Marion Reservoir CyanoHAB Website Project

By

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1: Introduction

1.1 Background

Located in the Flint Hills region of Kansas, Marion Reservoir is a large ($24.9km^2$) and shallow (mean depth = 3.4m) reservoir managed by the United States Army Corp of Engineers (figure 1). Built in 1968 on the North Cottonwood River, Marion reservoir is used for flood control, recreation, and drinking water supply for communities in Marion County, Kansas (Harris et al., 2024).

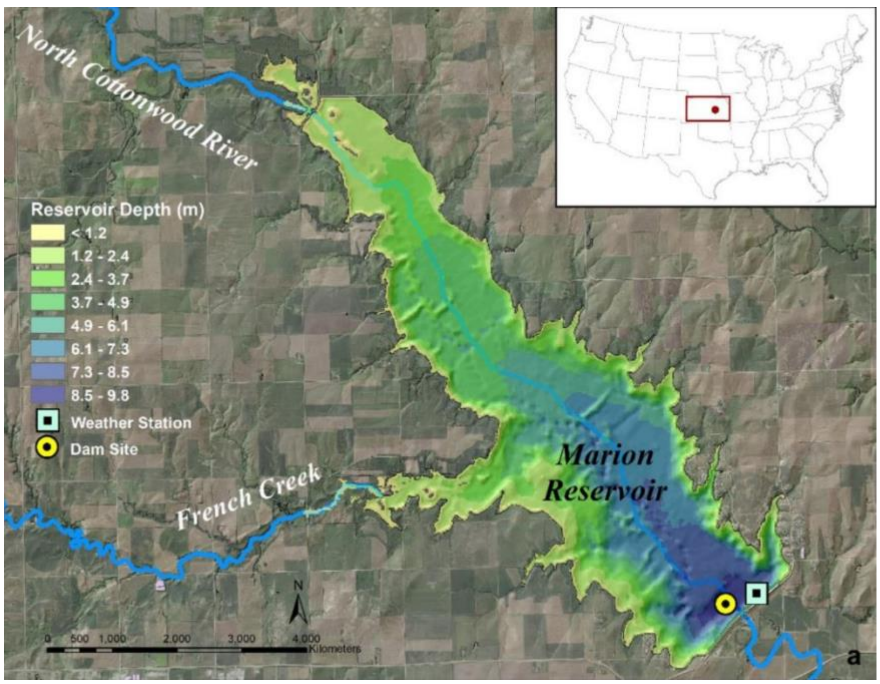

Figure 1 – Map of Marion Reservoir in Kansas showing bathymetric data, high-frequency buoy location (dam site), weather station operated by the U.S. Army Corp of Engineers (weather station), and inlet streams (French Creek and North Cottonwood River). Figure 3-1 from Hosseini (2023).

Marion Reservoir is categorized as a polymictic, eutrophic lake. The lake experiences multiple stratification events in a given year and has been loaded with nitrogen (N) and phosphorus (P) from the watershed. Hosseini (2023) found that CyanoHAB formation on Marion Reservoir is primarily driven by calm winds and strong thermal stratification. These conditions, when combined with the abundance of nutrients in the lake, favor buoyant cyanobacteria over other phytoplankton groups, causing their populations to bloom and dominate the water column.

Since 2003, Marion Reservoir has regularly experienced Cyanobacterial Harmful Algal Blooms (CyanoHABs) (T. Harris et al., 2023; Linkov et al., 2007). CyanoHAB occurrence greatly increases the cost of water treatment and can pose a threat to human health, which puts pressure on local water resource management. Thus, the need to model and forecast the occurrence of CyanoHABs exists.

1.2 Project Objective

The project aggregates several data sources into a publicly available website that displays current and historical conditions at Marion Reservoir. A high-frequency buoy was deployed near Marion Reservoir dam in Spring 2024. The buoy records real-time data and pushes the data to a website operated by NexSens Technologies, Inc. Data from this website is pushed to the KU computational hydrology lab's sever via an FTP/SFTP protocol every night. The U.S. Army Corp of Engineers operates a weather station on Marion Reservoir. Data from this weather station is published on their website and is publicly available. A web-scraping script is run every night to scrape data onto the server.

