UAV Deployable buoy-style sensor for in situ water quality monitoring

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Outline

- Introduction
  - Importance of water quality monitoring
  - Advantages of real-time spatial monitoring
  - Present standard of water-quality test
  - Shortcoming of present standard
- Methodology
  - Sensor node components and design features
  - Embedded system overview
  - Drone deployment mechanism
- Experimentation & results
  - Benchtop accuracy test
  - Test result from an urban creek
- Conclusion and future work

Background

- Pollution alters crucial water quality parameters like pH, total dissolved solids (TDS), & turbidity.
- It is necessary to track these parameters to ensure healthy eco system and safeguard public health.
- Real-time spatial monitoring can help to understand how pollution spreads over time and thus helps with pollution source tracking

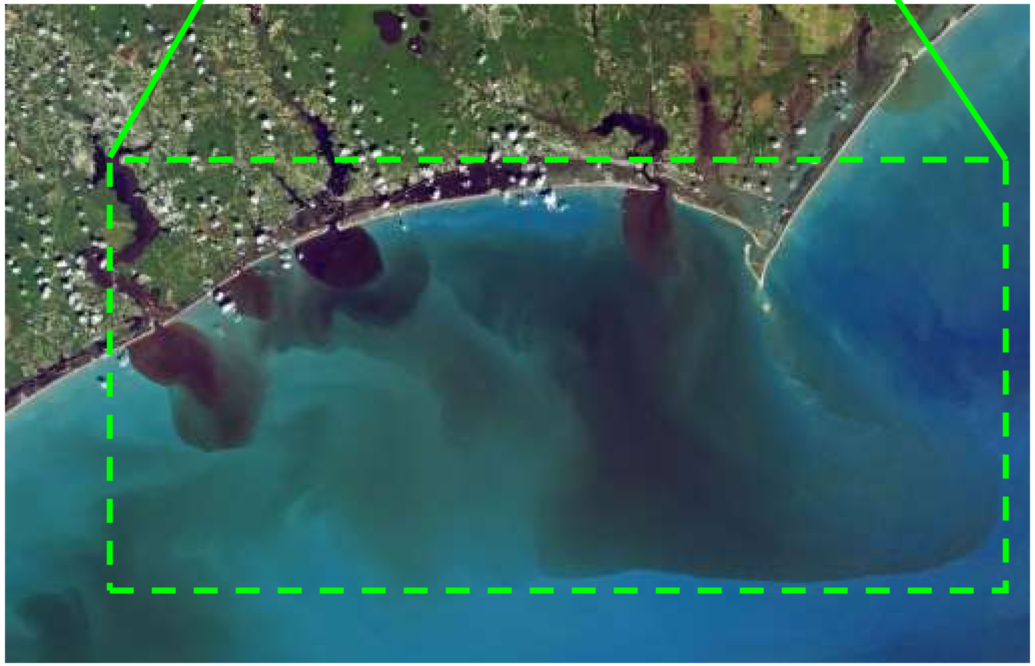
environmentalnote.com/understanding-pollution-causes-effects-and-prevention-strategies

Background

Wildfire runoff increases metal particles in water and increases conductivity

blog.geiworks.com/2018/02/wildfire-part-three.html

Hurricanes or storms increase water turbidity by mixing dirt/pollutants in water



livescience.com/63689-nasa-hurricane-florence.html

- Real-time spatial monitoring can help to passively track natural disasters like wildfires and hurricanes
- A rapidly deployable sensor cluster can be helpful in this regard

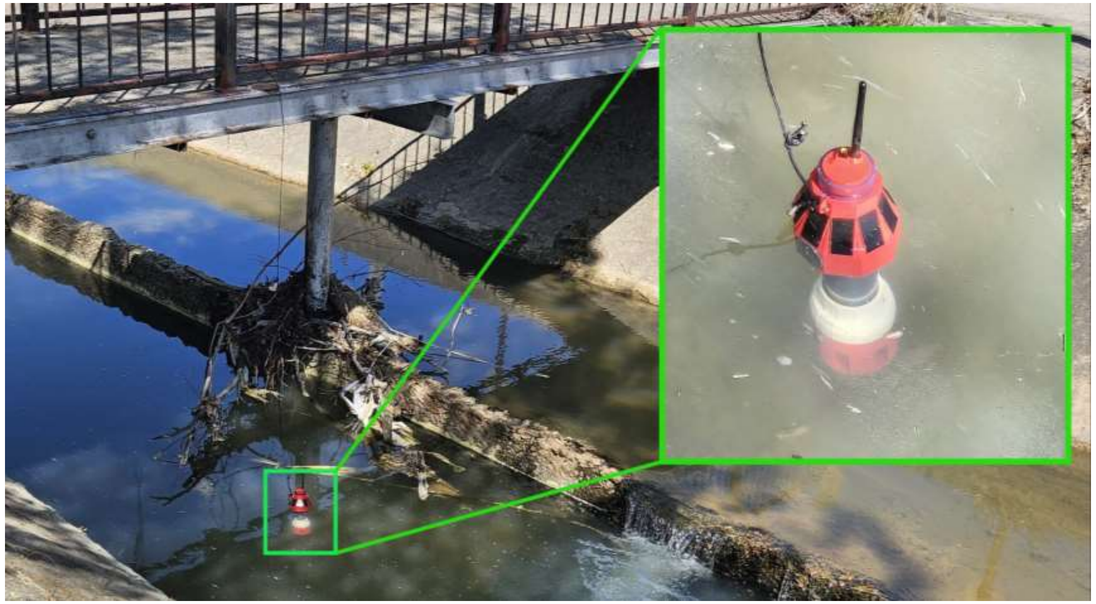
Background

- Present standard for water quality testing
  - Taking samples manually from waterbodies and performing analysis in lab
- Shortcomings
  - Requires manual labor
  - Poses health-risk
  - Doesn’t allow real-time spatial monitoring
  - Doesn’t allow rapid testing to track natural calamities

