WATER QUALITY MONITORING AND MAPPING USING RAPIDLY DEPLOYABLE SENSOR NODES

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Thesis Defense

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OUTLINE

- Overview
- Methodology
- System Hardware
- Kriging
- Validation
- Results & Discussion

OVERVIEW

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WATER

- Water covers 70% of planet Earth.
- Clean water is a fundamental human right and a critical factor in public health, agriculture, and ecosystems.
- However, the quality of our water resources is under constant threat due to various pollutants, industrial activities, and climate change.

WATER QUALITY MONITORING

- Continuous water quality monitoring is crucial to ensure the ongoing safety and sustainability of our water resources.
- However, It can be challenging to perform continuous water quality monitoring using traditional methods.

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REASONS

- High costs.
- Labor intensive.
- Limited Data.
- Delays in Data Reporting.
- Limited Coverage.
- Spatial Variability.
- Incomplete Monitoring.

ADVANCING METHOD CHARACTERISTICS

- Real-time Data collection.
- Autonomous system.
- Data logger.
- Multi-parameter monitoring.
- Data Processing and Interpolation.
- Cost effective.
- Long deployment duration.

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METHODOLOGY

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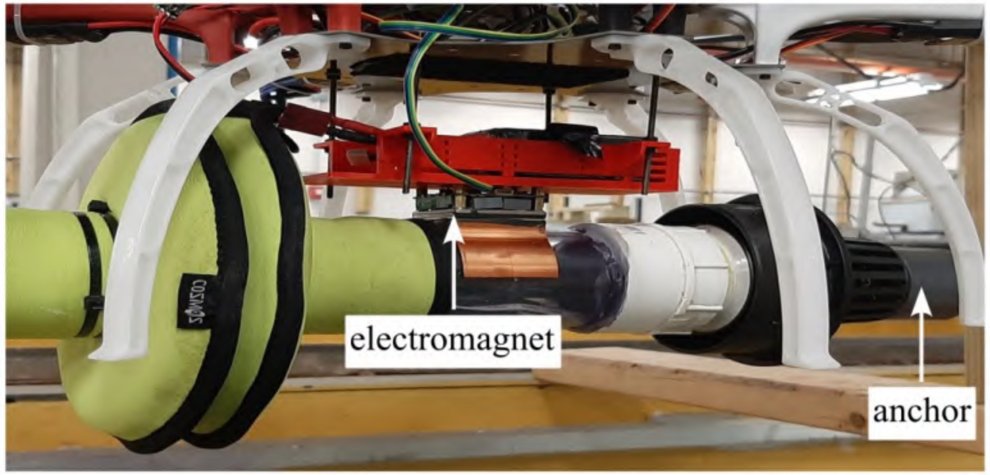
UAV
in-situ water quality sensor package
shore
water

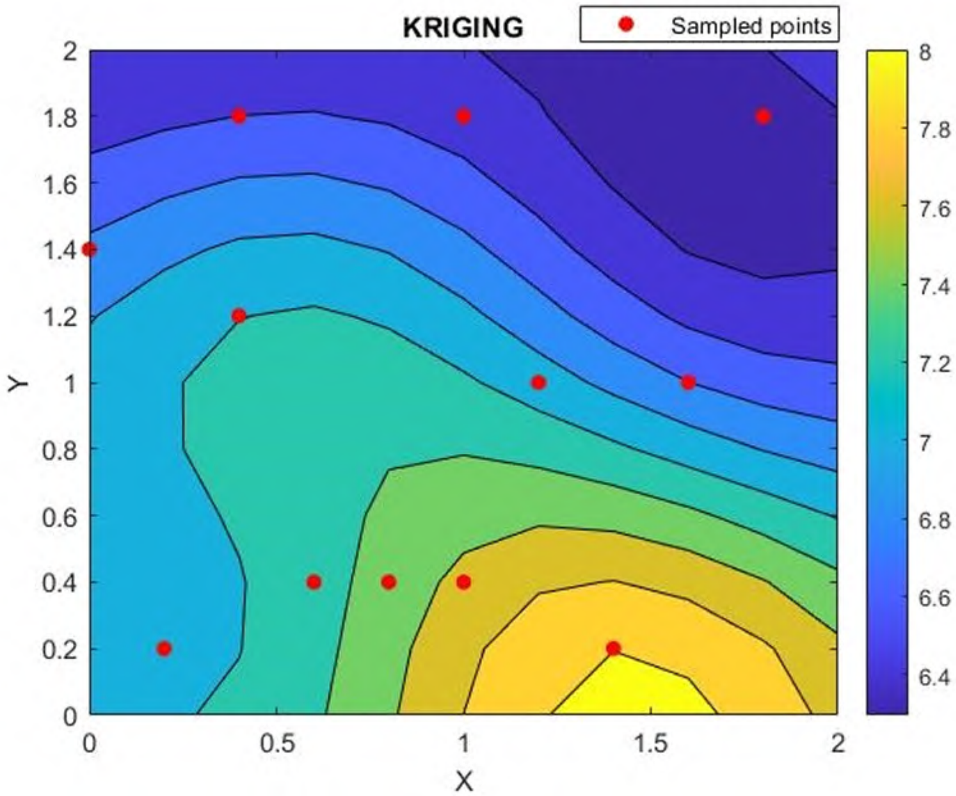
DEPLOYING MECHANISM

- An electromagnetic is used as a deploying mechanism
- Electromagnets use electric current in a coil to create a magnetic field.
- The current controls the magnetic field's strength and can be toggled on and off as needed.



WATER QUALITY MAPPING

- To determine the quality of the tested water bodies, we will employ kriging to create a spatial representation of the water parameters on a map.
- This will help us identify areas of concern and assess the overall water quality.



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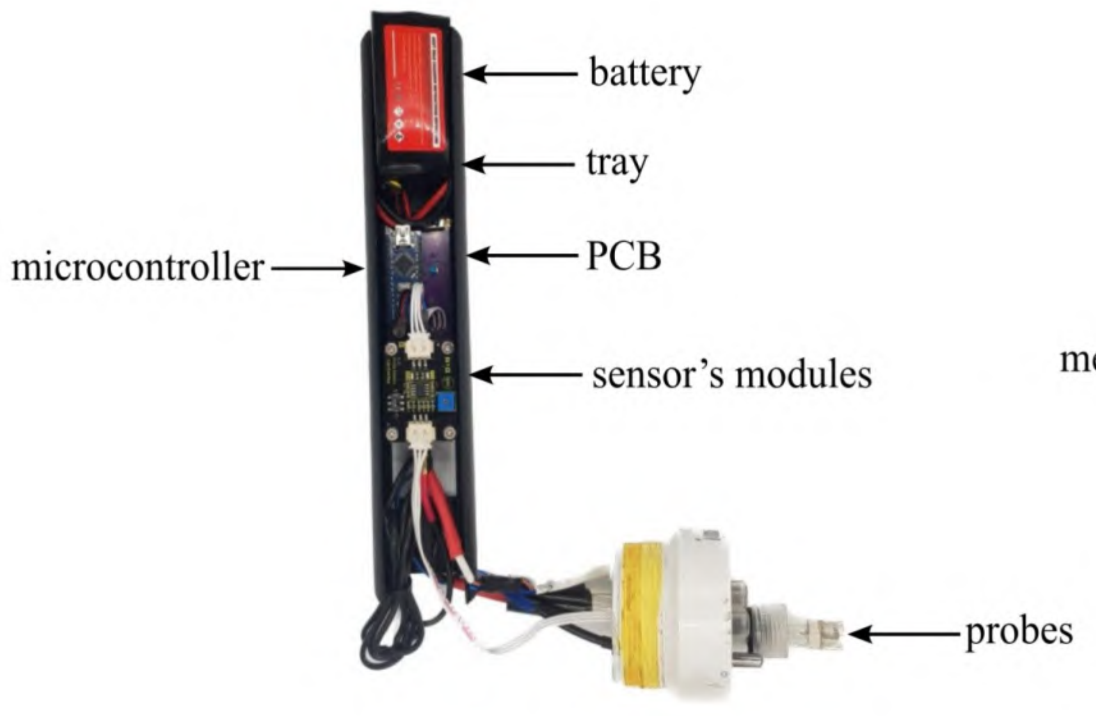
IN-SITU WATER QUALITY SENSOR PACKAGE

- Real time monitoring
- On-site Data Storage
- Data Accessibility
- Data Processing and Interpolation
- Aerial deployment
- Multi-parameter monitoring
- Power efficient
- Long-term testing capability
- Floating capability
- Fully waterproof

