The Cyber to Real World Integrated Testbed for Dam Safety Management and Water Governance System

Speaker : Asst. Prof. Dr. Somsanouk PATHOUMVANH

Institution : National University of Laos

Background : The Challenge of Dam Safety in a Changing Climate

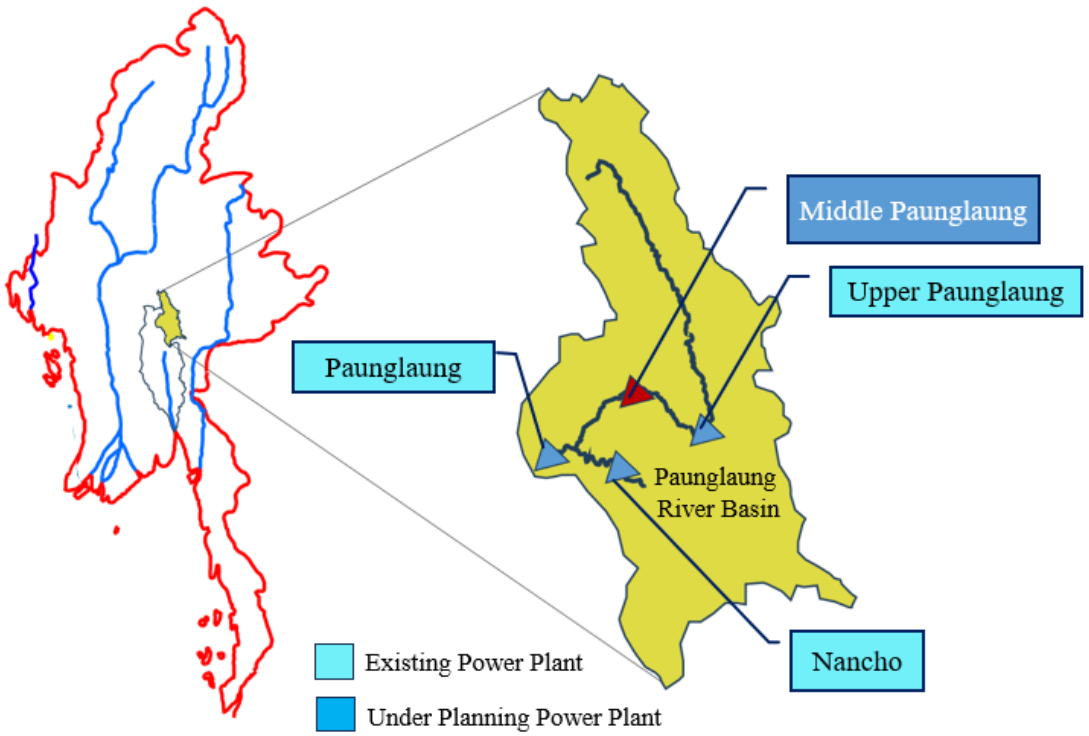
- Hydrological risk is a major concern during the operation of dams.
- Extreme weather events and climate change increase the risk of dam overtopping and structural failure.
- Effective flood control and management are crucial to ensure dam safety and mitigate impacts on downstream communities

