Lake Water Temperature Modeling Using Physics-Informed Neural Networks

Trieu H. Vo[1] Cuong V. Nguyen[2]
Dongsheng Luo[1] Leonardo Bobadilla[1]

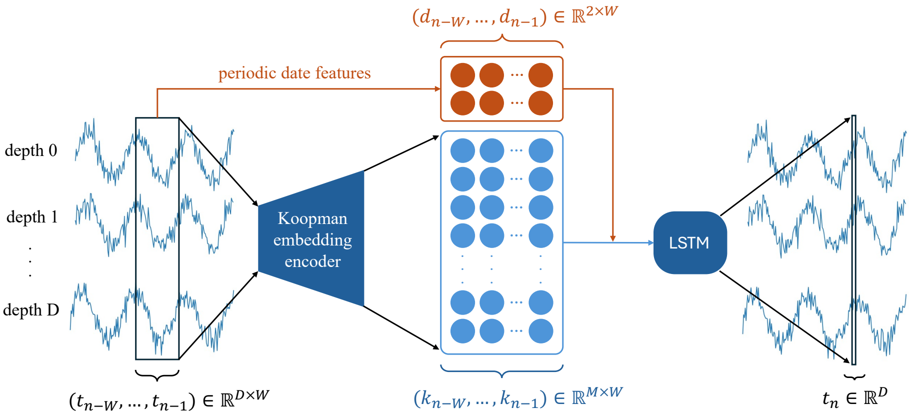
[1]Knight Foundation School of Computing and Information Sciences
Florida International University, USA

[2]Department of Mathematical Sciences
Durham University, UK

Introduction

- Water quality reflects climate and human impacts—key indices include temperature, pH, and oxygen levels.
- In-situ monitoring is accurate but costly, slow, and spatially limited.
- We develop water temperature forecasting models using in-situ and simulated data.
- Methods include physics-informed neural networks, Koopman embeddings, and LSTM.
- Our model outperforms standard LSTM in long-term forecasting.
- **Long-term goal**: efficient forecasting of water quality indices to support water management.

Physics-Informed Neural Networks



Koopman Embedding Encoder

- The Koopman embedding encoder is part of an encoder-decoder neural network.
- It maps physical states (multi-depth lake temperatures) into high-dimensional embeddings for deep learning.
- Uses the Koopman operator to linearize nonlinear dynamics.
- Only the encoder is used in our physics-informed LSTM model.

Experiment

- Used daily records (1980–2019) from a U.S. lake (Willard et al., 2021).
- Temperature data generated using the PB0 model from meteorological and lake attributes.
- Data split: 32 years training, 4 years validation, 4 years testing.
- Loss combines reconstruction, Koopman dynamics, and a decay term.
- Frozen Koopman encoder is used to train LSTM.
- First 4 days' temperatures used as seed for predictions on test series.

Results

- Baseline: LSTM without Koopman embeddings.
- Compare both models using test MSEs on 3 depth levels.
- Our method outperforms the baseline, with 70% MSE improvement.

Depth (m)	LSTM (baseline)	LSTM+Koopman (ours)
0	36.306	11.120
1	35.871	10.890
2	34.869	10.390
Overall	35.682	10.800