COMPONENTS

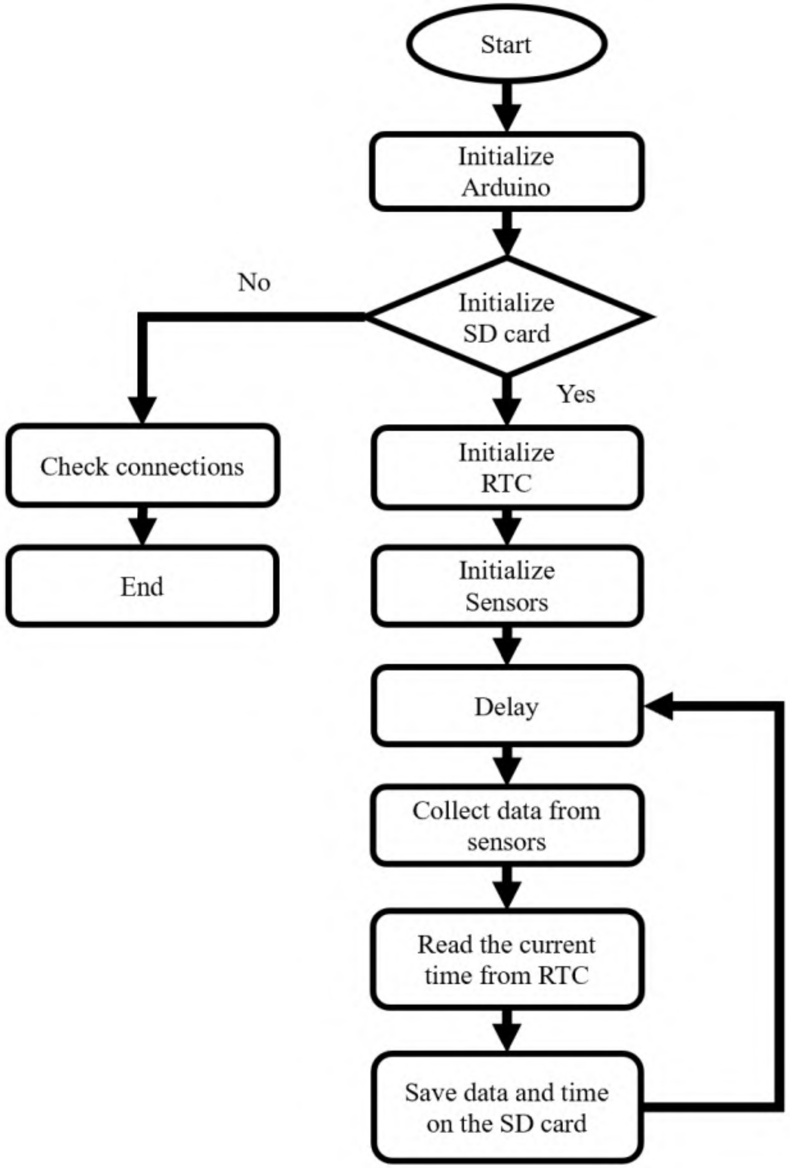


(a)

(b)

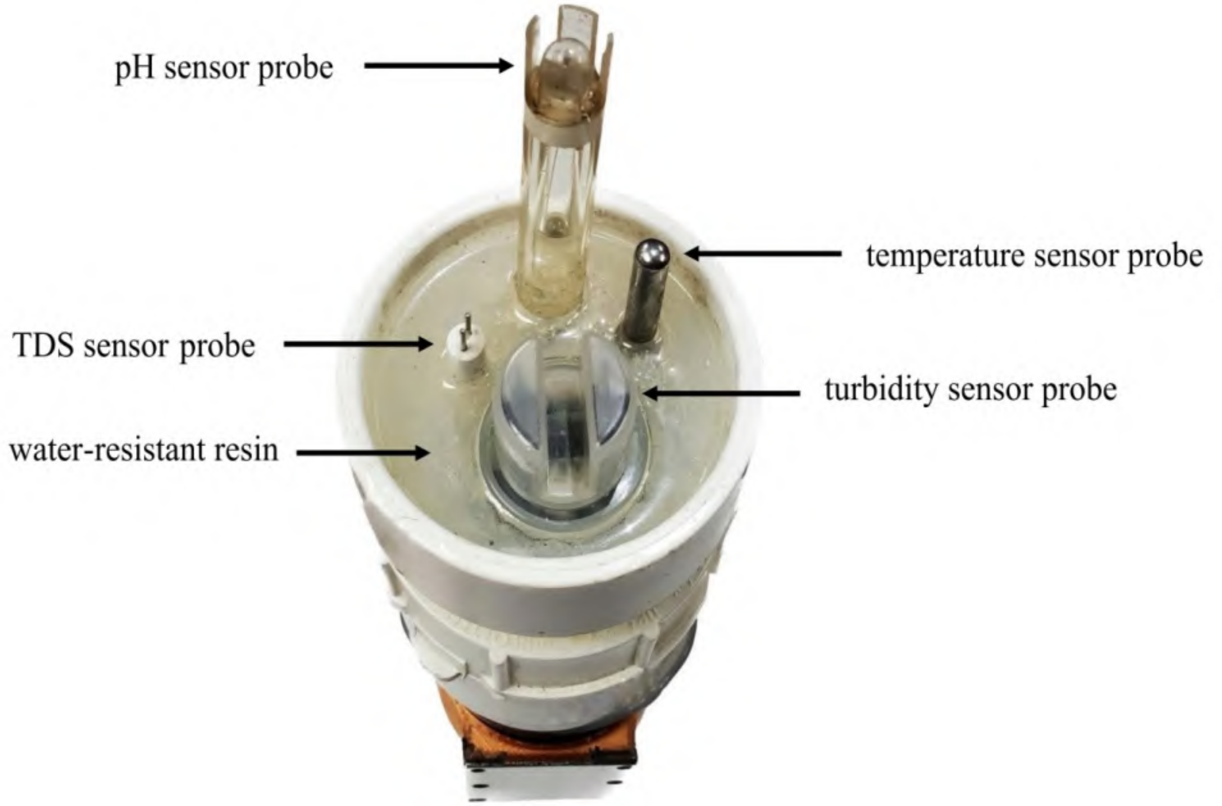
FLOW CHART

- Sensor package data collection mission algorithm breakdown.



SENSORS

- pH sensor.
- TDS (Total Dissolved Solids).
- Turbidity.
- Temperature.



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REASONS FOR CHOOSING THOSE SENSORS

- pH: Measuring the acidity and the alkalinity of water.
- TDS: Measuring the dissolved substances in water.
- Turbidity: Indicates water cloudiness.
- Temperature: Measures the water temperature.

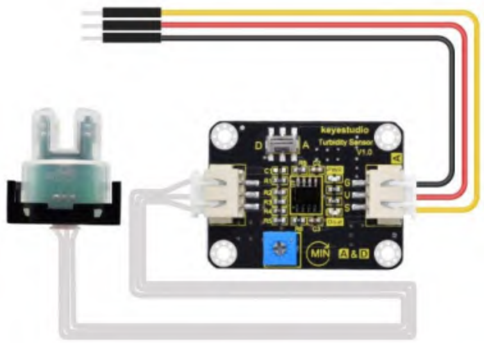
SYSTEM HARDWARE

SENSORS

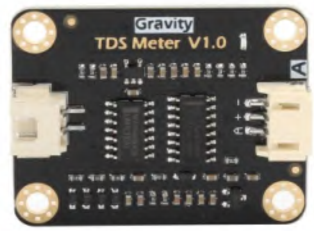
- pH sensor
- TDS (Total Dissolved Solids)
- Turbidity
- Temperature

- Analog Sensor
- Vcc: 5V
- Power consumption= 3mA
- Range: 0 – 14 pH

- Digital Sensor
- Vcc: 5V
- Power consumption= 2mA
- Range: -55 – 125 Celsius



- Analog Sensor
- Vcc: 5V
- Power consumption= 11mA
- Range: 0 – 100 NTU



- Analog Sensor
- Vcc: 5V
- Power consumption= 6mA
- Range: 0 – 1000 ppm

DATA LOGGER

- DS3231M
- Micro SD Card Module
- LED

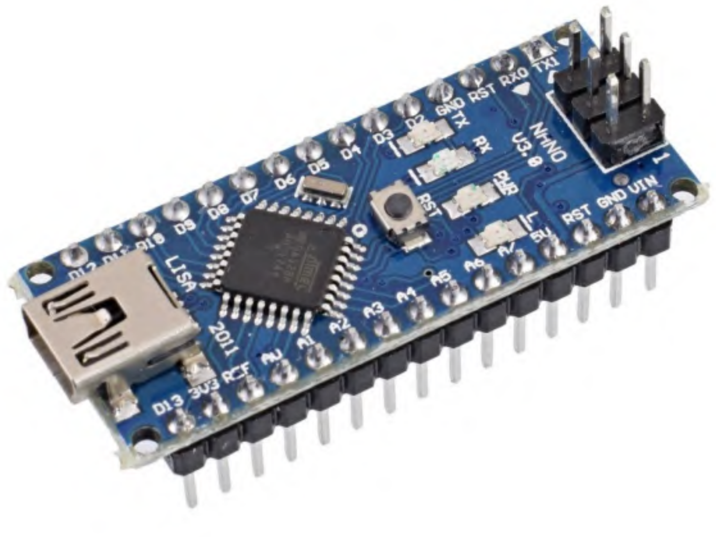
- Acting as an indicator while saving the Data on the SD card