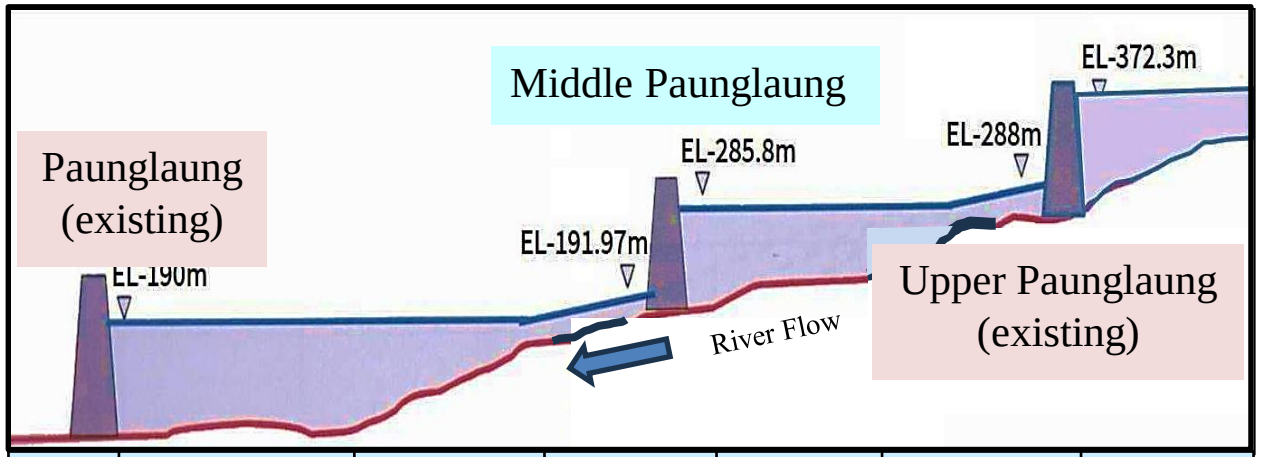
Breach in Xe Pian Dam Laos in 2018
https://hobomaps.com/XePianXeNamnoyDamsInfo.html

Targets: Building a Smarter Dams and Water Governance

- Our target is a "Cyber to Real World Integrated Testbed" to enhance dam safety and water governance.
- This platform will integrate physical infrastructure with advanced digital technologies.
- The goal is to move from reactive management to proactive, predictive decision-making.

