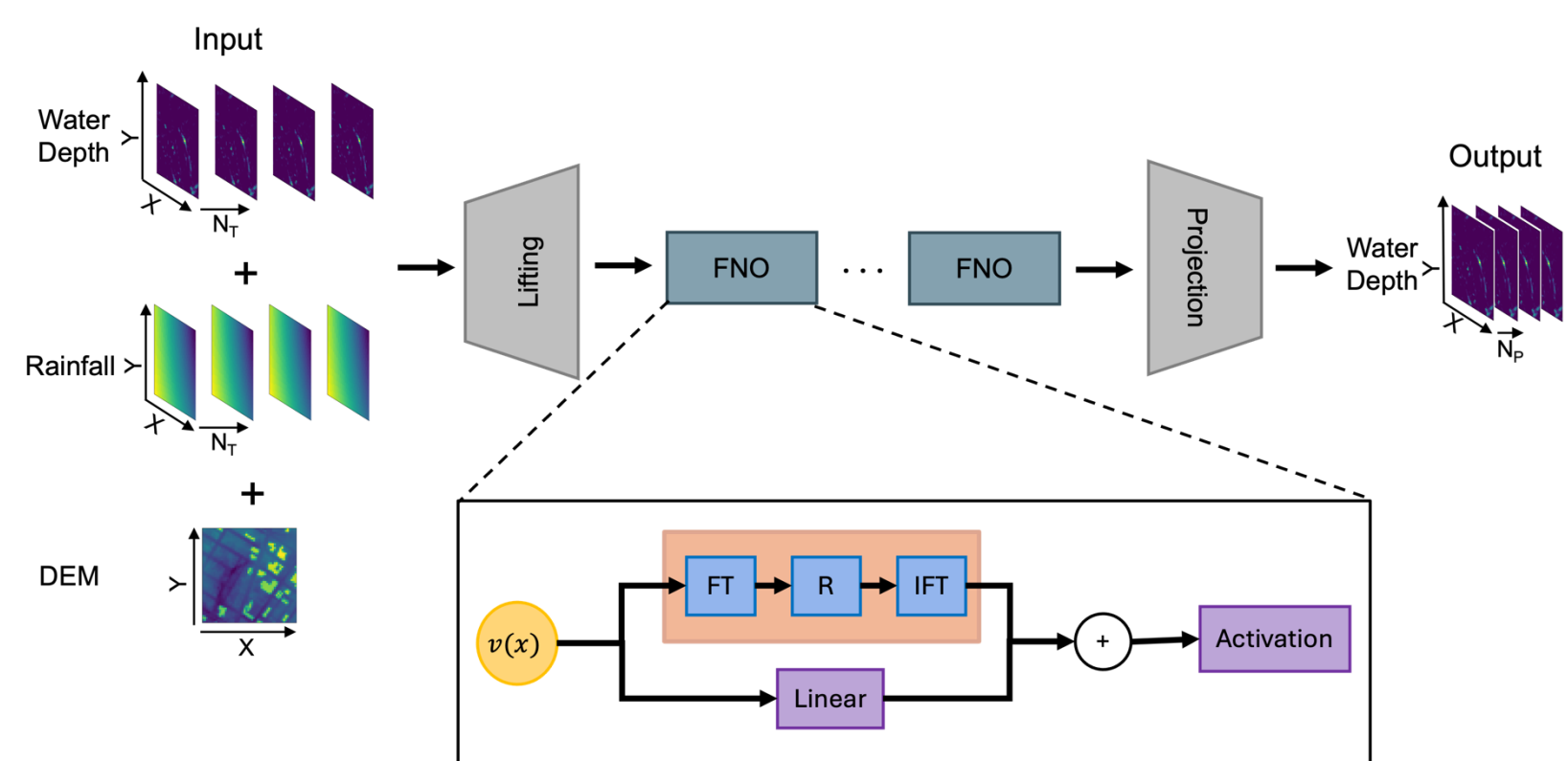


Figure 2: The model architecture consists of four Fourier Neural Operator (FNO) layers. N_T and N_P denote the input and output temporal resolutions, respectively.