- Surface mount IC
- Vcc: 2.3V - 5V
- Includes a coin cell battery backup
- Compact size

- Vcc: 3.3 V
- Compact size

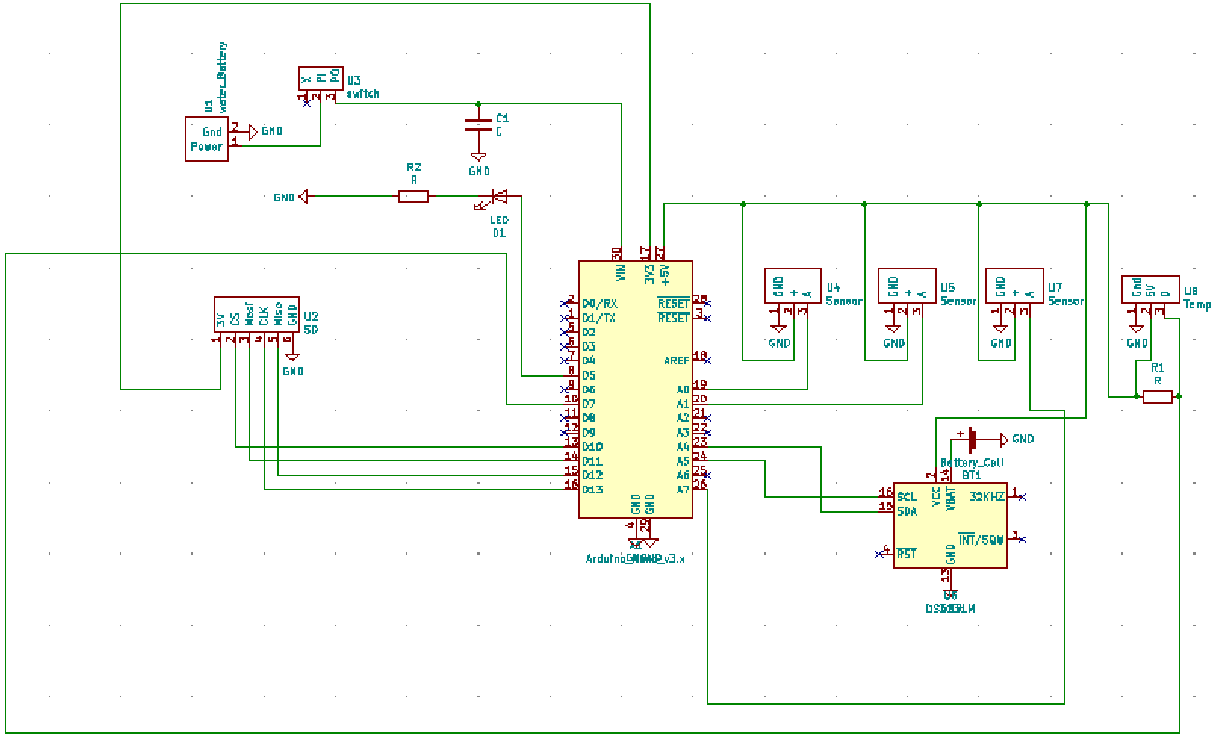
MICROCONTROLLER

- Arduino Nano:
- Power consumption: 15 - 30 mA
- Vcc: 7V - 12
- Compact size
- Low cost



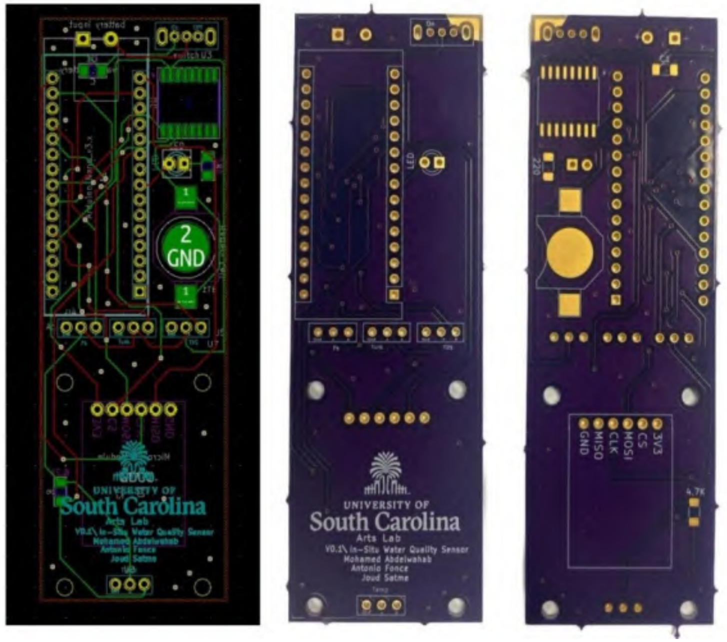
SENSOR PACKAGE CIRCUIT DESIGN

- To ensure effective operating procedure
- Error prevention



PRINTED CIRCUIT BOARD (PCB)

- A compact PCB was designed to fit all the electronic components into a limited space.
- Size: 97 x 32 mm