Background : The Challenge of Dam Safety in a geographic positions



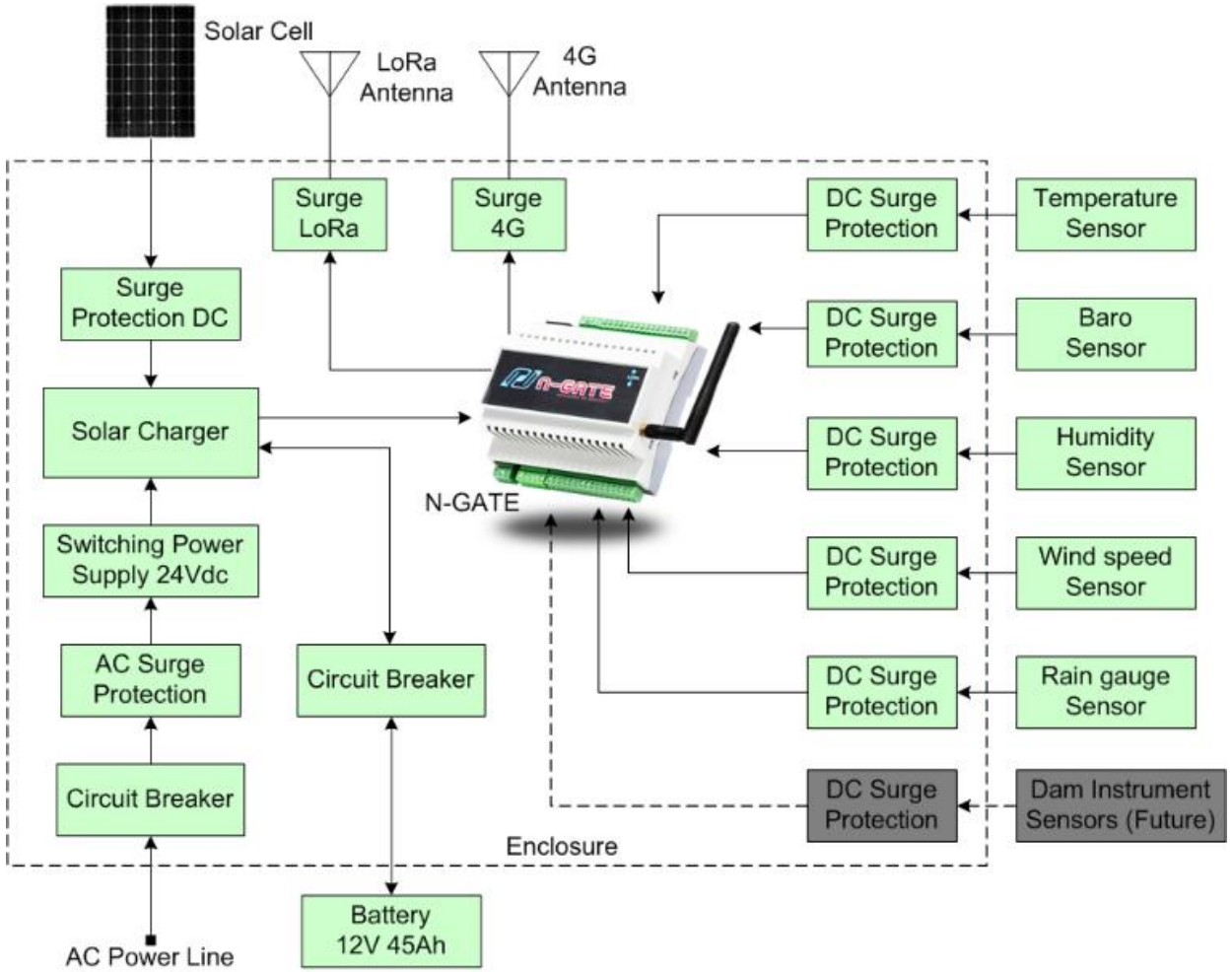


No.	Projects	Installed Capacity (MW)	Average Annual Energy (GWh)	Dam Height(ft)	Gross Storage Capacity (10^5Ac-ft)	Remarks
1	Paunglaung	280	911	430	5.49	2004
2	Upper Paunglaung	140	454	322	10.42	2014
3	Middle Paunglaung	166	592	355	1.43 (176) Mm^3	Under Planning

The Paunglaung River Basin contains multiple hydropower facilities, Cascade Hydropower model in Paunglaung River are needed to have good water Governance platform

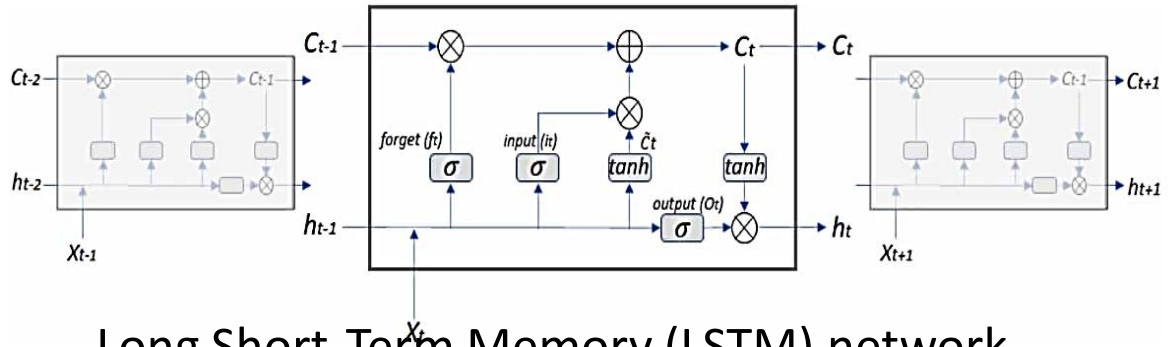
Proposed Method: IoT Based Data collection

- To perform emulation on the CyReal testbed of NICT, access to real-world environmental data is crucial.
- The meteorological parameters around the reservoir area at dam sites are required for inflow forecasting, this project will implement in Laos and Thailand first.
- In the case of Thailand, these data are collected by the existing Dam Safety Remote Monitoring System (DS-RMS). However, the DS-RMS is a closed system owned by EGAT
- For the case of Lao PDR, there are currently no meteorological sensors or data available at the target dams. Therefore, the new system is essential.

