# HaarUNet:

## A Novel Method to Accurately Simulate Turbulent Flow in Boiling Liquid

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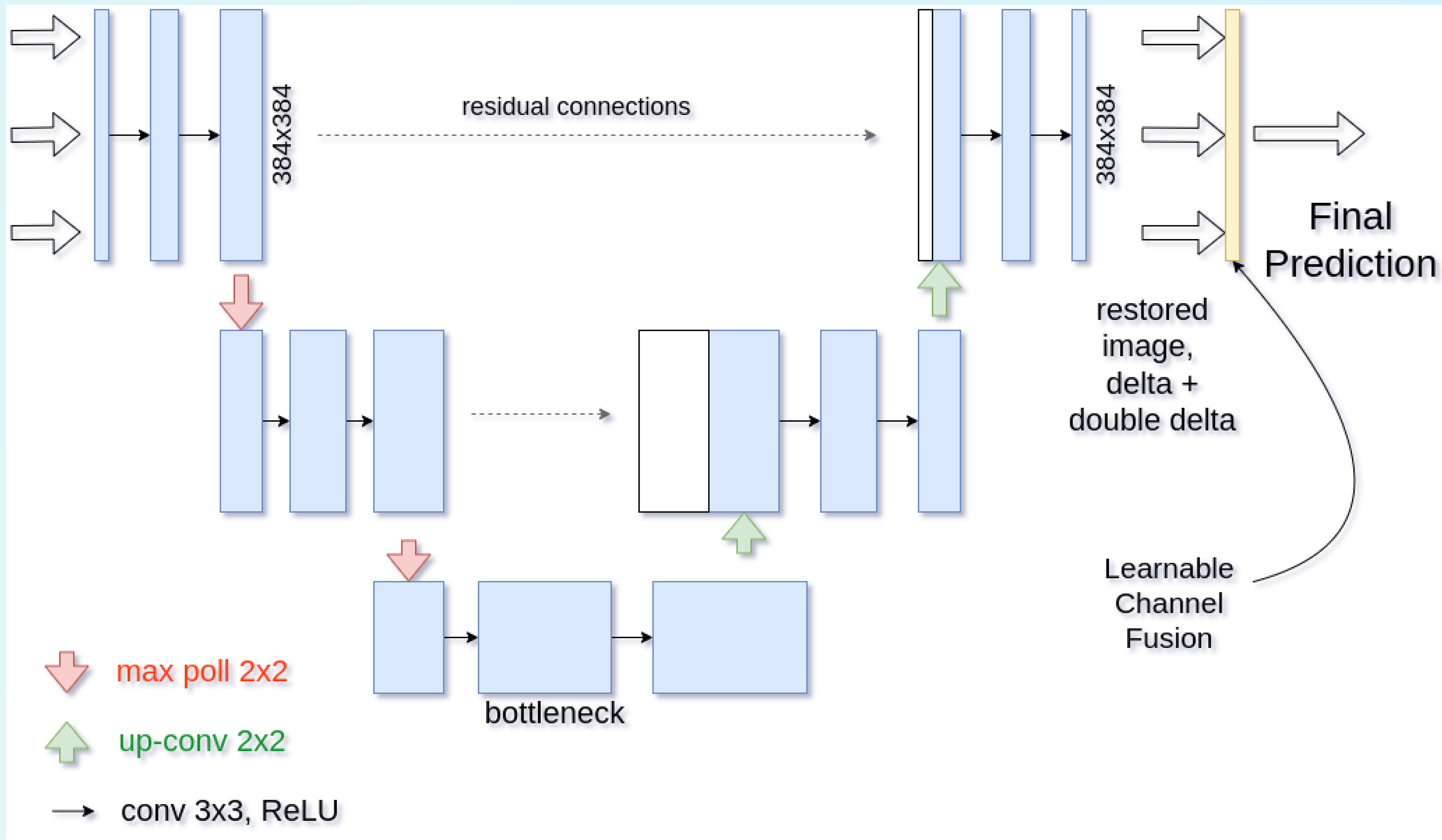
## Motivation

Most modern models (GNN, FNO, Unets) often struggle to capture the whole complexity of dynamics and sharp gradients inherent in certain physical systems, particularly those involving phase change phenomena like boiling.