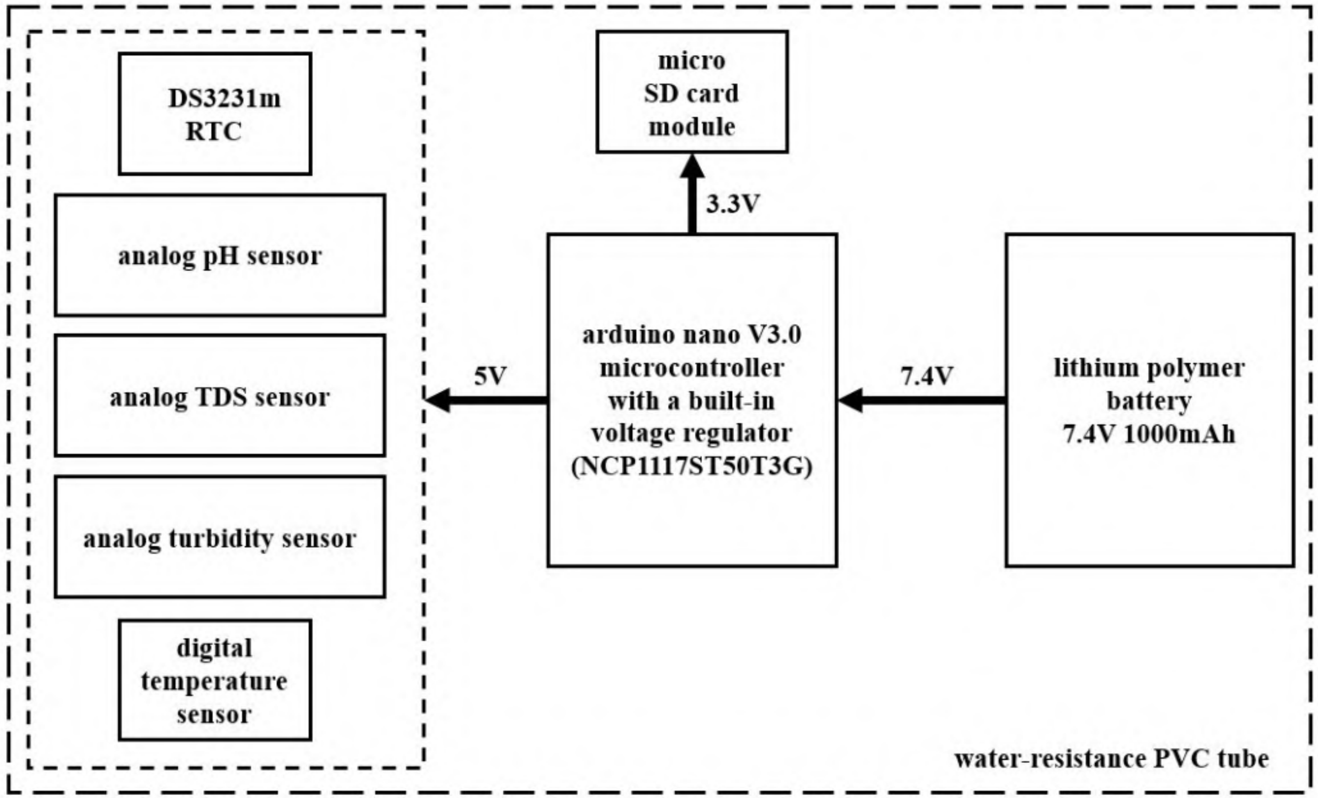


POWERING SOURCE

- Rechargeable Li-po battery
- 7.4V & 1000mAh

BLOCK DIAGRAM

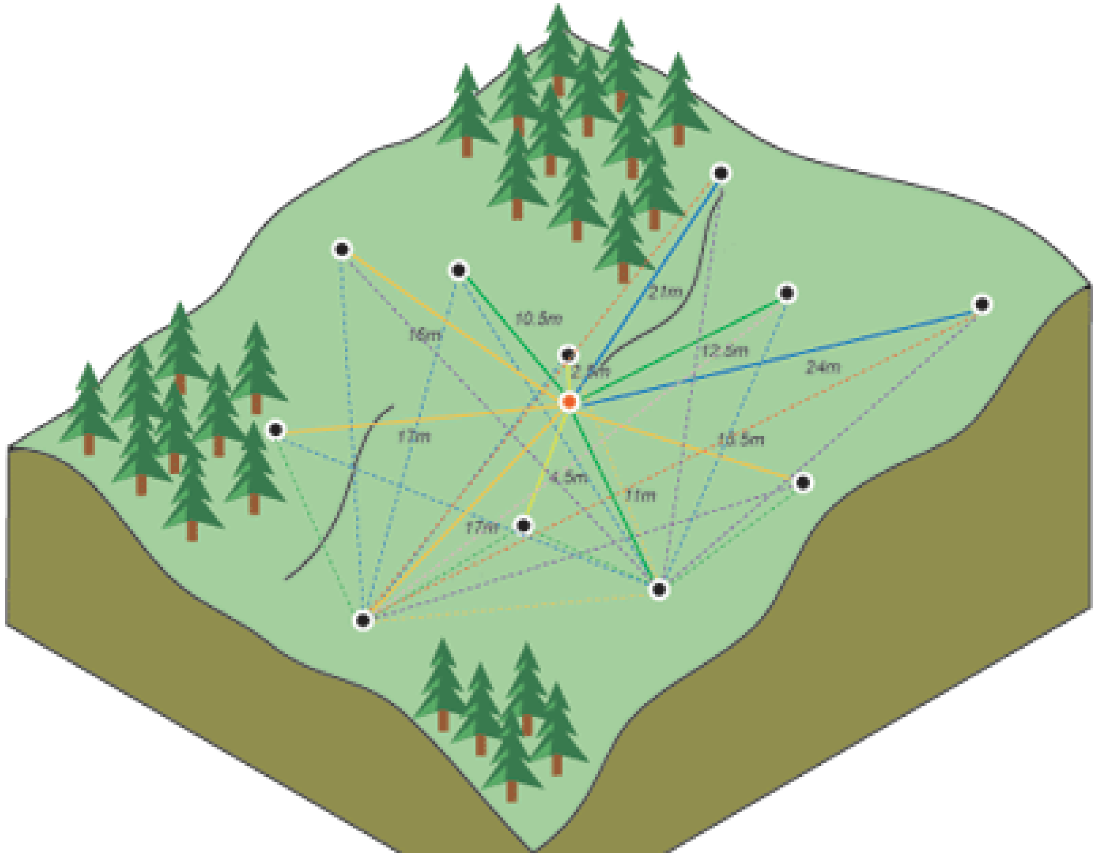
- Displaying the internal component of the sensor package.



KRIGING

KRIGING METHOD

- Used for estimating data in the unsampled location by considering the sampled points and their spatial relation.

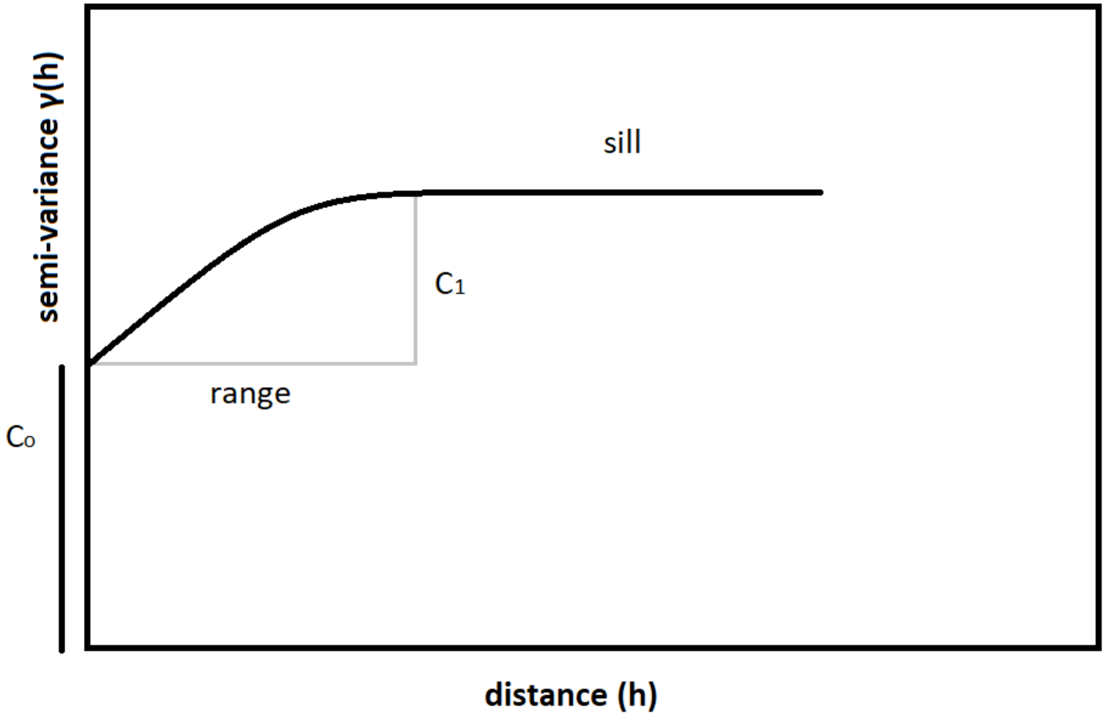


SEMI VARIOGRAM

- A spatial relationship map illustrates how data points become more similar or different as their distance from each other changes.

Components:

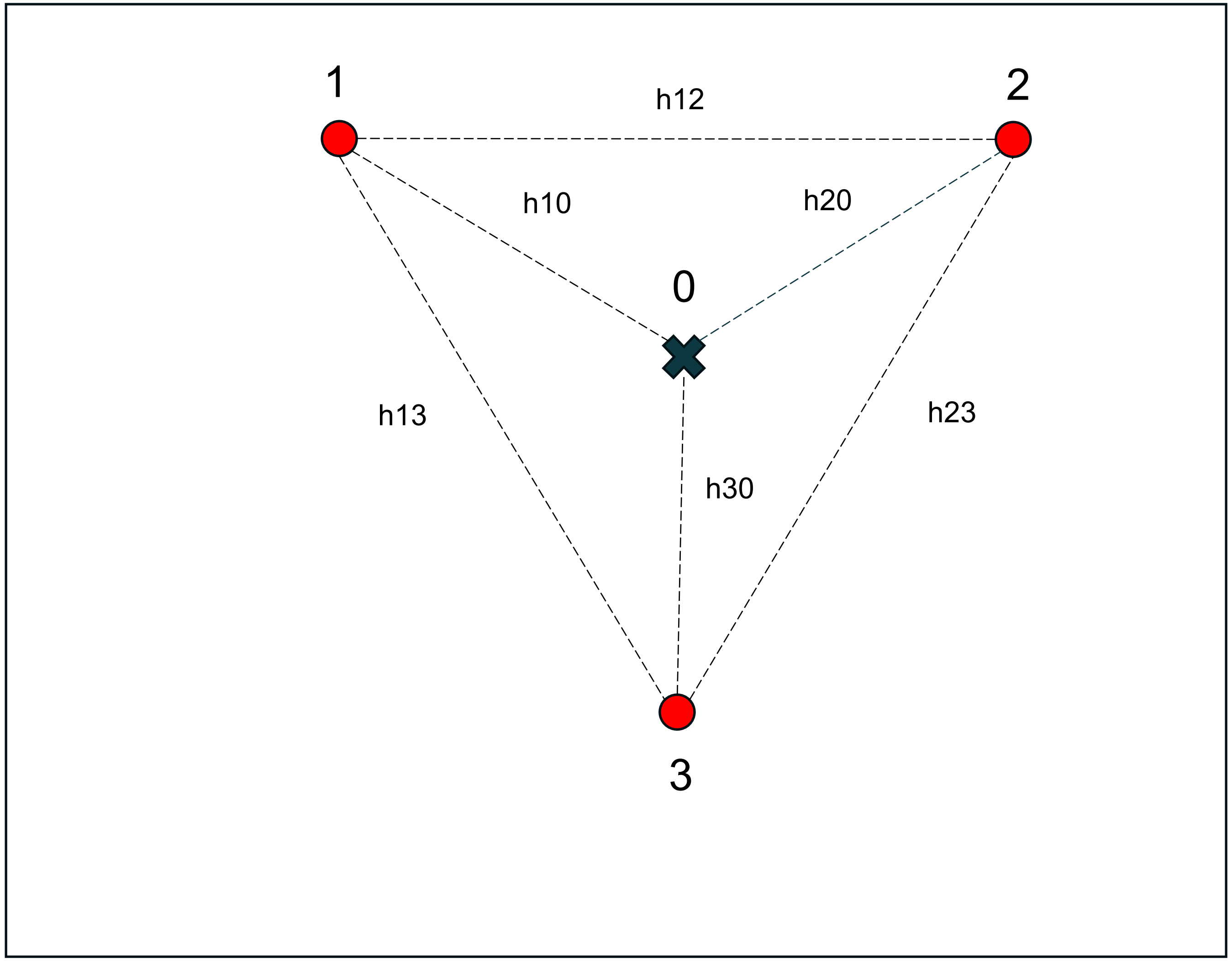
- Nugget: Represents the variation of the data at very small distances.
- Range: The distance in which the data become less similar and beyond this range, the data points become uncorrelated.
- Sill: The total amount of variation in the data set



