Deep Vision-Based Framework for Coastal Flood Prediction Under Climate Change Impacts and Shoreline Adaptations

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Introduction

Coastal areas are home to more than half of the world's population, yet they also face increasing risks of flooding due to global warming and its consequences, such as sea level rise (SLR). To assess these risks and inform adaptation measures, coastal engineers require predictive models capable of producing detailed flood depth maps while factoring in future climate change-induced effects and shoreline armoring scenarios. Traditional physics-based hydrodynamic simulators, although highly accurate, impose **excessive computational burdens**. Supervised DL techniques offer immense potential for creating data-driven surrogates that are orders of magnitude faster, however, training of such models typically demands **large amounts of annotated samples**, hence numerous time-consuming hydrodynamic simulations. In this paper:

- We present a systematic pipeline for training performant and scalable DL-based coastal flood prediction models **in low-data settings**.
- Additionally, we introduce a deep Convolutional Neural Network (CNN) architecture, termed **CASPIAN**, designed specifically for climate adaptation-aware coastal flood prediction problem.
- Lastly, we round up the contributions by providing a carefully curated database of synthetic flood deps maps of Abu Dhabi's coast. The provided dataset, to the best of our knowledge, is the **first of its kind**, and thus can serve as a benchmark.

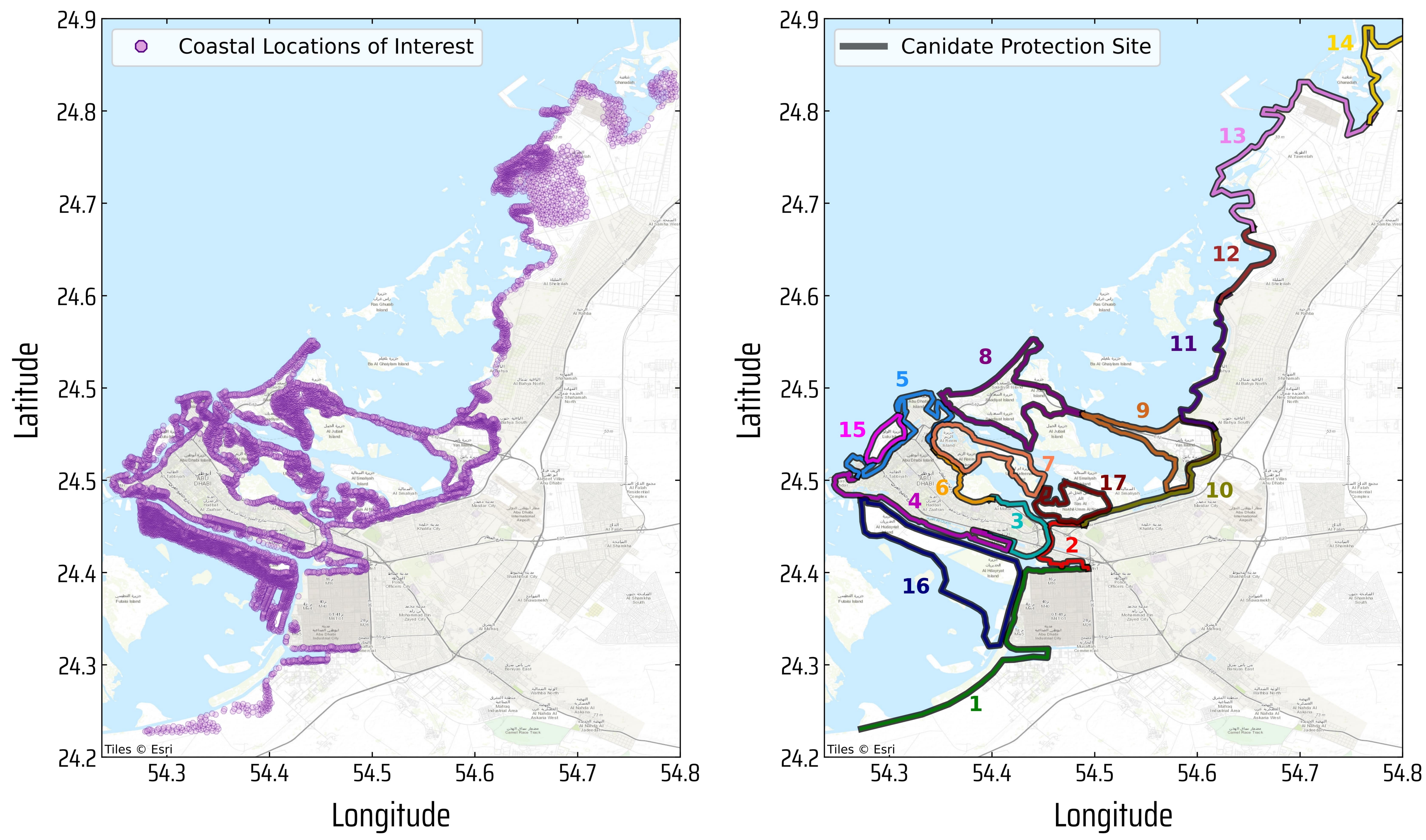
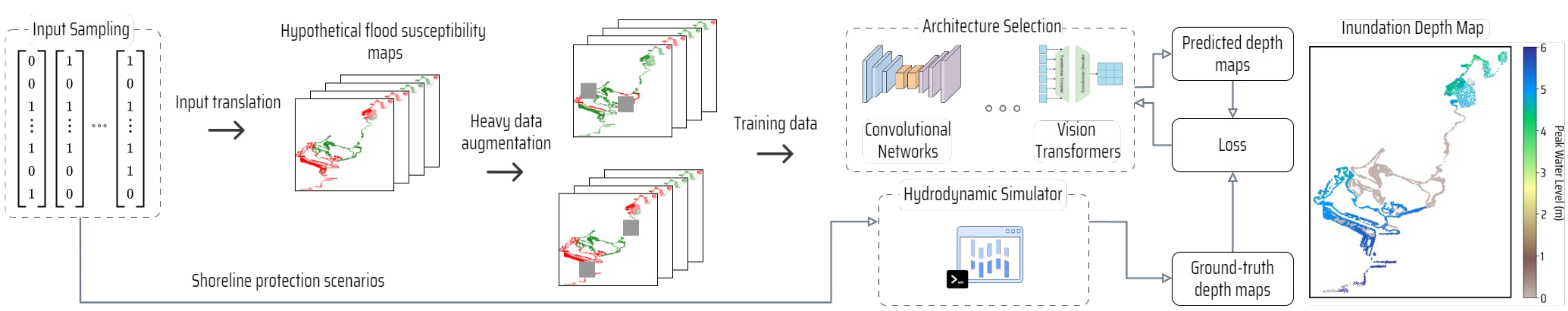