rpsgroup.com/services/laboratories/environmental-analysis/water-analysis

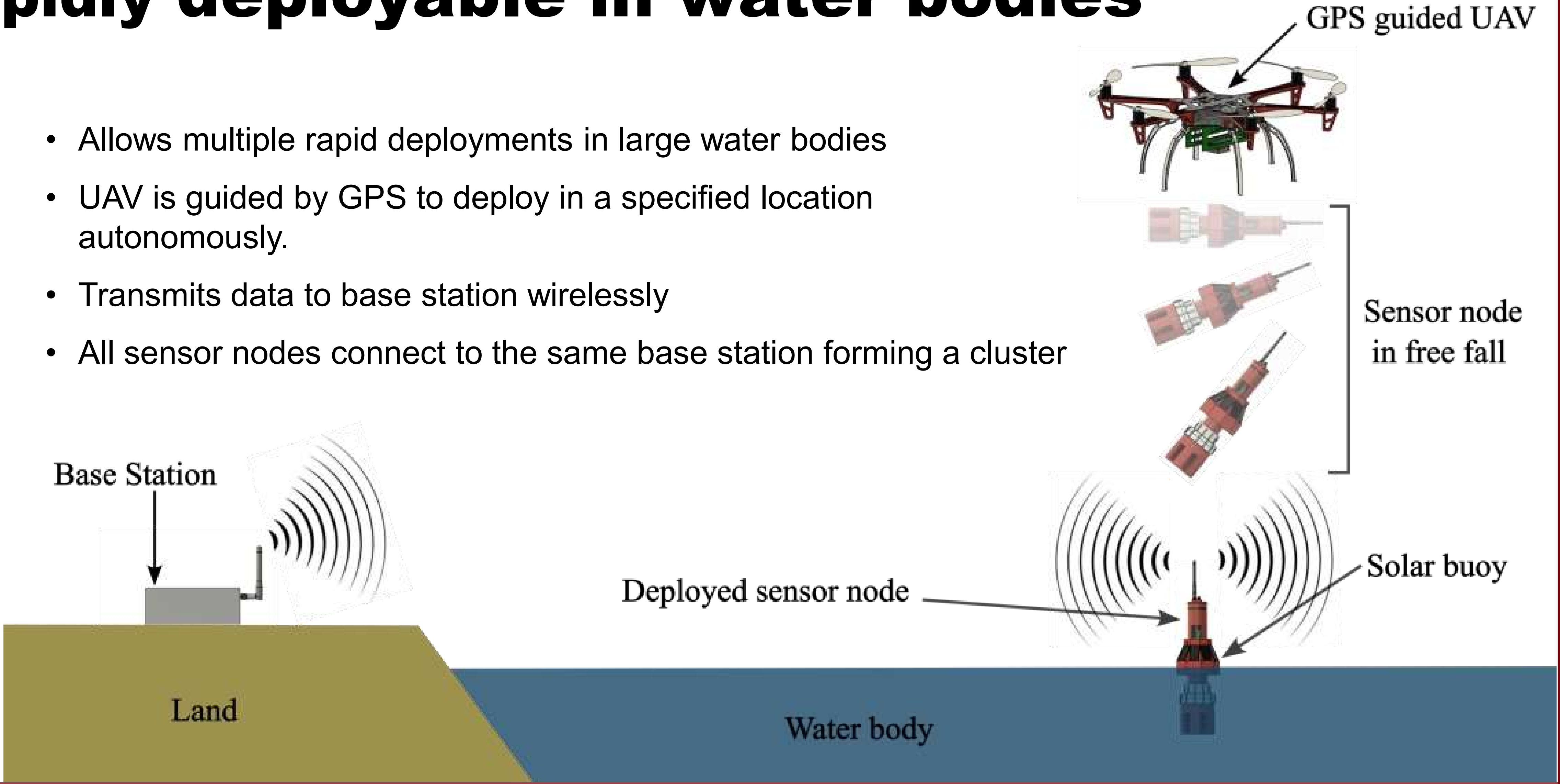
Proposed Buoy Style Sensor node

- Designed for autonomous, real time, in-situ monitoring of water quality conditions
- Open-source modular design with off the shelf hardware
- Senses pH, electrical conductivity, turbidity and temperature
- Equipped with GPS and wireless communication capabilities
- UAV-deployable package to enable deployment in remote environments