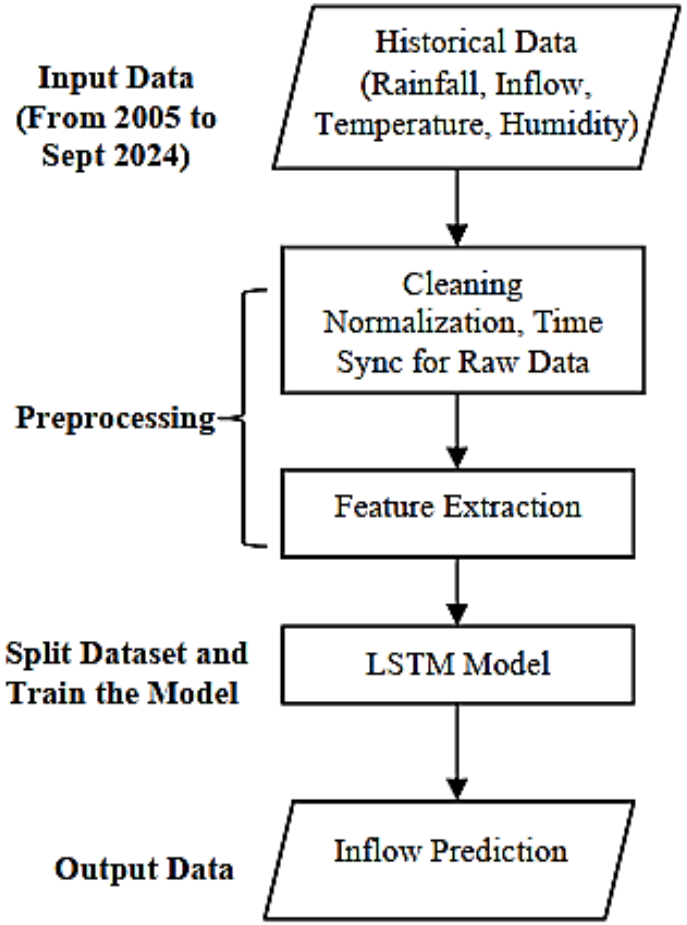


Proposed Method: A Data-driven Machine Learning Approach for Reservoir Water Level Forecasting

- Long Short-Term Memory (LSTM) network, a type of AI, for forecasting.
- The model uses long-term historical data from the Ubol Ratana dam in Thailand and Paunglaung Dam in Myanmar.
- The goal is to provide accurate 5, 10, and 15-day forecasts to improve dam safety.



Long Short-Term Memory (LSTM) network



Proposed Method: The Cyber to Real for Dam Safety

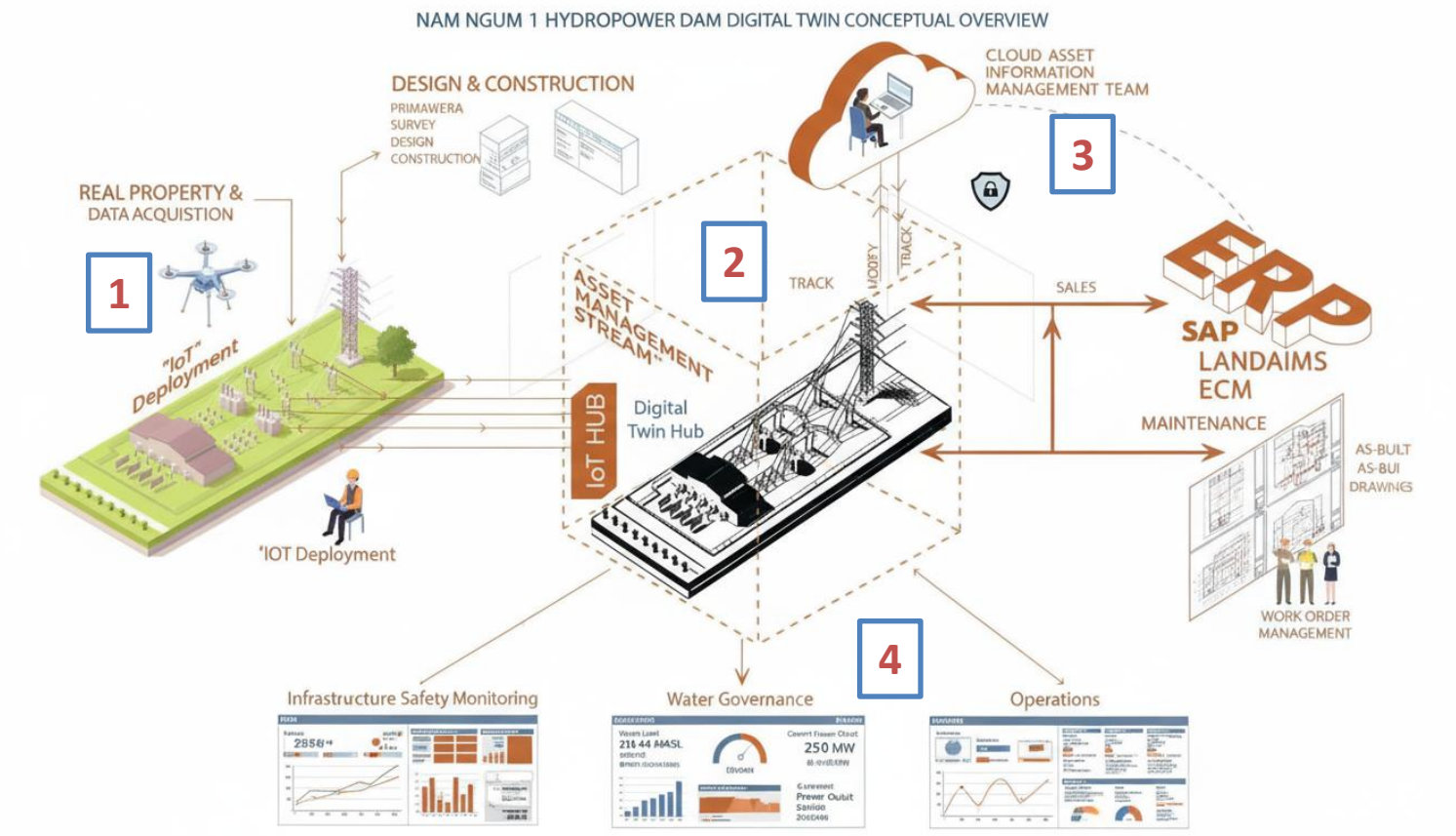
Cyber to Real or Digital Twin for Dam safety