Once data is collected on the server, a script uses two R packages to analyze lake dynamics of Marion Reservoir. The R package rLakeAnalyzer (Winslow, et al., 2018) is used to generate heat maps and Lake Number from buoy data. The R package GLM 3.0 (Hipsey et al., 2019) is used to model heat maps and Lake Number from USACE data. Wind speed from both data sources is also plotted.

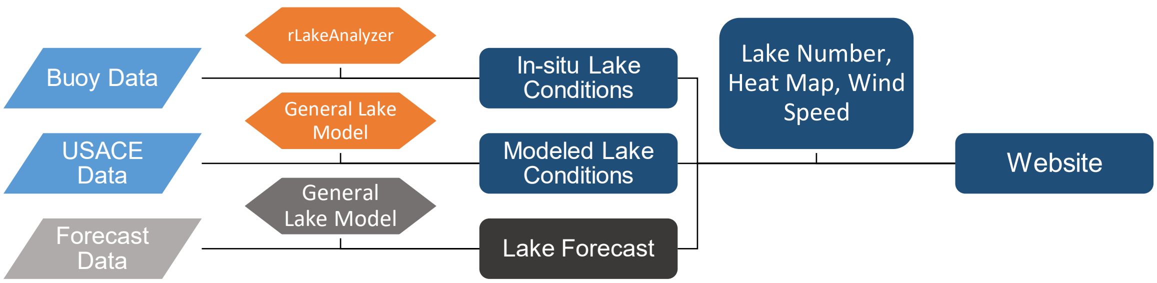

Figure 2 – Data flow from the buoy and USACE website are processed by lake dynamic R packages "rLakeAnalyzer" and "General Lake Model 3.0". Once data is processed, plots of Lake Number, water column temperature, and wind speed are generated and uploaded to the custom website. When forecasting is added, it will follow the framework above.

Once plots are generated, they are uploaded to a custom website. This website has four pages: a home page, a page displaying current conditions, a page displaying historical conditions, and a page for forecasting. Plots are generated nightly for the previous day and are displayed on the current conditions page. Previous days' plots are stored in the historical conditions page and can be accessed by users. The forecasting page will display plots from the forecast when it is active.

2: Datasets & Methods

2.1 Real-Time Buoy Data

A high-frequency buoy was deployed on Marion Reservoir near the dam on March 20, 2024 (figure 3). The buoy is a CB-150 data buoy developed by NexSens Technology, Inc. and can provide real-time water quality parameters at the site. The buoy transmits hourly data to a website operated by NexSens Technology, Inc. From this website, the data is routed to the Computational Hydrology lab group's servers at KU through a File Transfer Protocol (FTP).