Figure 1. Studied coastal area of Abu Dhabi. (A) Nearshore locations susceptible to flooding under a 0.5 m SLR scenario without any shoreline protection. (B) Candidate coastal segments considered for installation of seawalls.

Proposed Framework

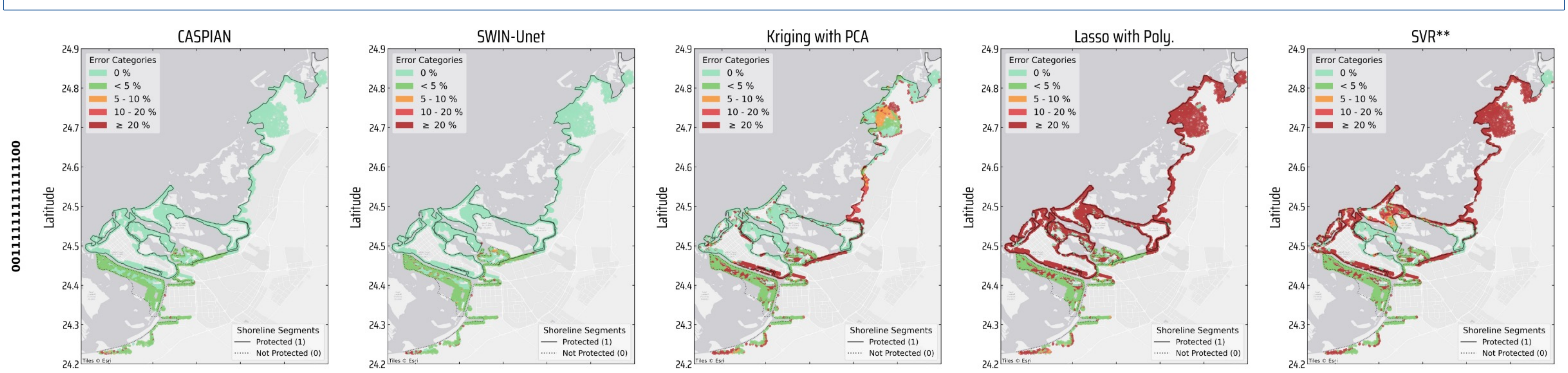
The workflow of the proposed vision-based surrogate modeling framework, visualized in below figure, can be dissected into four parts: (1) Sampling of protection scenarios for training data generation; (2) Remodeling of 1D inputs and outputs into **computationally-conducive** image-like representations; (3) Extensive **data augmentation**; (4) Neural network selection and training of the surrogate costal flood prediction model**.**

We evaluate the proposed framework on two existing vision models, SWIN-Unet and Attention U-net (originally designed for medical imaging tasks), thereby demonstrating the **generality** of the proposed approach. Additionally, to cater to resource-constrained scenarios and accessibility aspects, we introduce **CASPIAN**, a minimalistic CNN model designed specifically for **climate adaptation-aware** coastal flood prediction.



Results

The models were assessed considering **6 different metrics**, including both error and accuracy measures. The comparison results reveal significant gains in predictive performance, with improvements from the proposed DL-based models ranging from **100% to 400% across key metrics**. The best-performing model, **CASPIAN**, approached remarkably close to the results to the physics-based hydrodynamic simulator, effectively reducing the computational cost of producing a flood depth map from **days to milliseconds**.



Resources

Codebase: https://github.com/Arnukk/CASPIAN

Dataset: https://doi.org/10.7910/DVN/M9625R