EXAMPLE

$$B = \begin{vmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{vmatrix}$$

$$D = \begin{vmatrix} h_{10} \\ h_{20} \\ h_{30} \end{vmatrix}$$



CALCULATIONS

$$\gamma(h) = \begin{cases} c_0 + c\left(\frac{3h}{2a} - \frac{1}{2}\left(\frac{h^3}{a^3}\right)\right) & 0 < h \le a \\ c_0 + c & h > a \\ 0 & h = 0 \end{cases}$$

Hyperparameters:

Sill (C): Variance of the Data set

Nugget (C_0): Variation of the Data at a very small distance

Range (a): ½ the maximum distance between the sampled points

$$V = \begin{vmatrix} V11 & V12 & V13 \\ V21 & V22 & V23 \\ V31 & V32 & V33 \end{vmatrix} \qquad V_0 = \begin{vmatrix} V_{10} \\ V_{20} \\ V_{30} \end{vmatrix}$$

$$\lambda = \begin{vmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \end{vmatrix} = V(\text{inverse}) \times V_0$$

$$Z_0 = \sum \lambda_i Z_i$$

VALIDATION

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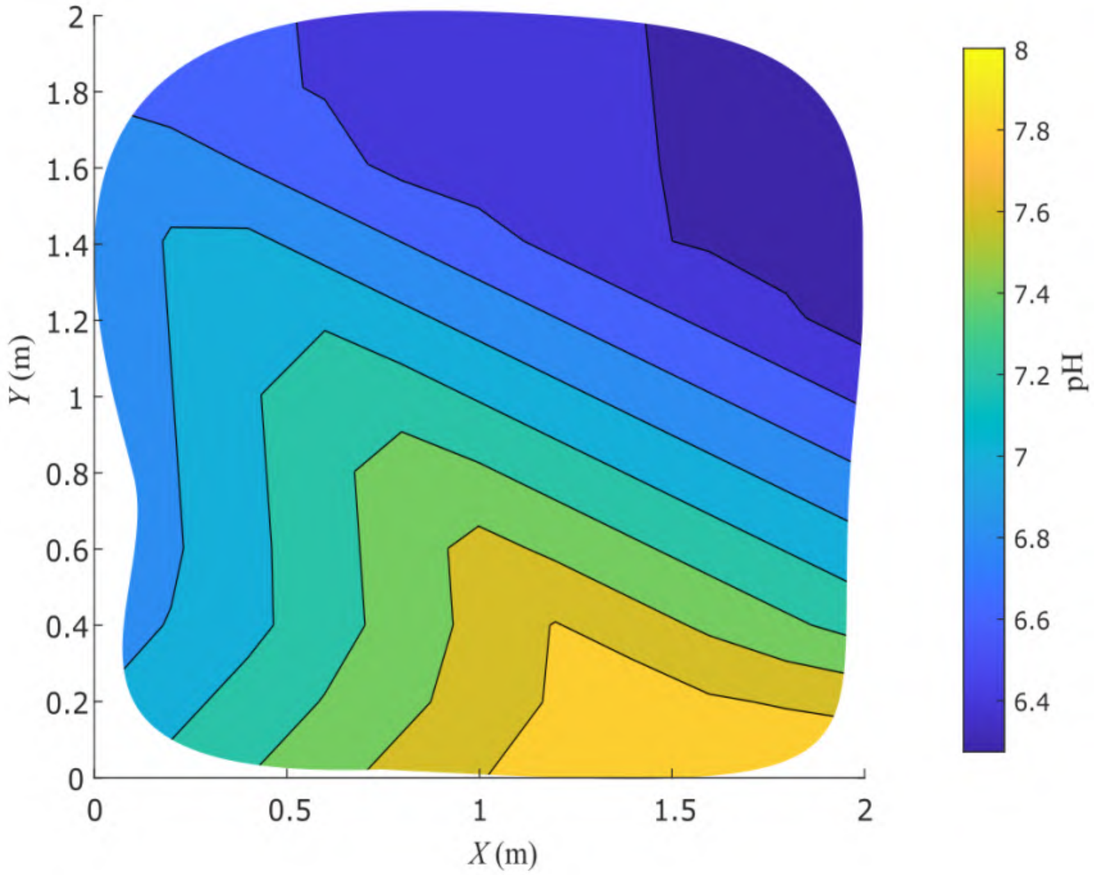
KRIGING

- Generated a fake lake to mimic a distribution of pH values across its surface.



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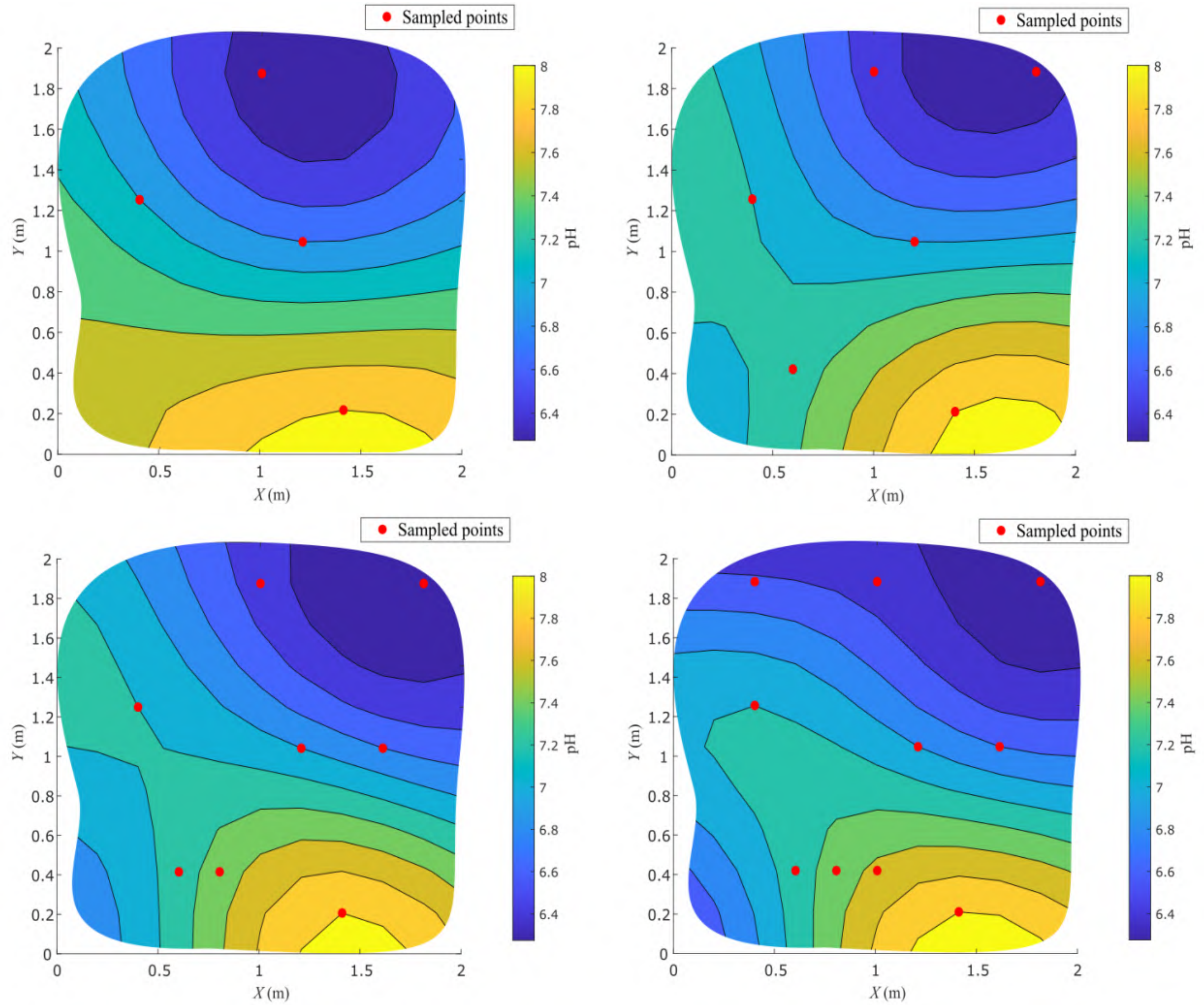