Rapidly deployable in water bodies

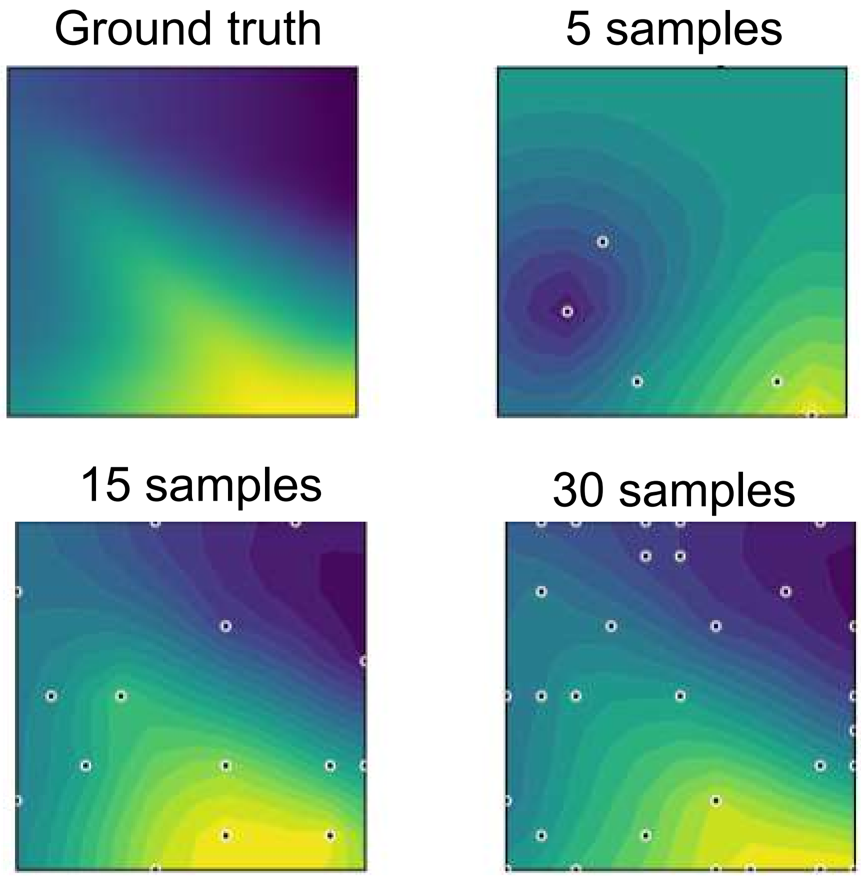
- Allows multiple rapid deployments in large water bodies
- UAV is guided by GPS to deploy in a specified location autonomously.
- Transmits data to base station wirelessly
- All sensor nodes connect to the same base station forming a cluster



Enables real-time spatial monitoring

- Spatial maps of key water quality parameters using a cluster of GPS equipped sensor nodes in conjunction with Kriging
- Kriging is a geostatistical interpolation technique used for spatially correlated domains like water bodies

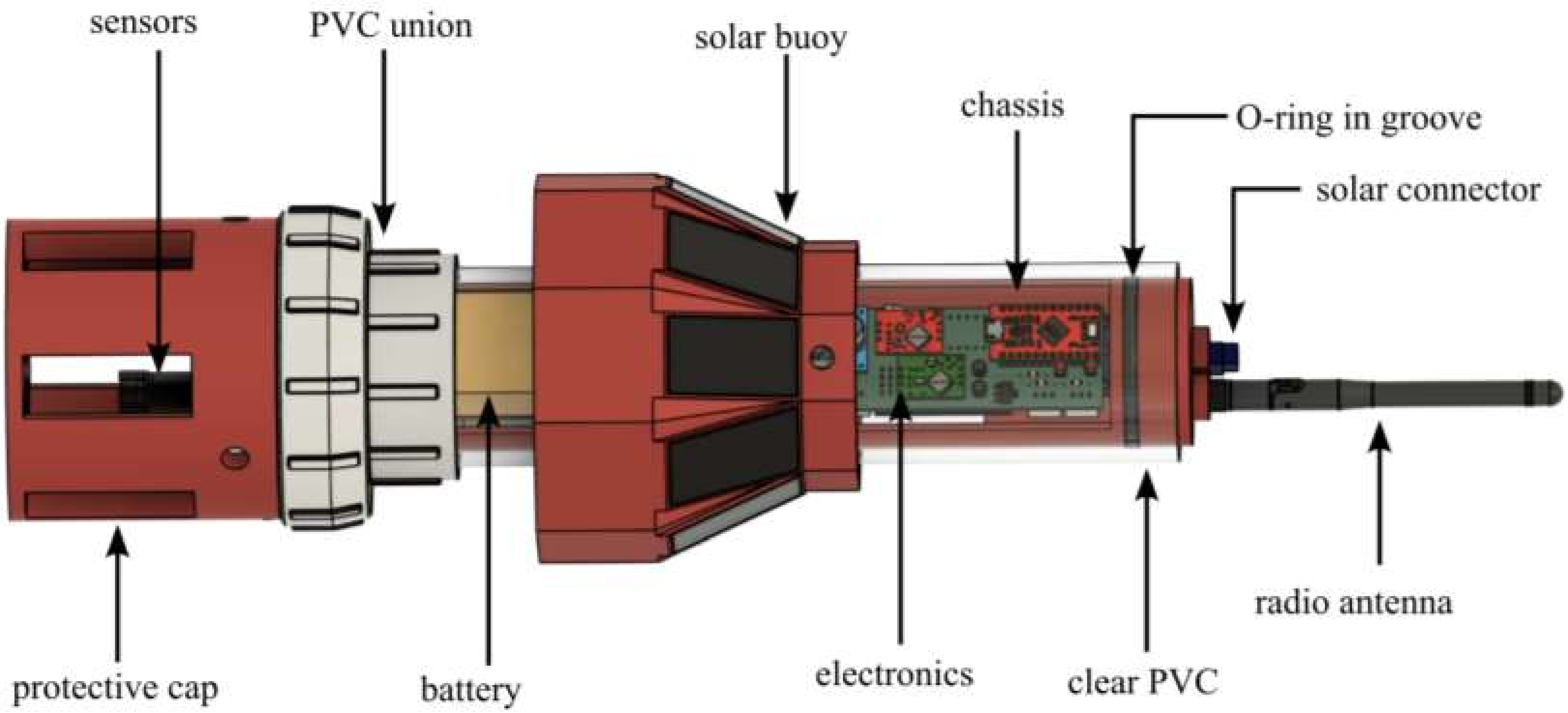
Sensor node cluster in a water body marked with red pin