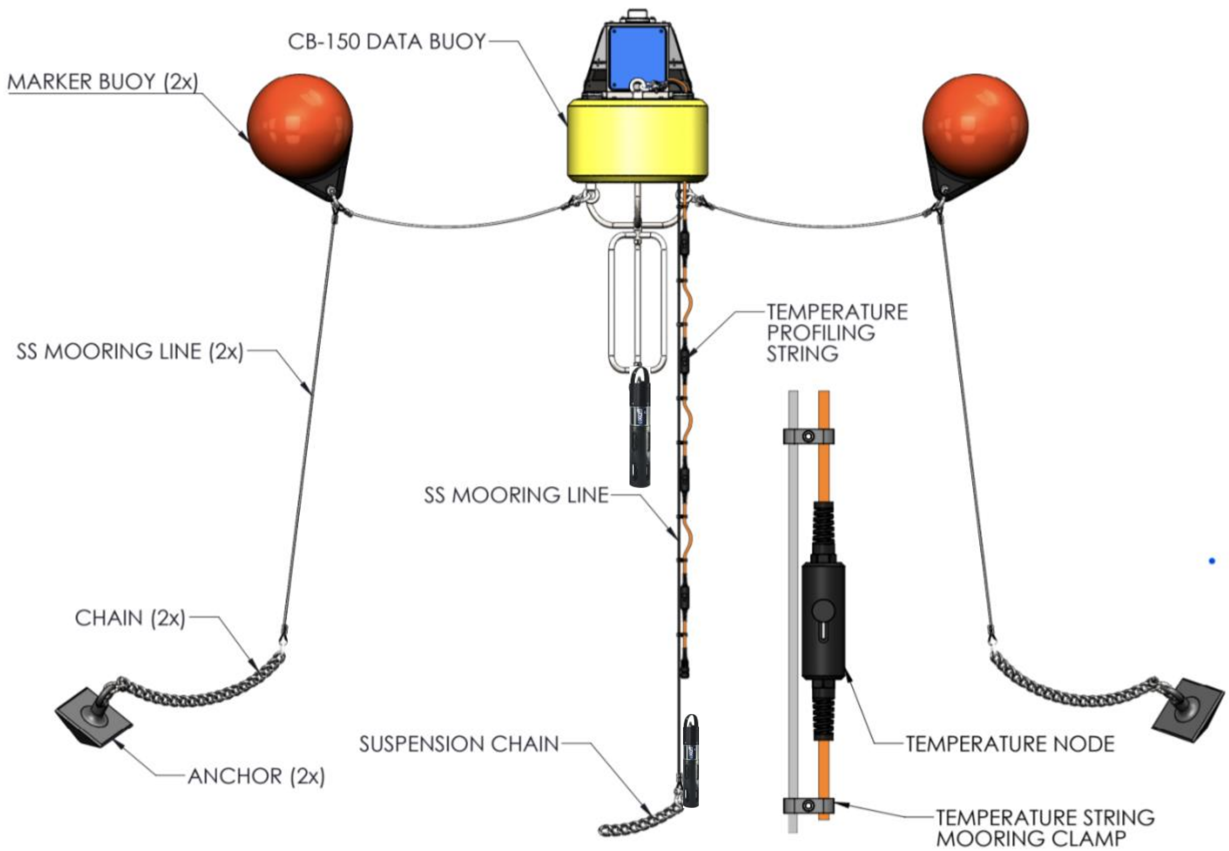

Figure 3 – Schematic of the high-frequency buoy deployed at the dam site. YSI EXO probes are placed at 1 and 6 meters, and temperature nodes are placed at 2, 3, 4, 5, and 6 meters. A weather station sits atop the buoy to record meteorological forcing data.

Data is collected from 2 YSI EXO 3s water quality probes located at 1 and 6 meters, from temperature nodes at 2, 3, 4, 5, and 6 meters, and from a weather station on top of the buoy. The YSI probes provide temperature, dissolved oxygen (DO), pH, oxygen-reduction potential (ORP), organic dissolved oxygen (ODO), conductivity, turbidity, chlorophyll, and blue green algae (BGA). The temperature probes provide water temperature, and the weather station provides barometric pressure, air temperature, relative humidity, wind direction, and wind speed.

2.2 Meteorological, Inflow, and Outflow Data

The United States Army Corp of Engineers (USACE) collects data for Marion Reservoir at daily and hourly intervals. This data is hosted online by the USACE and is publicly available. Hourly data is available from January 1st, 2021, to present, and contains meteorological and hydrological information (table 1).

Table 1 – The parameters collected by the USACE at Marion Reservoir and their corresponding input files for the General Lake Model.

USACE Data	**General Lake Model Input Files**		
	Meteorological File	Inflow File	Outflow File
Datetime	X	X	X
Precipitation (in.)	X		
Elevation (ft.)			
Storage (ac-ft.)			
Inflow (cfs)		X	
Release (cfs)			X
Air Temperature (F)	X		
Wind Speed (mph)	X		
Relative Humidity (%)	X		
Solar Radiation (W/m^2)	X		

The General Lake Model (GLM) requires three csv files containing hourly data for the lake. These three files contain the inflow, outflow, and meteorological conditions of Marion Reservoir. To extract this information and put it in a file format that the GLM will accept, a python script was created. The python script utilizes the BeautifulSoup and Numpy libraries. The BeautifulSoup library is an HTML parsing library that allows data scraping from HTML sources (Richardson, 2007). The script extracts the raw data from the USACE website containing the hourly conditions for the following variables: datetime (mm/dd hh:mm), precipitation (in), inflow (cfs), release (cfs), air temperature (F), wind speed (mph), relative humidity (%), and solar radiation (W/m^2).

The script creates all three files at once. The inflow file contains two columns, “datetime” and “FLOW”. The GLM requires the inflow column to be titled “FLOW” and has options for additional columns containing water quality data. The datetime column of all three files must be in “yy/mm/dd hh:mm:ss” format. These columns are populated with the data from the “datetime” and “inflow” columns from the USACE data. The outflow file contains two columns “datetime” and “outflow” and is populated with the data from the “datetime” and “outflow” columns of the USACE data.