Training Approaches

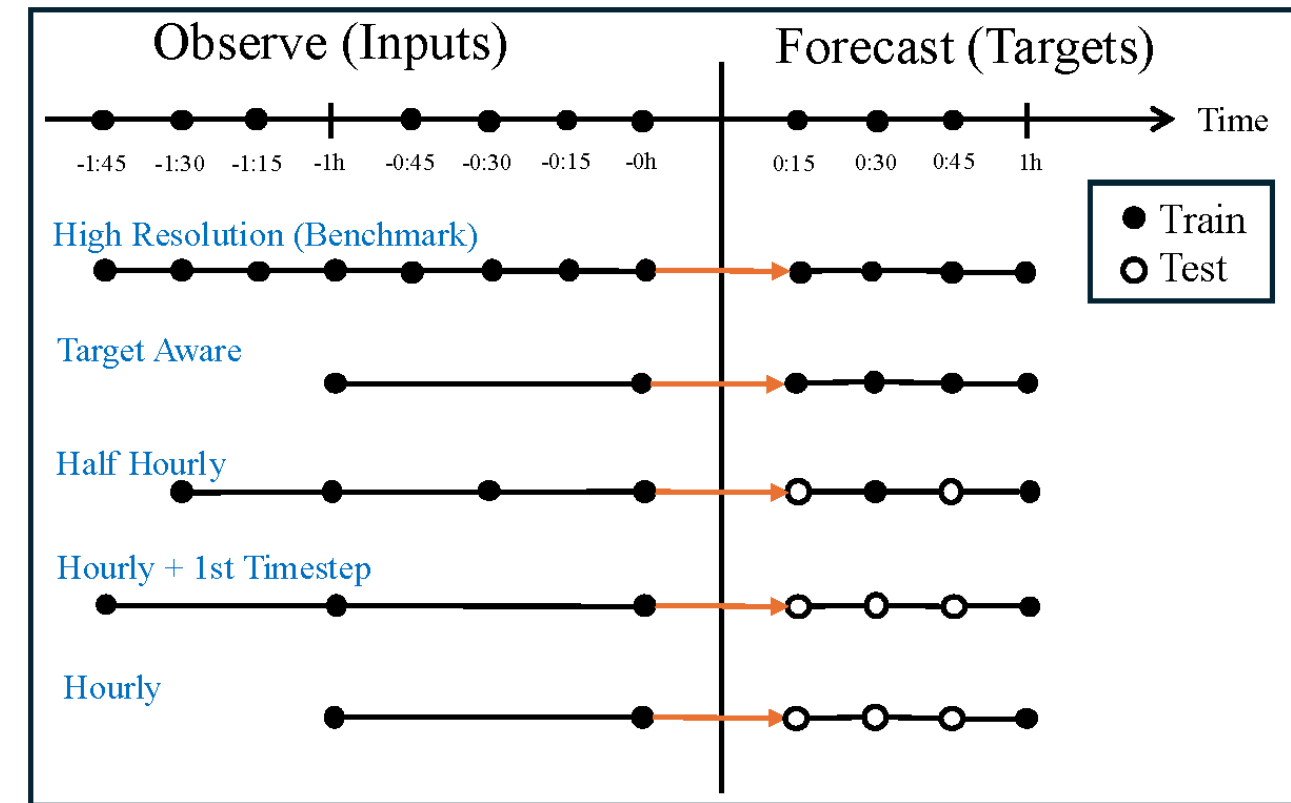


Figure 3: Training configurations with different temporal resolutions. Solid circles show timesteps used in both input and target data during training, and open circles show target timesteps used during testing.

Results

Table II: Performance on the test data across k-fold models.

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.