A numerical simulation of lake sampling with kriging

Components of the sensor node

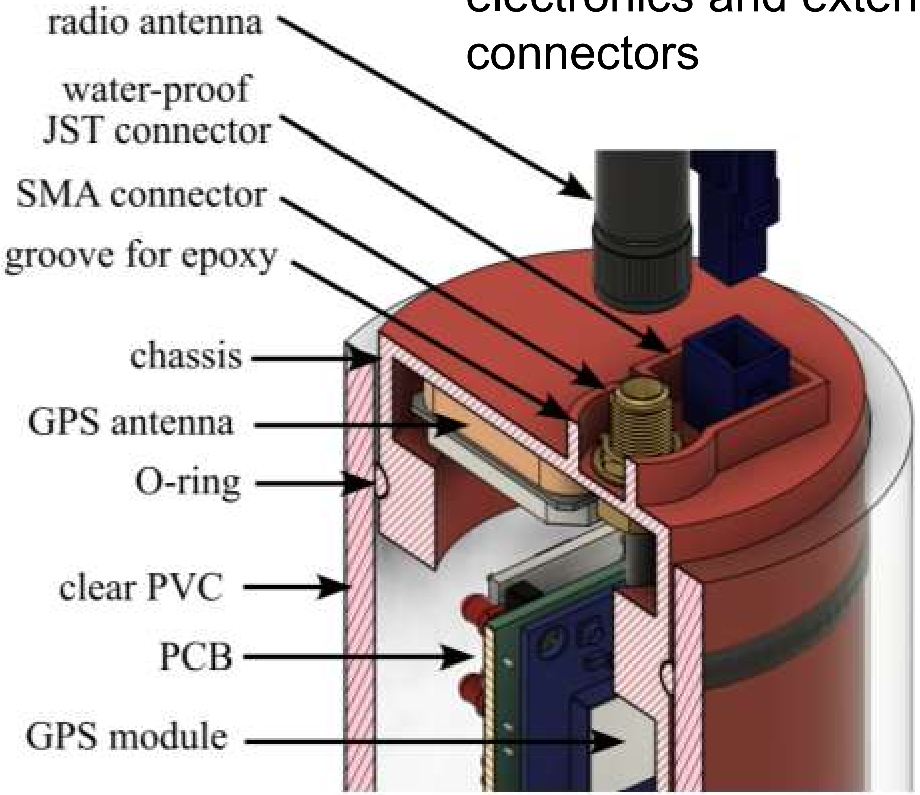
- The left side represents the bottom portion that stays submerged in water
- The right side represents the top portion that stays above water
- Vertically adjustable Solar buoy illustrated in the middle provides buoyancy and solar power to charge battery

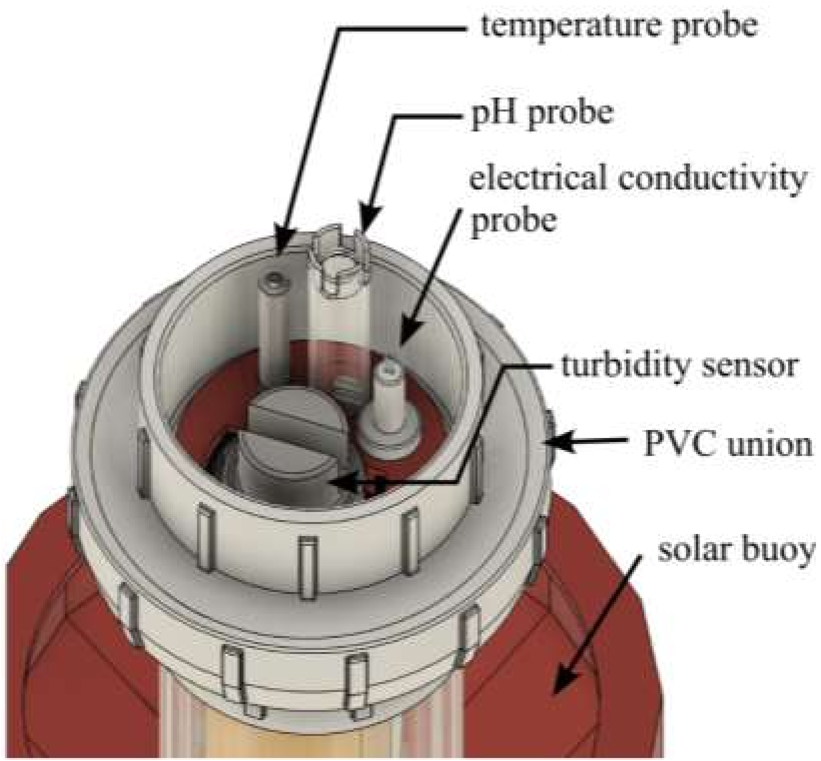


Horizontal view of the fully assembled sensor node.