- A digital twin is a virtual representation of a physical object, system, or process.
- It is created using real-time data from sensors and can simulate, analyze, and predict the behavior of the real entity.
- Digital twins can optimize operations, perform predictive maintenance, and test scenarios in a virtual environment.

Proposed Method: The Cyber to Real for Dam Safety

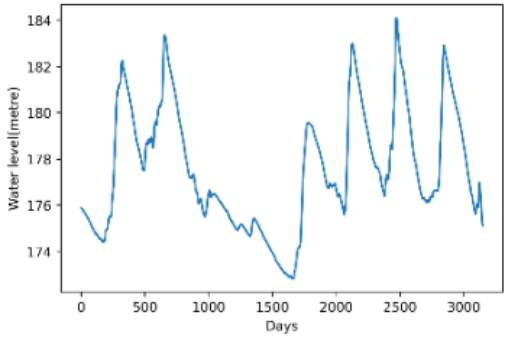
A Modular and Scalable System

1. **Data Acquisition Layer**: Gathers real-time data from sensors.
2. **Digital Twin Layer**: The core modeling and data processing component.
3. **Simulation/Emulation Layer**: Runs models to predict behavior and test scenarios.
4. **Visualization Layer**: Provides a user-friendly interface for monitoring and control.

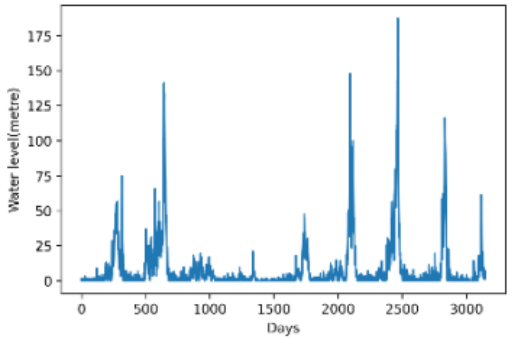


Impact: Prove Concept Data Collection

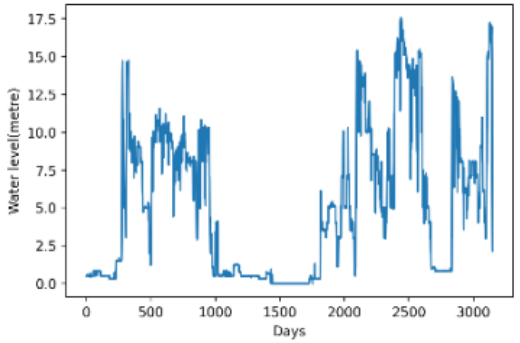
- The first experiment uses **long-term historical data** collected by the DS-RMS (Dam Safety Remote Monitoring System) in Thailand, specifically for the Ubol Ratana dam.
- The goal is to provide **accurate, long-term forecasts** (5, 10, and 15 days) to enhance water resource management
- The core component is the LSTM unit, which has three gates to control information flow (forget, input, and output gates), allowing it to retain important sequences and forget irrelevant data.
- The model was built using TensorFlow and Keras libraries in Python.



(a) Reservoir Water Level



(b) Inflow



(c) Outflow

Impact: Prove Concept Data Cleaning & Preprocessing

- **Data Source:** Reservoir Water Level (RWL) and environmental parameters (like rainfall) are collected every 4 hours by the Remote Terminal Unit (RTU) and stored in the DS-RMS database.
- **Dataset:** A total of 3,090 days of data from the Ubol Ratana dam was used.
- **Preprocessing:** The daily mean value was determined from the collected records, which can vary due to operator checks or RTU outages.
- **Training/Testing:** The dataset was split into 70% for training and 30% for testing.
- **Tuned Parameters:** Optimal settings: 100 epochs, 50 LSTM units, 15 backstep, and 25 batch size.