The meteorological data file contains the columns “ShortWave”, “LongWave”, “AirTemp”, “RelHum”, “WindSpeed”, “Rain”, and “Snow”. Shortwave radiation, air temperature, relative humidity, wind speed, and rain were populated with data from the USACE website. Snow was set to 0 for the entire study period. Longwave radiation was estimated by using relative humidity and temperature following the methods of Brutsaert (1975) and Follum (2015). The longwave radiation estimation was compared to longwave radiation from the North American Land Data Assimilation System (NLDAS) for the period of May 18 to October 5, 2022 (figure 4).

The Spearman R correlation between NLDAS and estimated longwave radiation was 0.73, which indicates a strong positive correlation between both measurements of longwave radiation.

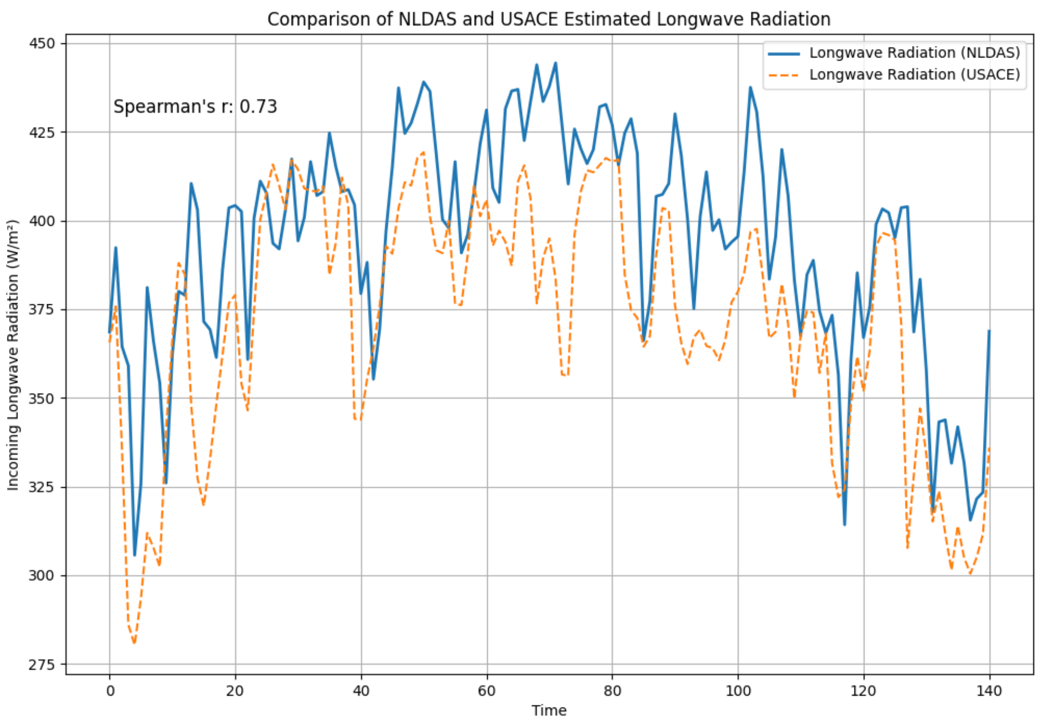

Figure 4 – The relationship between estimated longwave radiation from the USACE meteorological data, and longwave radiation from NLDAS from May 18 – October 5, 2022, at Marion Reservoir.

The GLM cannot process missing or NaN values, so missing data from the USACE data is filled in with ‘0’. Supporting examples from the GLM library follow this method, and the outputs of the GLM are on a daily scale, not hourly. This may create uncertainties in modeling results, but complete data outages are rare, and the in-situ data from the buoy is also available for end-users to compare.

2.3 General Lake Model

The General Lake Model (GLM) is a 1-dimensional open-source hydrodynamic model designed to simulate conditions at a wide variety of aquatic ecosystems including lakes, reservoirs, and wetlands (Hipsey et al., 2019). The GLM simplifies lake dynamics by using vertical approximation, where horizontal variability is ignored. It is capable of modeling water column temperatures and lake stratification.