Components of the sensor node

- The cross-section of the top portion displaying internal electronics and external connectors

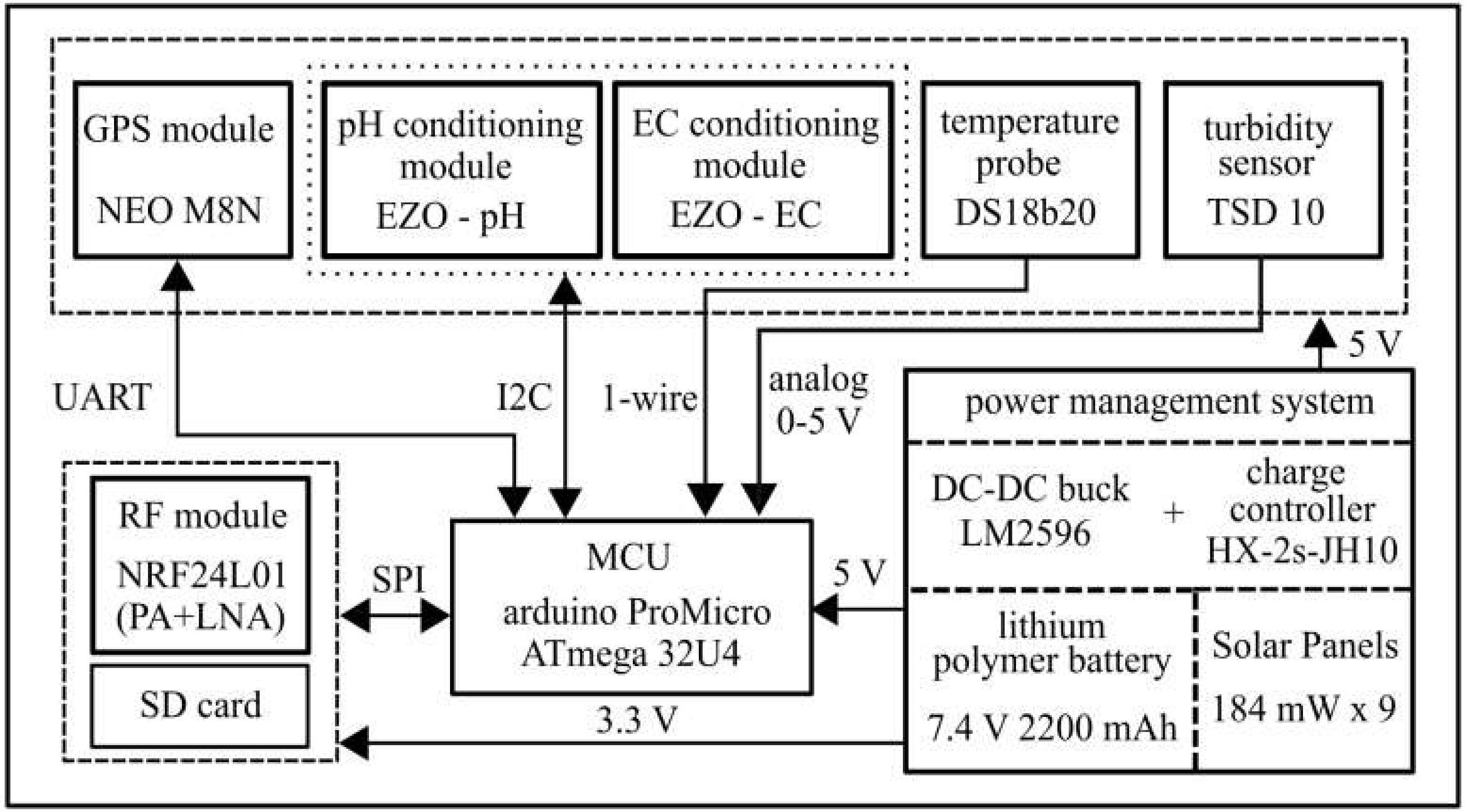




- The bottom view of the sensor node without the protective cap, displaying the measurement sensors.

Embedded system of the node

- Atmega32U4 as the brain of the system
- GPS for time and location data
- nRF24L01 for wireless communication
- SD card for data backup
- Respective signal conditioning modules for pH and conductivity sensor
- Powered by 7.4 V 2200 mAh lithium polymer battery
- 9 x 184 mW solar panels to charge battery at daytime
- Solar power handled by a battery charge controller



UAV deployment mechanism

- Deployed using an Electro-Permanent Magnet (EPM) mounted on the UAV.
- EPM can retain its magnetization without constant energy input.
- EPM can be toggled on (magnetized) or off (demagnetized) using electrical pulses.