Our design is inspired by success and accuracy of wavelet analysis in its application to image decomposition and synthesis. We decompose the original images into three components: a base image, delta images (representing details or changes relative to the base), and double-delta images (representing finer details or sharper transitions), which then fed into UNet model. The outputs are combined via learned weighting scheme into final prediction.

We are targeting systems with complex, quasi-chaotic dynamics.

## Model Structure

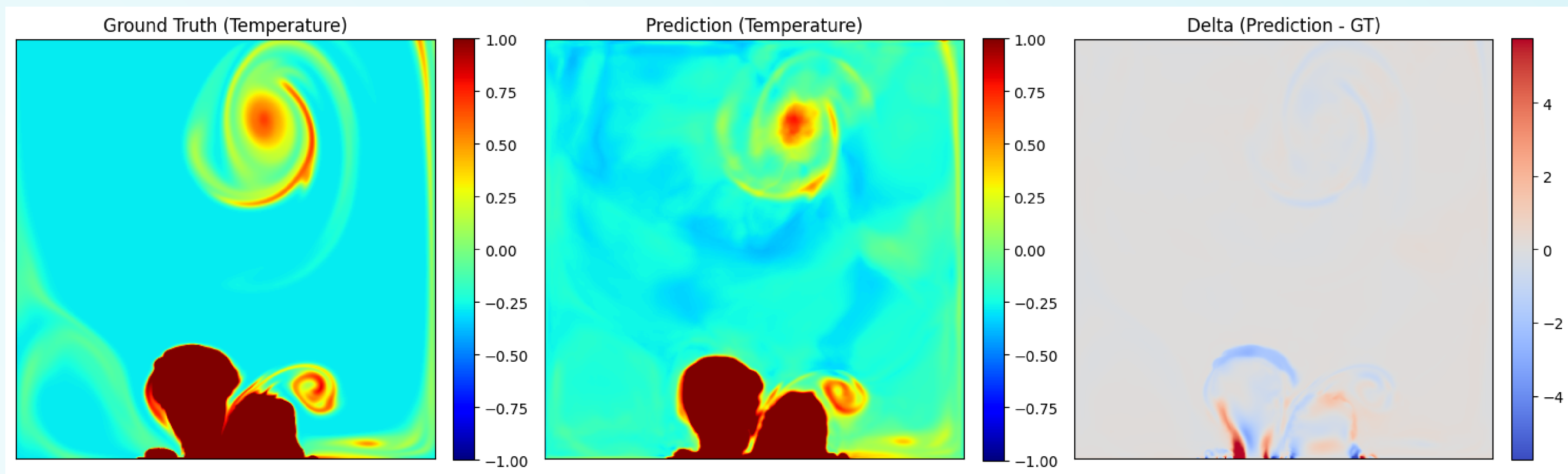



## Experimental Results

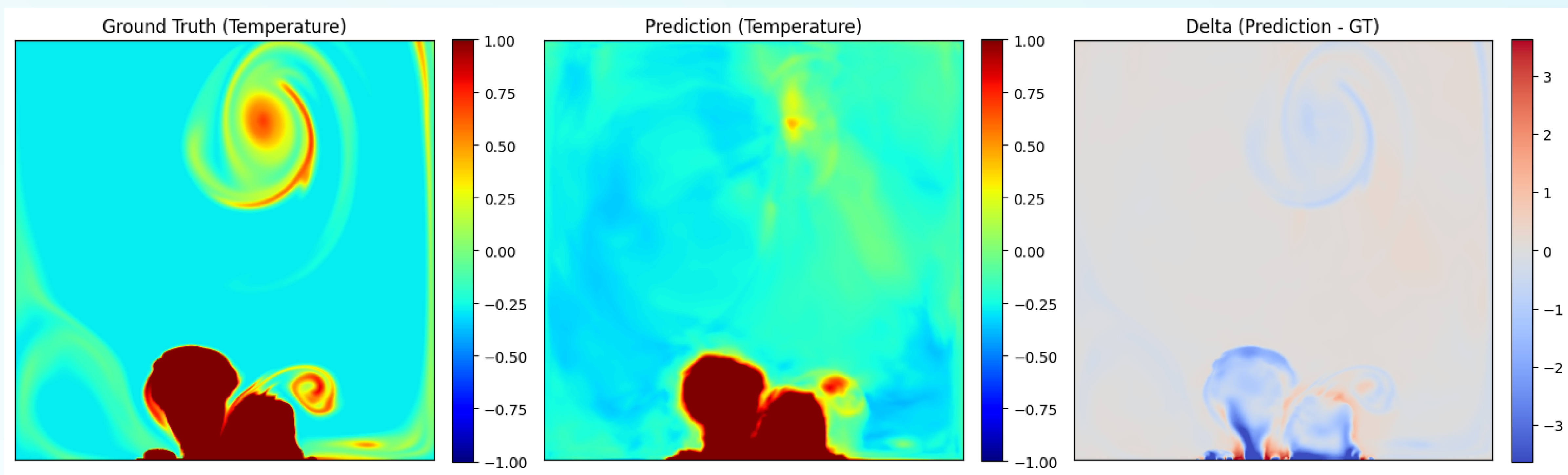
Preliminary results show an improvement in accuracy prediction for the task of Subcooled Pool Boiling.

Ground truth and prediction for frame #140 in the Twall-100 dataset.