(Hosseini, 2023) used the GLM to model the hydrodynamics of Marion Reservoir from 2021-2022. They performed automatic and manual calibration of the GLM using high frequency temperature data. Table 2 provides a summary of the GLM parameters used after calibration.

Table 2 – Description and calibrated values of General Lake Model parameters used in Hosseini (2023). Adapted from Table 4-1 (Hosseini, 2023).

Parameter	**Description**	**Model Value**
rain_factor	Scaling factor to adjust the rainfall	0.8
inflow_factor	Scaling factor that can be applied to adjust the provided input data	3.39
outflow_factor	Scaling factor that can be applied to adjust the provided input data	1.0
sw_factor	Scaling factor to adjust the shortwave radiation data	0.46
lw_factor	Scaling factor to adjust the longwave (or cloud)	1.35
wind_factor	Scaling factor to adjust the windspeed	1.30
kw	Light extinction coefficient (1/m)	0.88

3: Results

3.1 Website

A website was developed to provide real-time monitoring of conditions at Marion Reservoir. The website is divided into four main pages: a landing/home page for navigational purposes, a page showing current conditions at Marion Reservoir, a page showing the historical conditions at Marion Reservoir, and a page for when forecasting goes live.

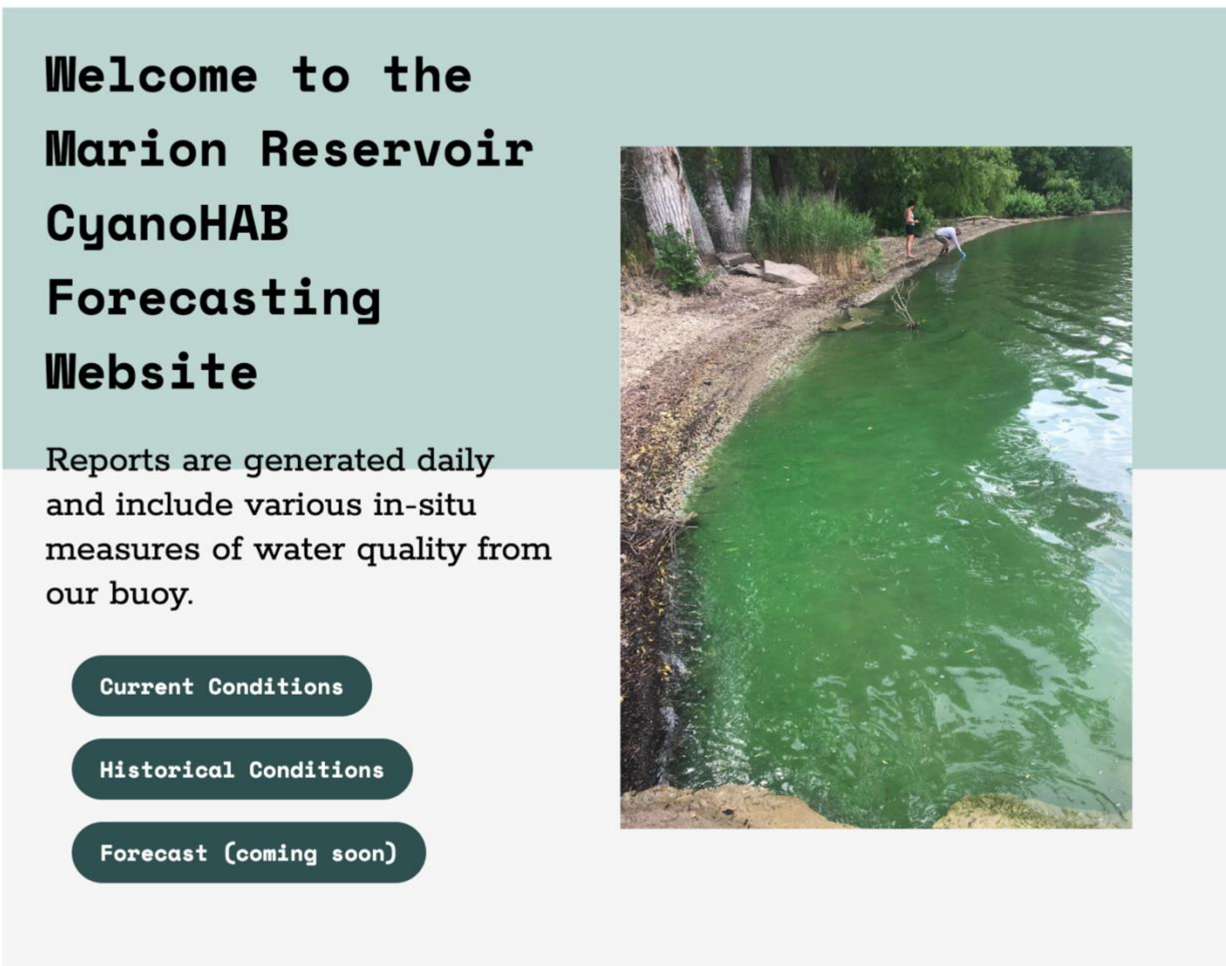