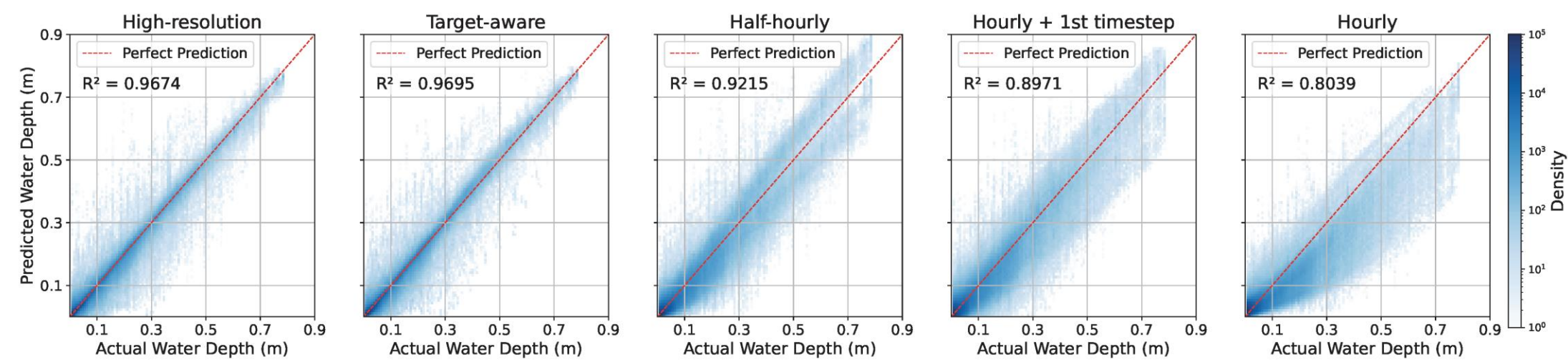


Figure 4: True vs. predicted water depth for different training temporal resolution approaches.

- Predicted and observed values align closely for all approaches; the hourly model shows slight underprediction but most points remain near the ideal line.

Categorical Results

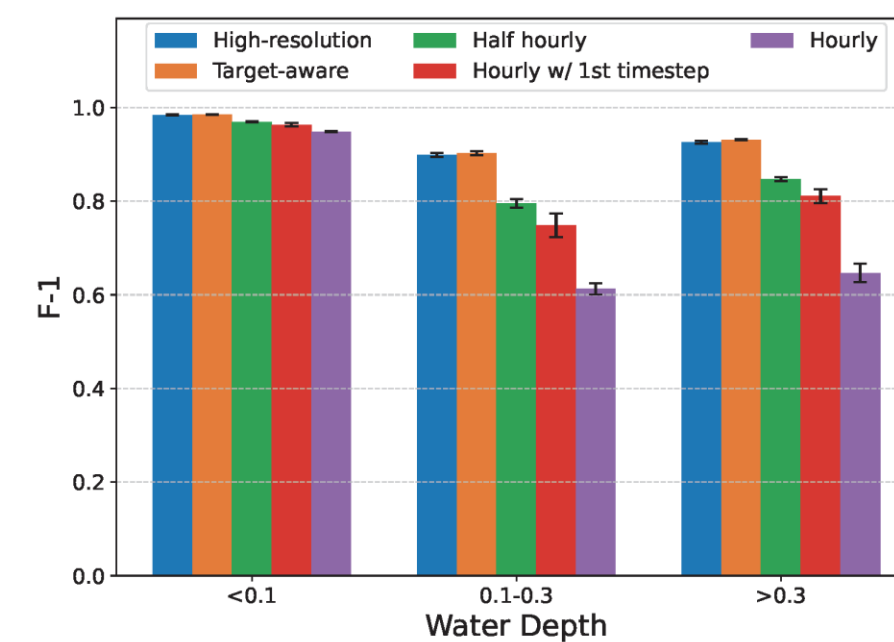


Figure 5: F1 score on test data for three water depth categories.

High Water Depth

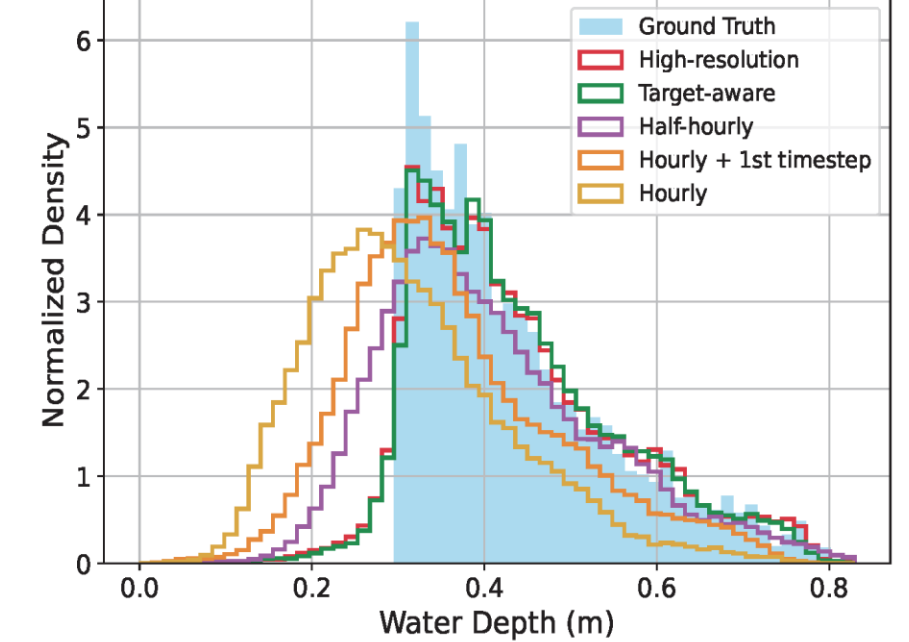


Figure 6: Test data distribution plot of water depth higher than 0.3m.