**Model: HaarUNet (UNet-4 + deltas + double deltas)**

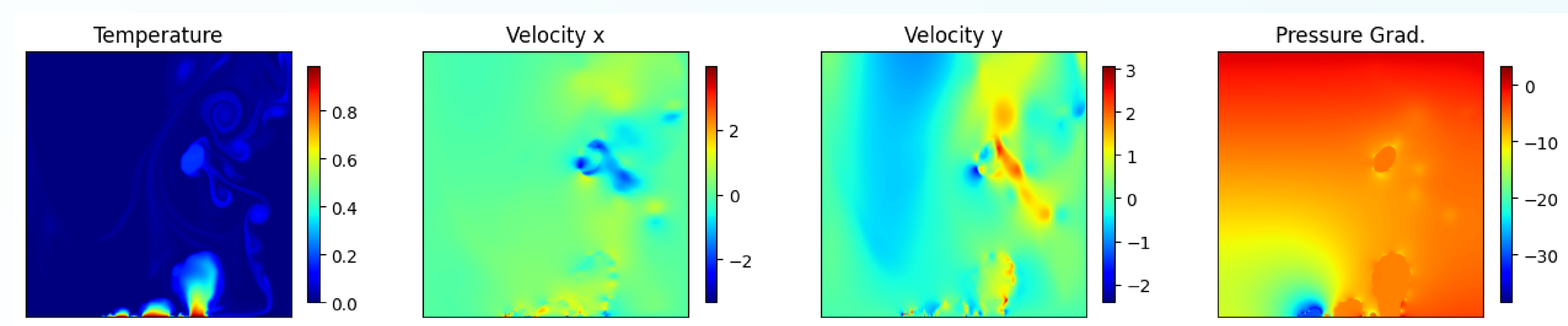



**Model: Unet-4 (baseline)**




## Methodology and Data

We are using datasets from BubbleML project[1], specifically dataset #3: Pool Boiling Subcooled. This dataset comprises 10 time series, each with 200 steps, and represents the boiling phenomenon. We generate delta and double delta images to prepare the data for training.




[1] https://github.com/HPCForge/BubbleML

## Conclusion

In this work, we have demonstrated a novel technique to improve turbulent quasi-chaotic simulation, contributing to advancements in the broader field of Scientific Machine Learning (SciML).

Further generalization of this method using more sophisticated decomposition techniques, such as POD or PCA, holds promising potential.