OpenGrab
EPM V3

Sensor accuracy validation and power consumption

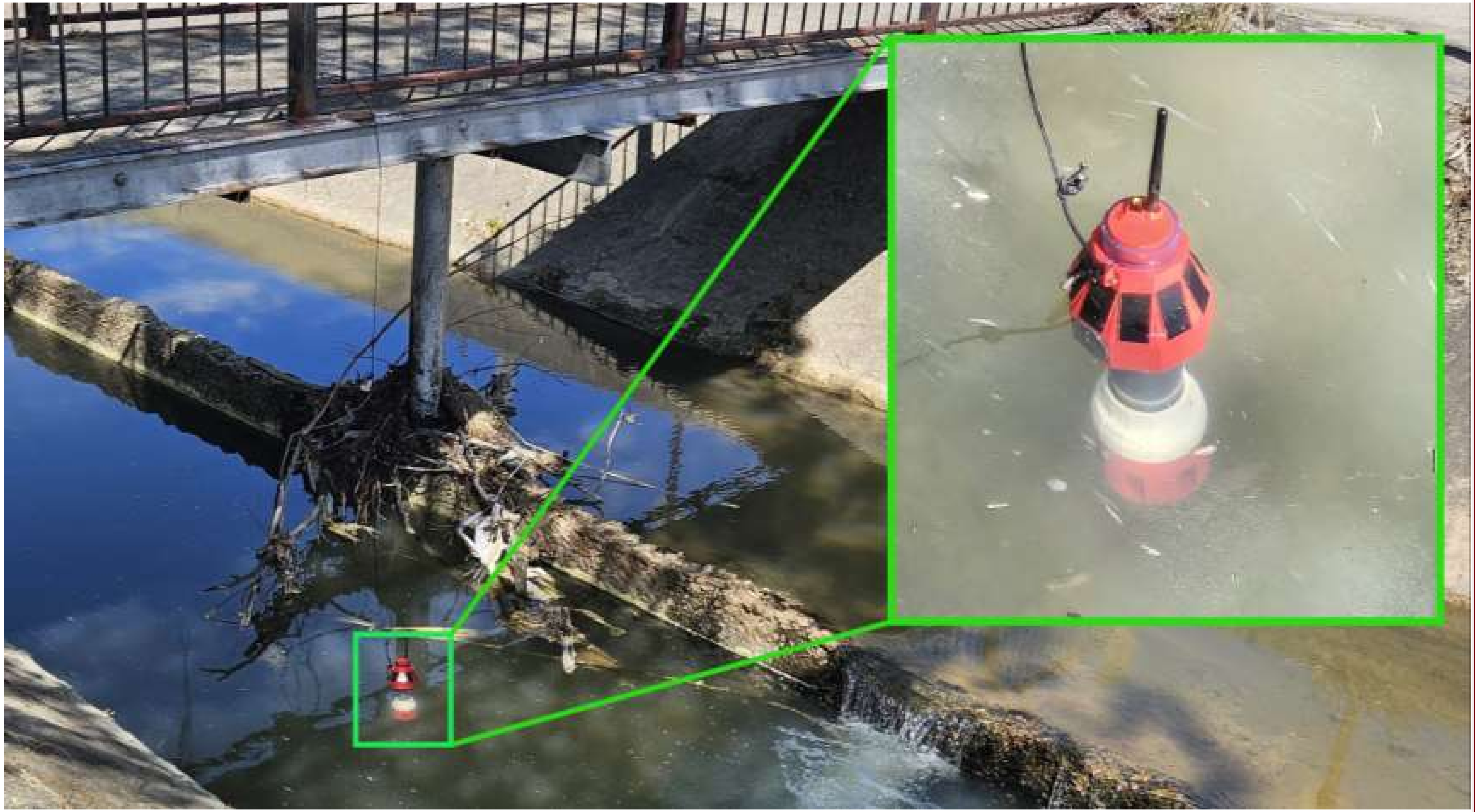
- A benchtop test was performed to verify the accuracy of the pH, conductivity, and temperature sensors.
- Sensor readings showed deviations of 0.71–4.2% compared to industrial reference instruments, indicating high accuracy.

parameters	sensor node's value	reference sensor's value	error (%)
pH	7.01	6.96	0.71
electrical conductivity (µS/cm)	12619	12108	4.22
temperature (°C)	25.7	26	1.15

- Consumes an overage of 930.254 mW in steady-state operation
- Equipped with 9 x 184 mW solar panels providing a nominal 1656 mW, which is 1.8 times the average power consumption