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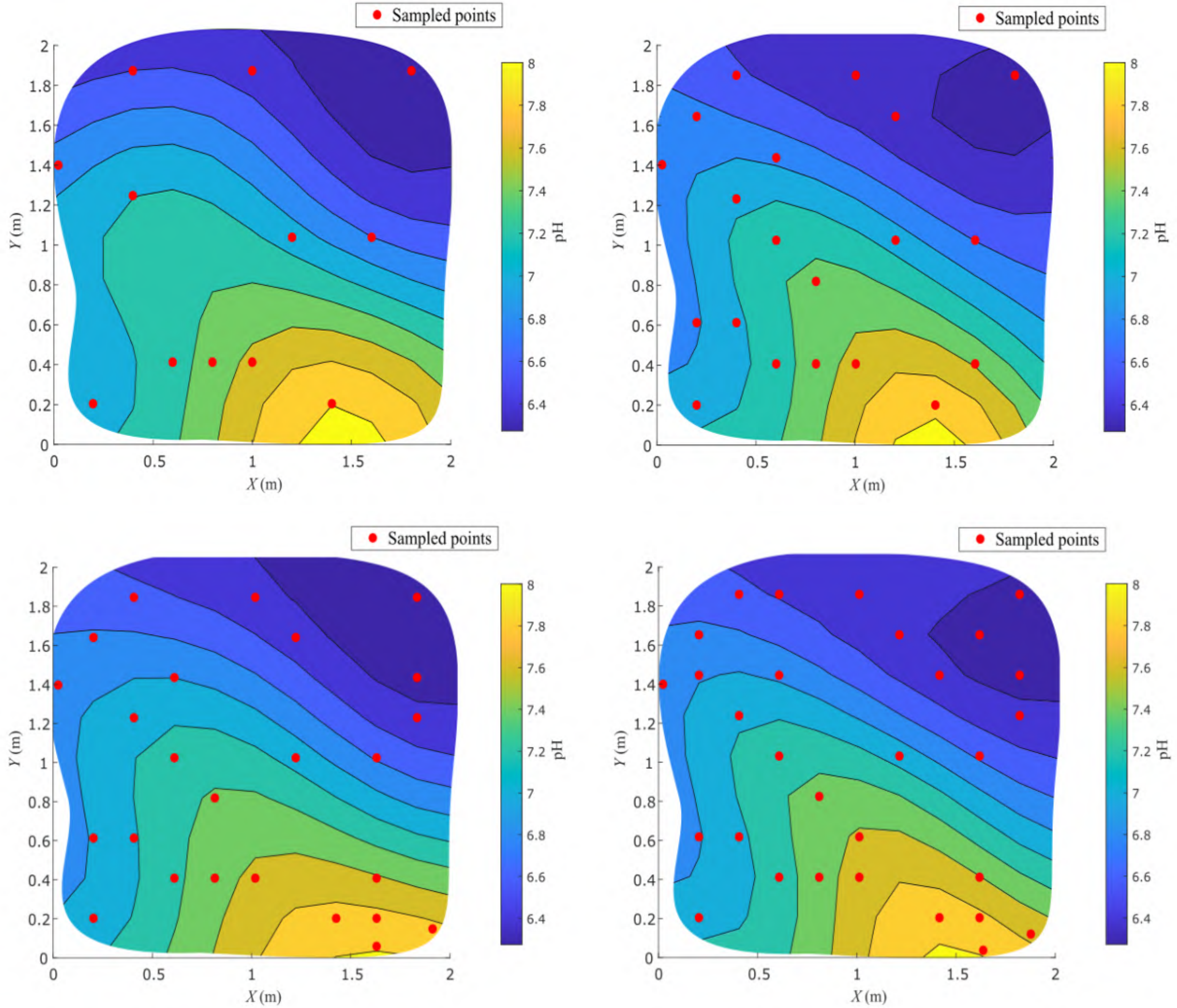

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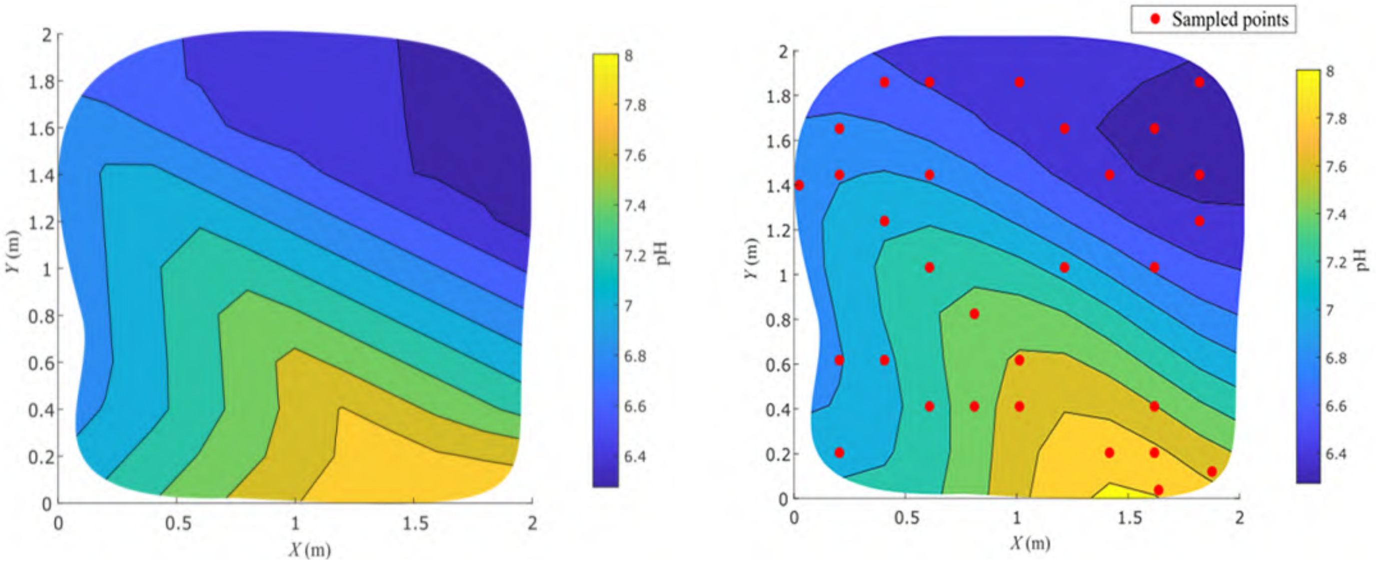
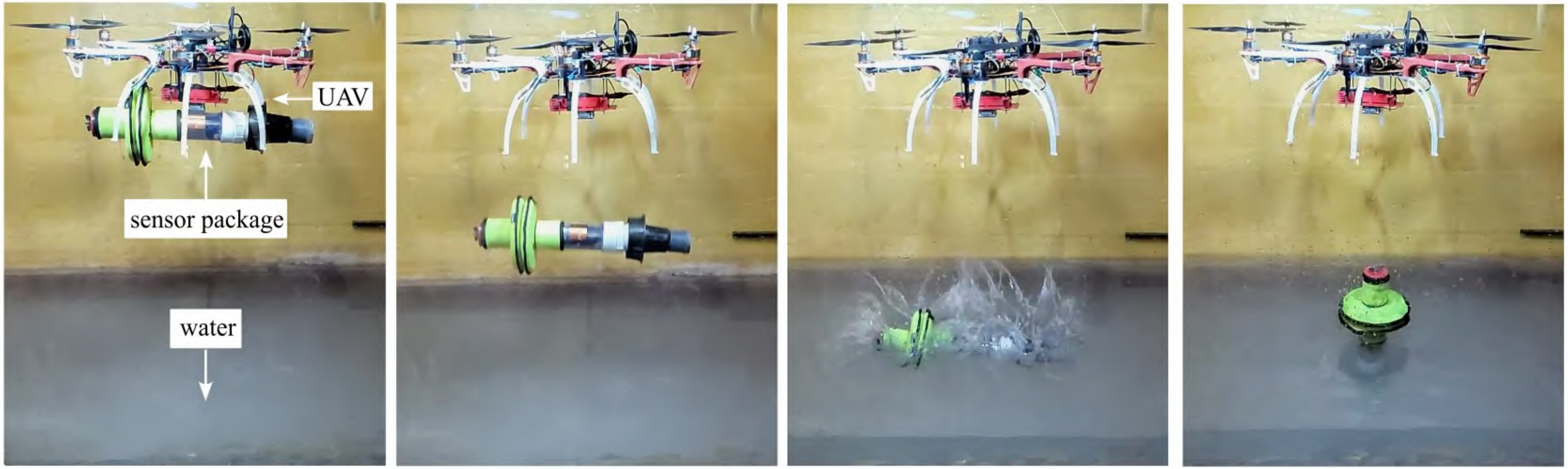
KRIGING VALIDATION RESULTS