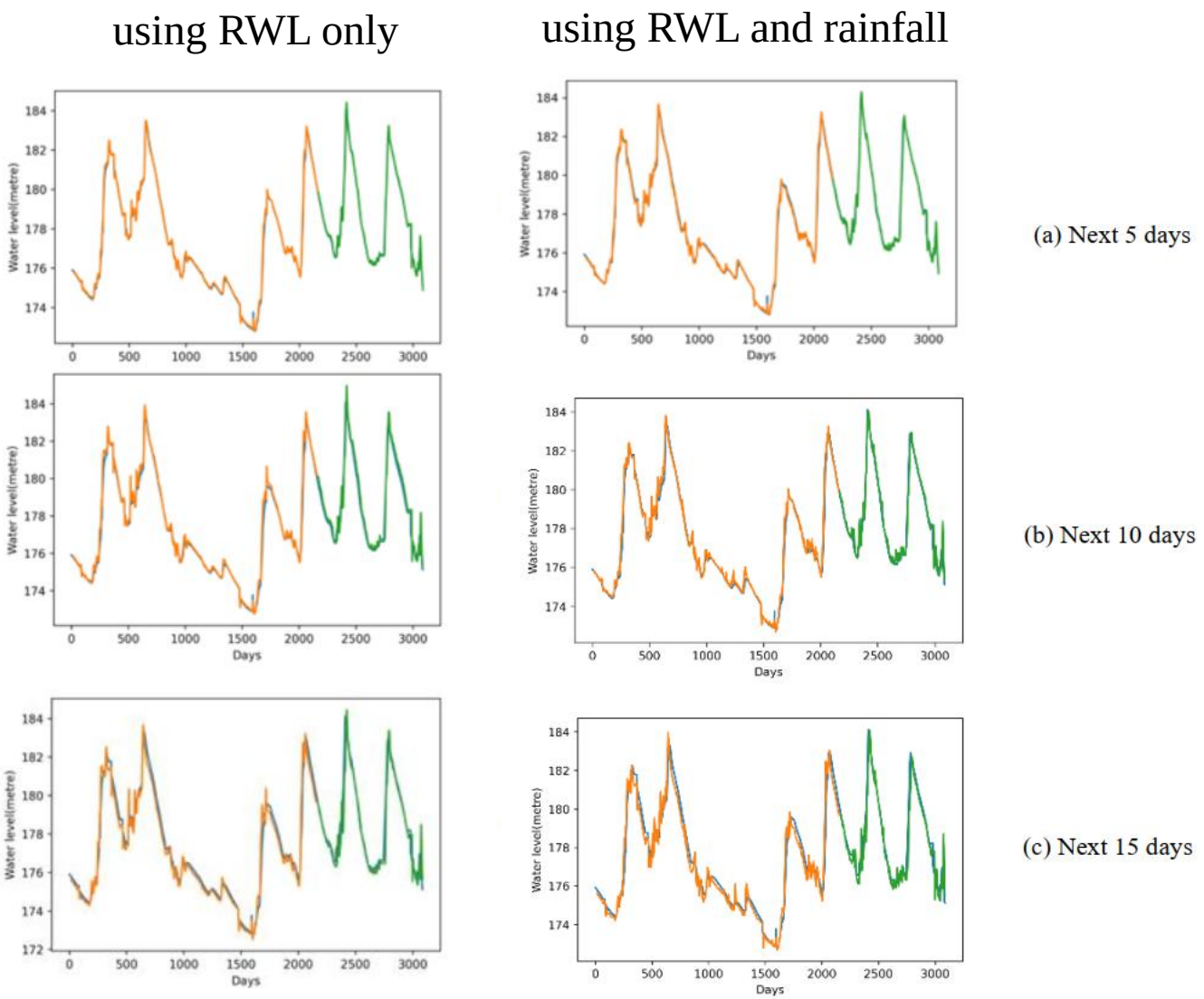


Fig 1. Plots of forecasted RWL compared to actual RWL

Output/Outcome: our Publication

[1] Zin May Oo, Thin Lai Lai Thein, Kanokvate Tungpimolrut, Somsanouk Pathoumvanh, Nay Win Aung, Ly Rottana, Toshiyuki Miyachi, Jennifer C. Dela Cruz, Cheab Sovuthy, "**Inflow Prediction of Lower Paunglaung Dam for Water Resource Management", ICCA 2025.**

[2] Zin May Oo, Thin Lai Lai Thein**, "IoT-Enabled Wireless Sensor Network for Dam Safety Management", ICCA 2025.**

[3] Seubsuang Kachapornkul, Rangsarit Vanijjirattikhan, Jittiwut Suwatthikul, Kanokvate Tungpimolrut and Toshiyuki, Miyachi, **"A Data-driven Machine Learning Approach for Reservoir Water Level Forecasting", ICCAI 2025**

Output/Outcome: Cyber to Real World Integrated Testbed for Dam Safety Symposium in Luangprabang

- **Objective #1:** To share information and knowledge about this collaborative project with representatives of dam operators in Lao PDR, and to reconfirm the requirements of local partners as well as how they could effectively use the outputs/outcomes of this project.

- **Objective #2:** To visit the Namkham 3 Dam sites in order to observe the actual system in a real environment, and to reconfirm how to perform simulations and/or emulations on the CyReal Testbed. Weather station for Data collection, data analytic, prediction of water in-flow and water level control

Output/Outcome: Cyber to Real World Integrated Testbed for Dam Safety Symposium in Khon Kean