Figure 5 – Navigational section on the home page of the website. The three buttons allow users to navigate the website.

Figure 6 – The website header includes five buttons: A) the KU logo takes users to the KU website, B) takes users to the home page, C) takes users to the current conditions page, D) takes users to the historical conditions page, E) takes users to the forecast page.

Users are able to navigate to the different pages using the navigational section on the main page (figure 5) or the header (figure 6). From the header, clicking the KU logo will take users to the main KU website (www.ku.edu).

The current conditions page displays data from both the buoy and the GLM (figure 7). The two R-packages used in the project, rLakeAnalyzer and GLM3.0, are used to generate heat-maps and Lake Number graphs displayed on this page. Wind speed from both data sources, the buoy and the USACE, are also displayed. An information box is also included on this page to help users understand the source of the data.

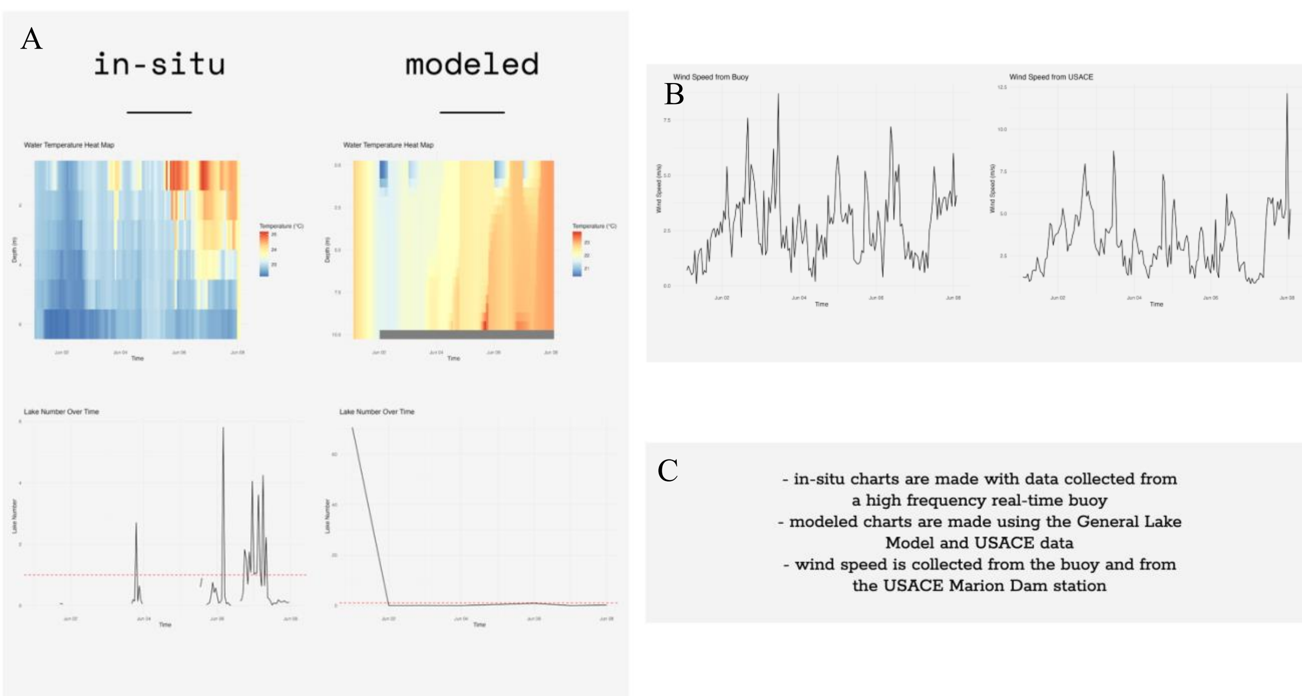

Figure 7 – The contents of the current conditions page contains three sections: A) contains two columns with in-situ and modeled water temperature heat maps and lake number, B) contains wind speed from the buoy and from the USACE station on Marion Dam, C) contains information about the graphs.