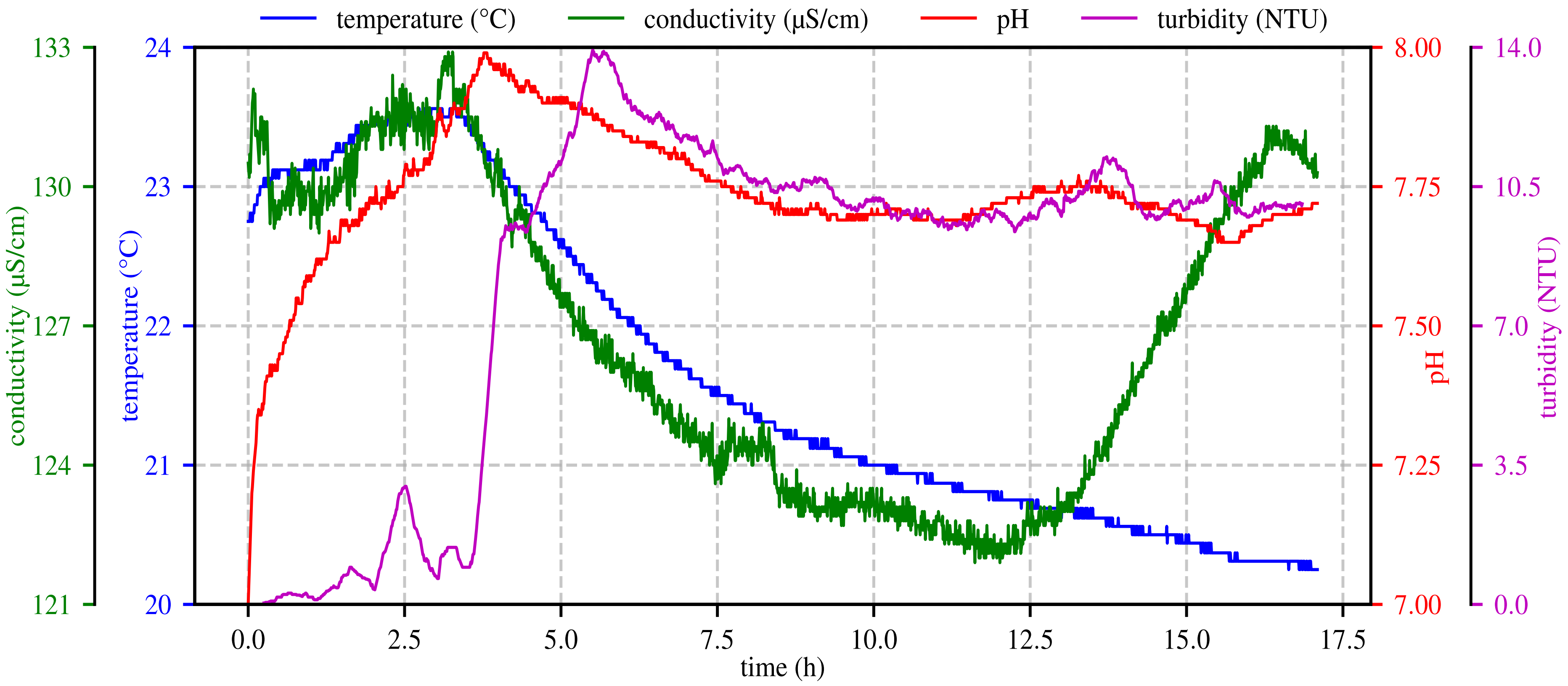
Deployment in an urban creek

- Experiment goal-
  - Check water quality parameters in local creek
  - Test variation in parameters over time
- Deployment time-
  - 4/3/2025 @ 2 pm EST.
  - Spring of 2025
- Duration- 17.5 hours
- Location-
  - Rocky Branch creek, downtown Columbia, South Carolina, USA.



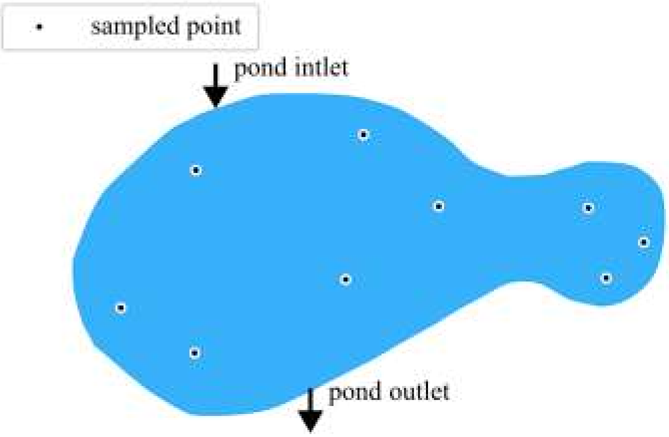
Data from urban creek

- Sensor node lasted for 17.5 hours on standalone power (no solar charging)
- Variations in pH, conductivity, turbidity and temperature demonstrates real-time changes in water quality detection
- pH, conductivity and turbidity exhibit a downward trend as night falls
- possibly indicating a change in the effluents in the water as work hours conclude.



Spatial mapping in an urban pond

- Nine-point spatial mapping conducted in A.C. Moore Garden pond using UAV-deployable sensor nodes
- Collected in-situ measurements of pH, temperature, turbidity, and total dissolved solids (TDS)
- Spatial distribution analyzed using Kriging interpolation, revealing localized variations linked to sunlight, algae, and organic matter



google.com/maps/place/A.C.+Moore+Garden/@33.995149,-81.0248008,133m

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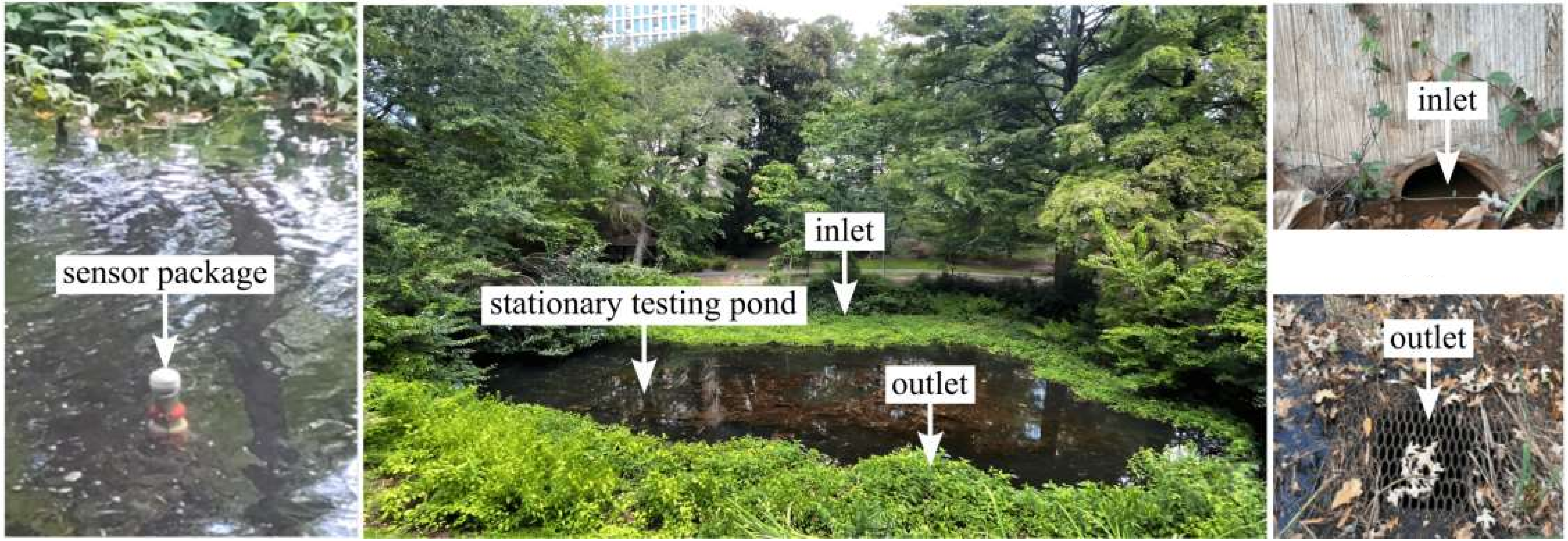
Spatial mapping in an urban pond