Number of Sampled Points	Mean Absolute Error	RMSE	Maximum Error
4	0.36	0.46	0.91
6	0.32	0.41	0.86
8	0.28	0.36	0.81
10	0.25	0.33	0.77
15	0.22	0.29	0.71
20	0.20	0.26	0.66
25	0.18	0.24	0.62
30	0.16	0.22	0.59

DEPLOYING MECHANISM



(a) (b) (c) (d)

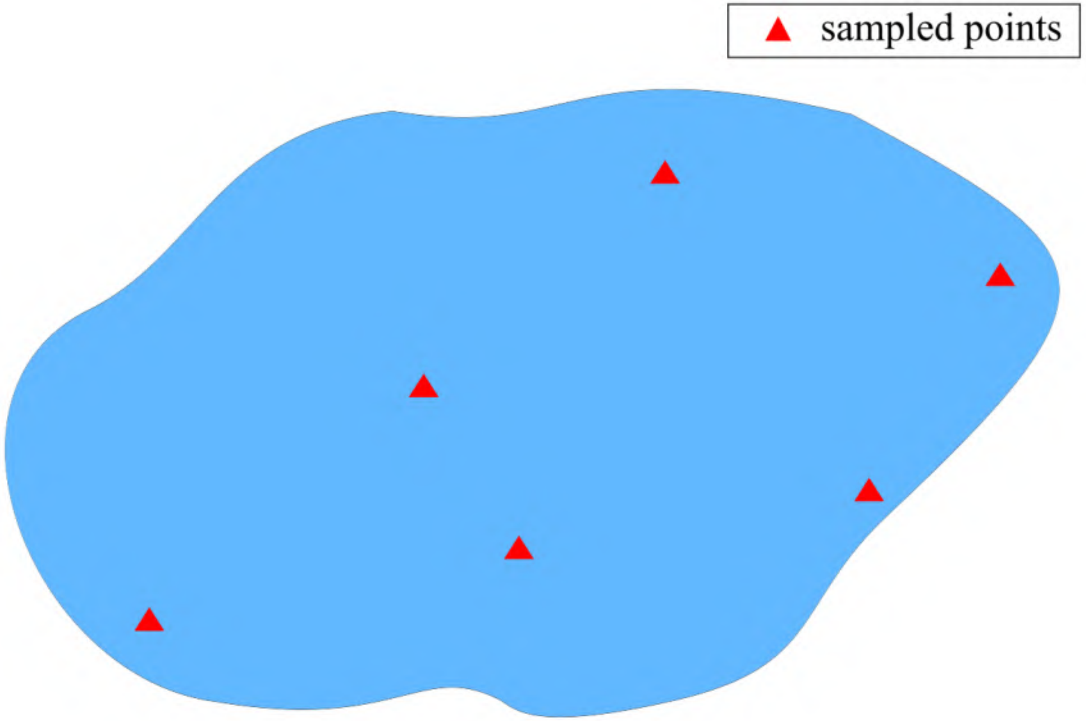
SENSOR'S VALIDATION

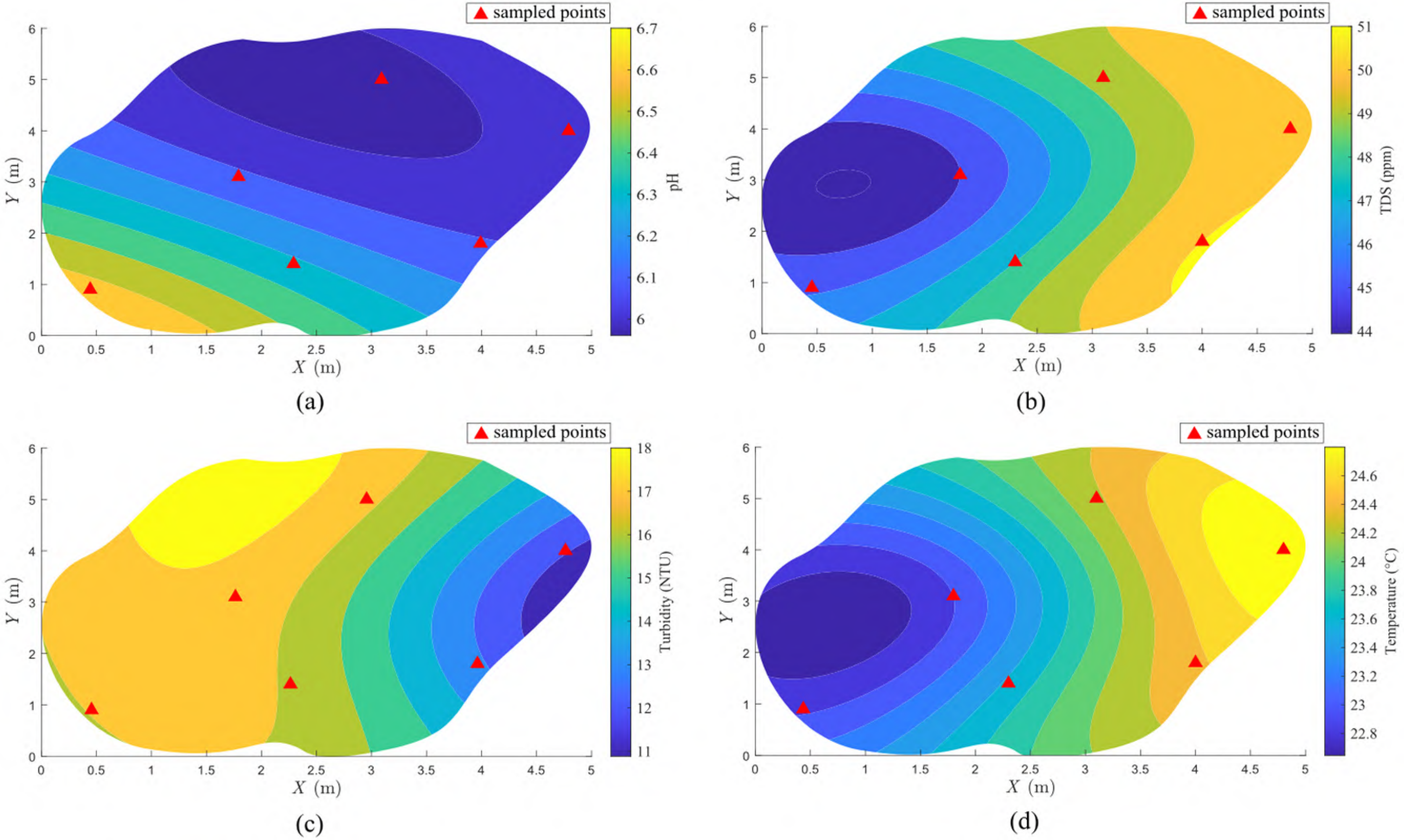
Parameters	Sensor package value	Reference Sensor Value	Absolute Error (%)
pH	6.62	6.71	1.34%
TDS	181	172	5.23%
Temperature	25	24.8	0.81%