Graphs generated for previous days are available to view using the historical conditions page. This page contains the same information as the current conditions page but allows users to select the date they would like to view (figure 8). In addition to viewing data, users can also download the buoy data for their selected day in csv format.

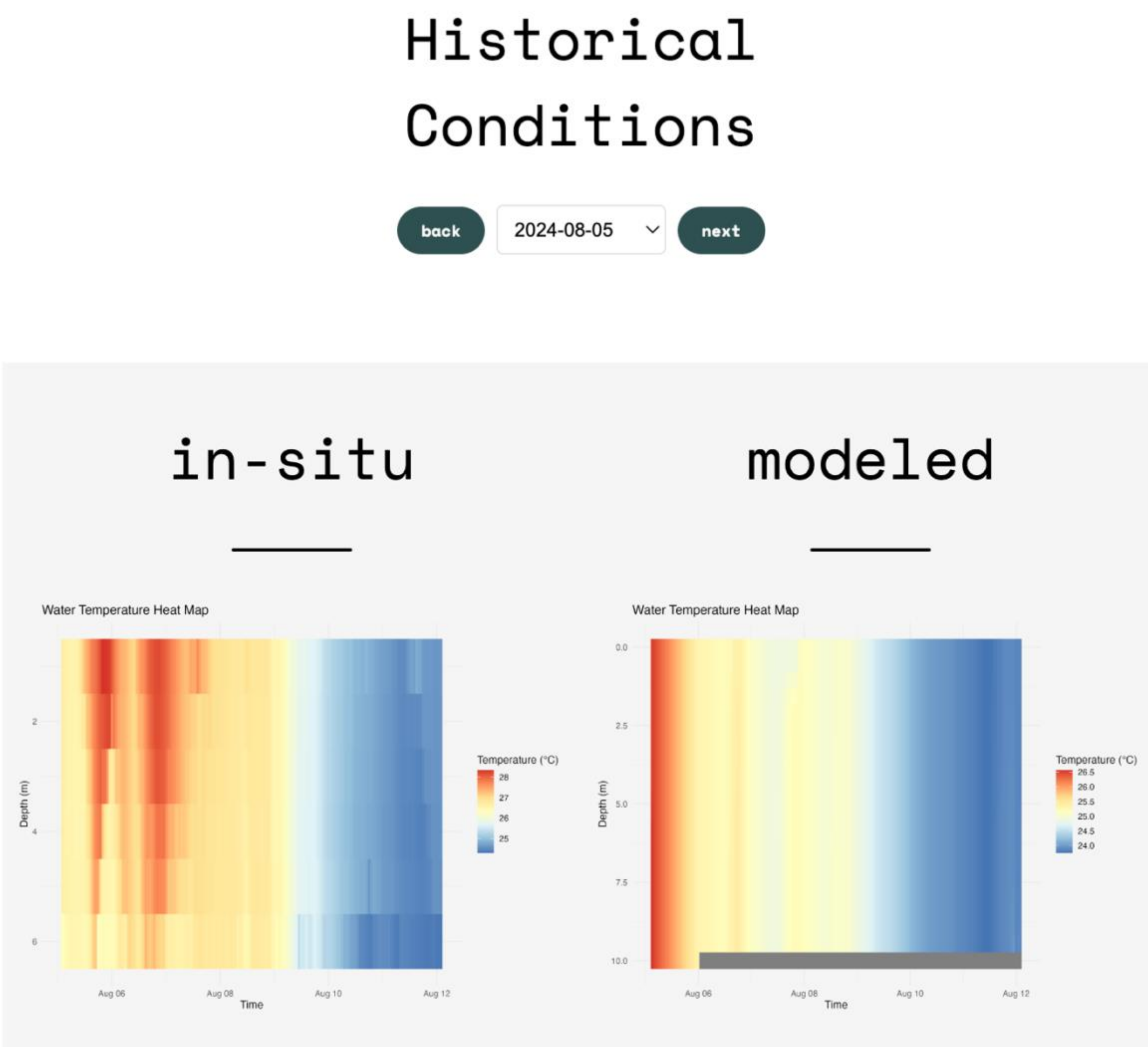

Figure 8 – The historical conditions page allows users to select dates for which graphs have already been generated. There is also an option to download the buoy data in csv format.