- 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

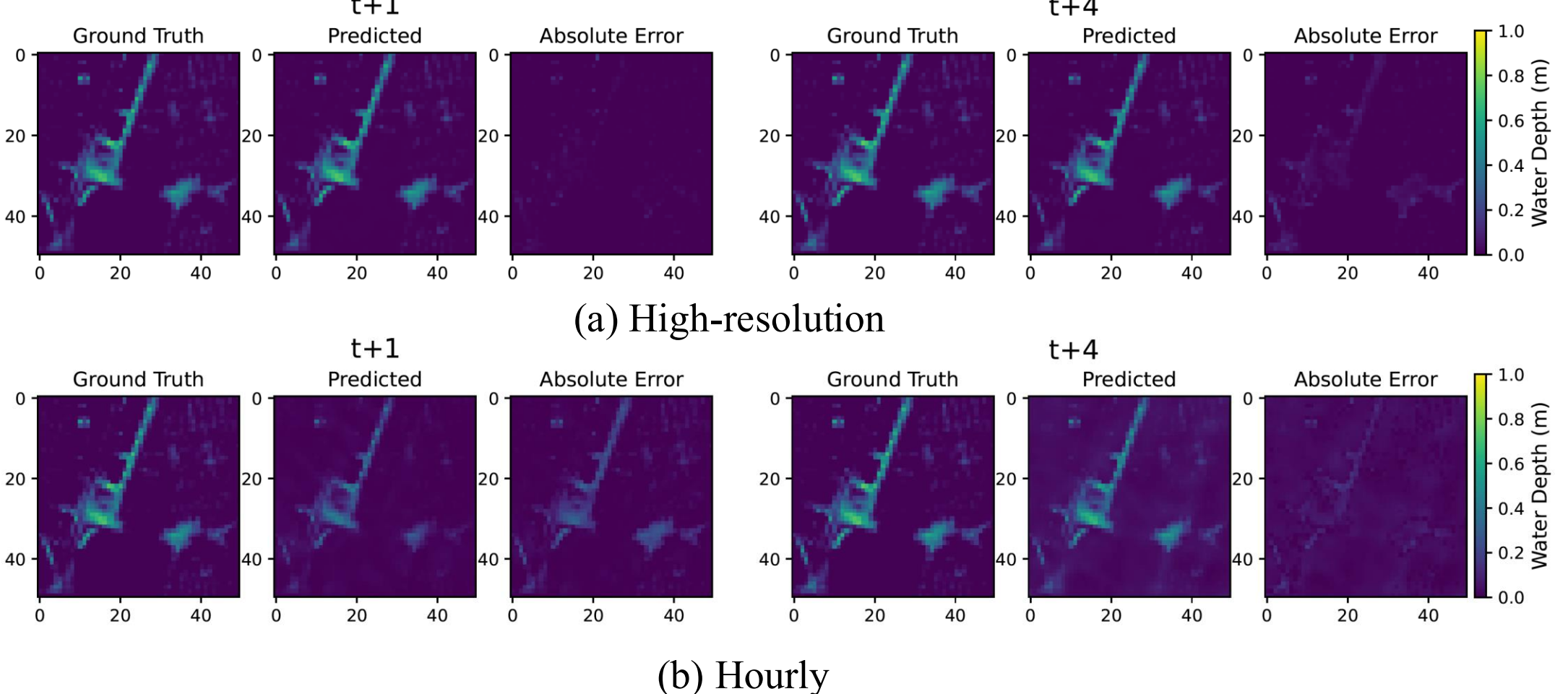


Figure 7: Visual Performance with different training approaches.

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

Acknowledgments

The Hampton Roads Biomedical Research Consortium provided funding for this work as part of the efforts associated with the Joint Institute for Advanced Computing on Environmental Studies between Old Dominion University and Jefferson Laboratory. This manuscript has been authored by Jefferson Science Associates (JSA), operating the Thomas Jefferson National Accelerator Facility for the U.S. Department of Energy under Contract No. DE-AC05-06OR23177.