RESULTS

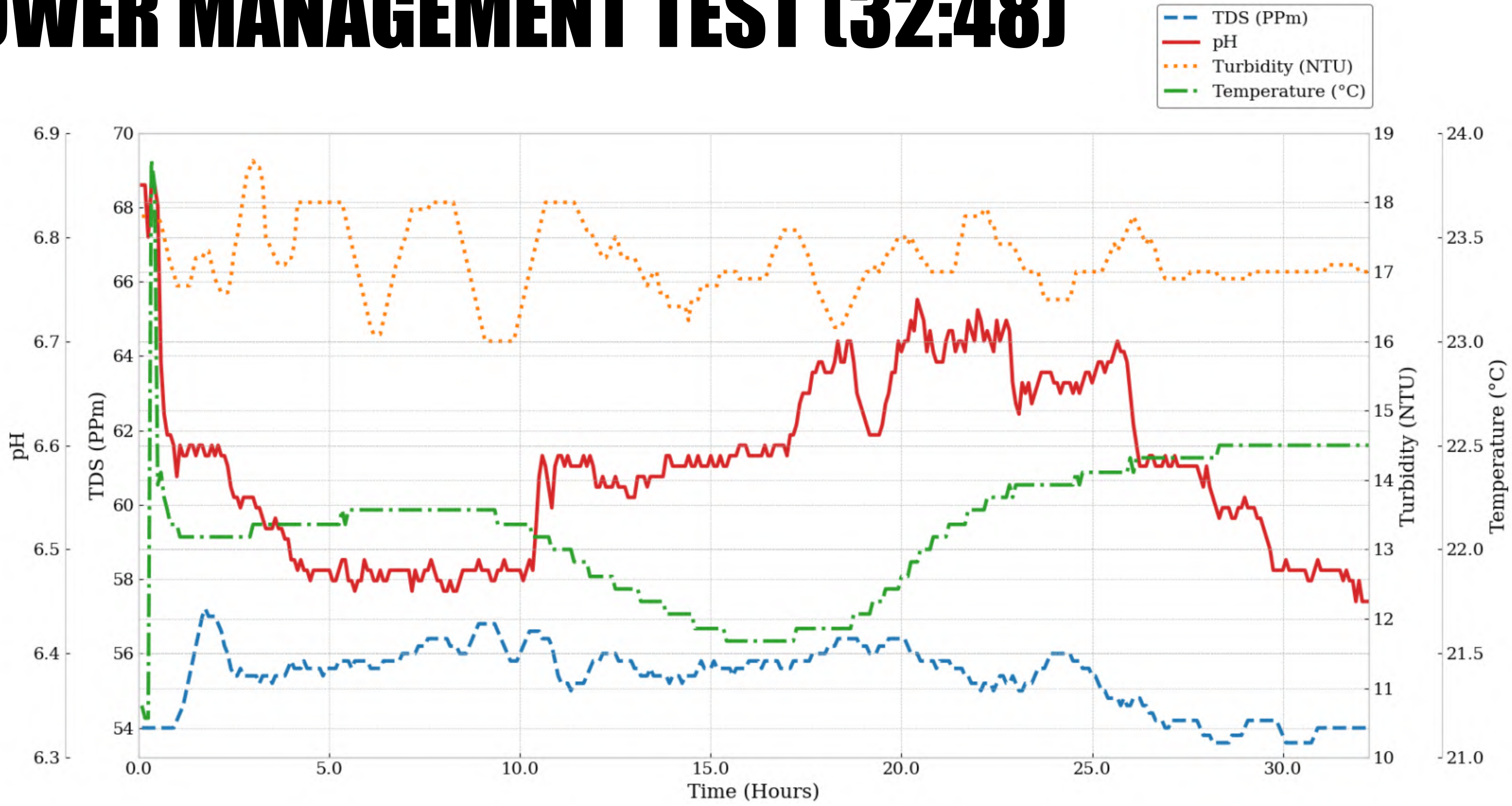
REAL TEST

SAMPLED LOCATIONS




sampled points
X (m)
Y (m)
pH
6.7
6.6
6.5
6.4
6.3
6.2
6.1
6
(a)
TDS (ppm)
51
50
49
48
47
46
45
44
(b)
Turbidity (NTU)
18
17
16
15
14
13
12
11
(c)
Temperature (°C)
24.6
24.4
24.2
24
23.8
23.6
23.4
23.2
23
22.8
(d)

POWER MANAGEMENT TEST (32:48)



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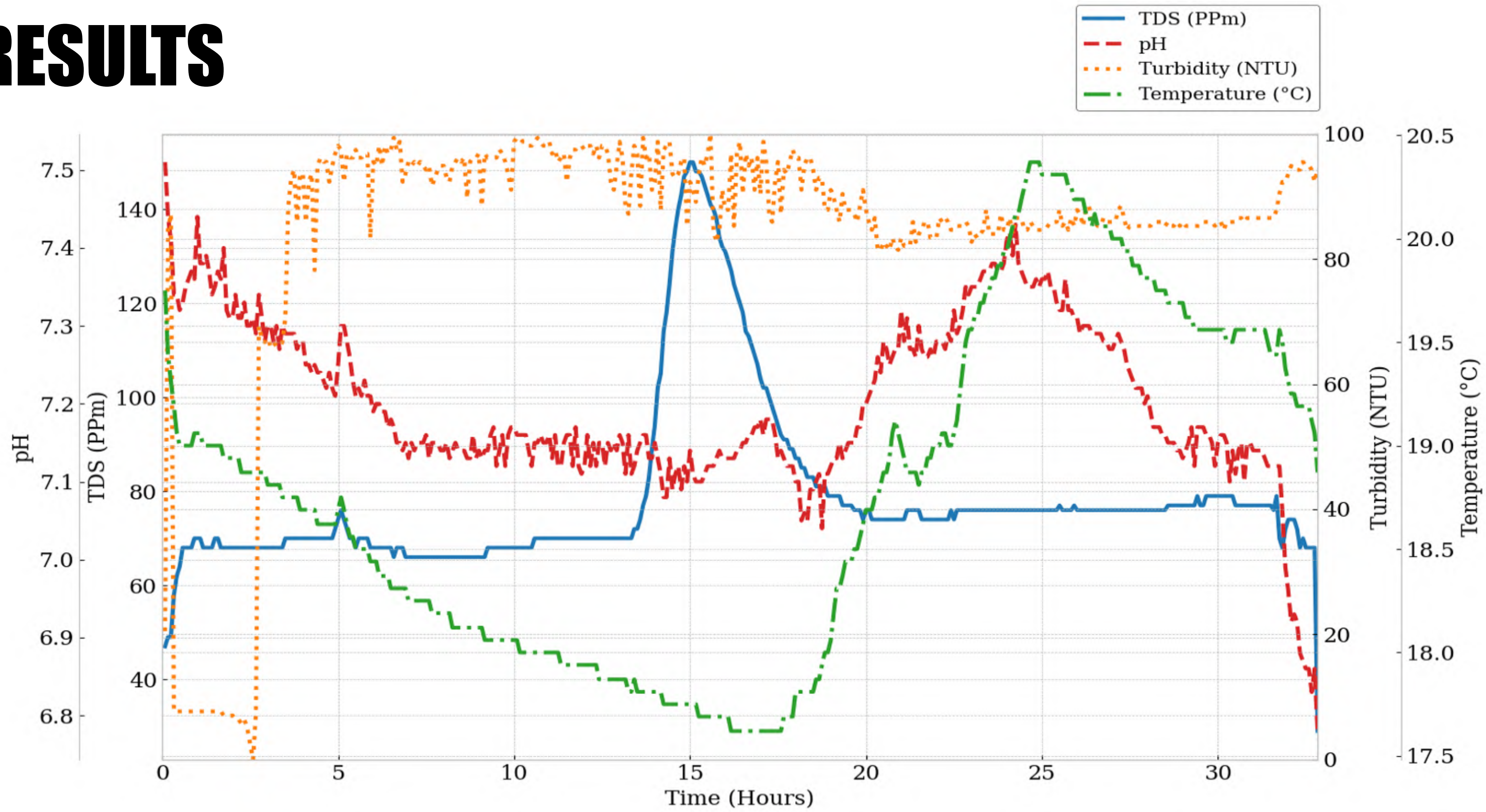
TESTING IN DYNAMIC WATER BODY

RESULTS



TDS (PPm)
pH
Turbidity (NTU)
Temperature (°C)
pH
TDS (PPm)
Turbidity (NTU)
Temperature (°C)
Time (Hours)
7.5
7.4
7.3
7.2
7.1
7.0
6.9
6.8
140
120
100
80
60
40
100
80
60
40
20
0
20.5
20.0
19.5
19.0
18.5
18.0
17.5
0
5
10
15
20
25
30

ONGOING RESEARCH PUBLICATIONS

- Title: Spatial and Temporal In-Situ Water Quality Monitoring and Mapping via UAV-Deployable Smart Semi-Permanent Sensor Nodes.
- Journal: MDPI Sensors
- Estimated Submission Date: December 2023

THANKS

QUESTIONS?