4. Future Work

4.1 Forecasting

Forecasting cyanobacterial harmful algal blooms (CyanoHABs) on Marion Reservoir has proved to be a difficult task. There were issues with routing data from the buoy and from the U.S. Army Corps of Engineers (USACE) to the servers at KU on a daily basis. After the data stream was complete, there were further issues with getting the General Lake Model (GLM) to run. Preparing the real-time data into an acceptable format for the GLM was a time-consuming task. Preparing the website for a public launch was also time-consuming. These issues have delayed the next step: near-term CyanoHAB forecasting on Marion Reservoir.

Near-term forecasting of lake hydrodynamics is an emerging field with promising results being published in the last five years. Thomas et al. (2020) successfully developed a framework, Forecasting Lake And Reservoir Ecosystems (FLARE), to forecast conditions at Falling Creek Reservoir, Virginia. Their project utilized the GLM to model and forecast the hydrodynamics of their study lake. The forecast data they used came from the National Oceanic and Atmospheric Administration Global Ensemble Forecasting System (NOAA GEFS). Following a similar approach to the Marion project, they downloaded forecasted meteorological drivers daily to use as the boundary conditions in the GLM. Their project differs from ours by incorporating errors and sources of uncertainty.

When forecasting is implemented for Marion Reservoir, the NOAA GEFS data would be a great source of forecasted boundary conditions for the GLM. This data would be implemented into the GLM in the same way the USACE data currently is. The forecasted heat map, Lake Number, and wind speed will be displayed on the website on its own web page. Users could access previous forecasts from the historical conditions page as well.

4.2 Scaling to Other Reservoirs

This project established a workflow for collecting data from a NexSens Technologies, Inc. buoy and the USACE website to model conditions in a reservoir. CyanoHAB occurrence is on the rise in Kansas lakes, but the ability to forecast blooms in these lakes has not been fully developed. Scaling this project to other reservoirs would allow stakeholders to monitor CyanoHAB development across multiple Kansas reservoirs from one website.

There are a few challenges to scaling this project across the state. The first is that CyanoHAB development in Marion Reservoir is largely driven by hydrodynamics. This may not be the case in other reservoirs as Marion is a uniquely large and shallow system in Kansas that is greatly impacted by wind. Therefore, modeling CyanoHABs elsewhere may require a different approach. The General Lake Model (GLM) was deemed suitable for Marion because it is adept at modeling lake stratification, however, water quality models may be better suited for other lakes. This brings up the second challenge, which is calibrating a model. The calibration of the GLM was accomplished by the work of a former student who spent many field days collecting data and many model iterations to reduce errors. If the project were scaled to other lakes, then models would need to be calibrated to each lake, which requires multiple periods of observation. The final challenge would be to deploy buoys on each lake that are able to transmit data wirelessly to KU. The buoy used in this study is available for purchase, and buying more buoys within this ecosystem would greatly simplify this process. However, there is a large cost associated with these buoy systems.

Currently, there is one such buoy deployed on Clinton Lake in Lawrence, KS. The buoy on this lake transmits data to the same website that the Marion buoy does, and data retrieval from this site would follow a similar FTP/SFTP protocol as the Marion buoy. Also, Clinton Lake is operated by the USACE, so the script that retrieves boundary conditions for the GLM could be modified for Clinton Lake.

If another lake(s) had similar buoys and calibrated models, the model outputs could be displayed on the same website. The HTML structure of the Marion website can be easily copied and modified to accommodate multiple lakes. The resulting website would feature a home page and a page for each lake. The current conditions, historical conditions, and forecasting web pages for the Marion website could be distilled into one comprehensive web page, allowing each lake to have their own web page on this larger website.

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