- **Output #1:** To demonstrate the project's findings to the end users dam operators in Thailand and Lao PDR engage in discussions and gather feedback for further development.
- **Output #2:** To share progress updates from NICT and other project members, engage in discussions, provide mutual feedback, and explore potential solutions within the scope of the project.
- **Output #3:**To observe the real system in operation at Ubol Ratana Dam, engage with the dam's representatives who will use the developed system, and clarify specific requirements and concerns.

Output/Outcome: Project Development Timeline

Building the Foundation

1. **Jan 2025-Now:** Data Collection and Sensor Integration. (Completed)
2. **April 2025-Now:** Digital Twin Model Development for a key component (e.g., spillway gates) Using Blender 4.2.2. or LiDar Scanner (On-Going)
3. **March 2026 - May 2026:** Real-time Data Stream Integration and Platform Prototyping. (Future Plan)

Conclusion and Future Plan:

- **IoT based Data Collection** and Sensor Integration is proved the concept and ready to install
- The **LSTM network** successfully provided accurate and crucial long-term RWL forecasts for proper dam operation.

- **Future research** will focus on utilizing more meteorological parameters around the reservoir area at dam sites for inflow forecasting and **more environmental parameters** to further improve the forecasting performance.
- **3D Digital Twin Model as Cyber domain is** under development and Real-time Data Stream Integration, Simulation/Emulation and Platform Prototyping is expect to complete by April 2026