- Sensor package (without solar module) deployment test — buoyant module collecting data in a mostly stationary pond, with views of the pond's inlet and outlet.



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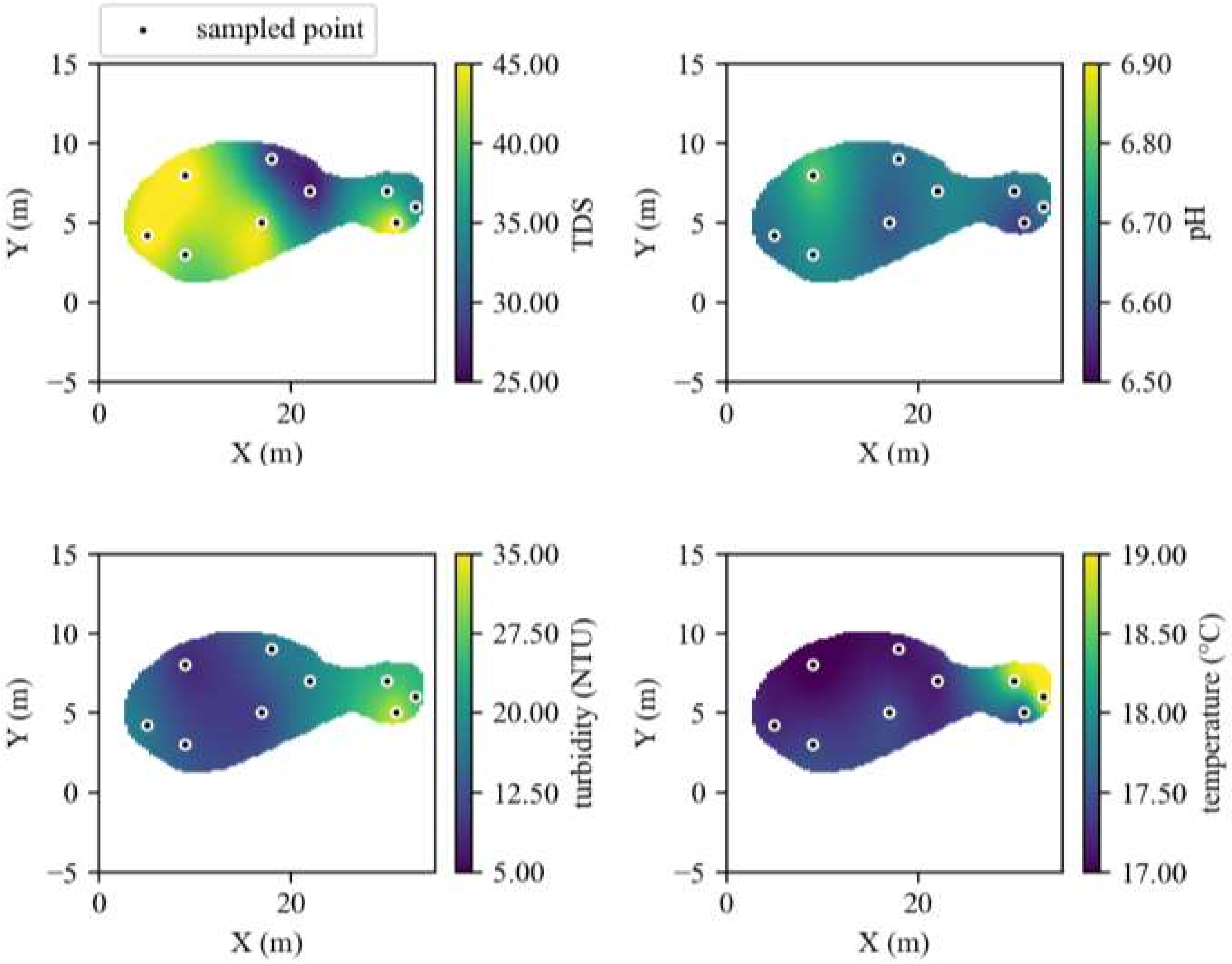
Spatial Results

- Kriging interpolation revealed spatial trends in pH, TDS, turbidity, and temperature across the pond
- Single sensor package was repositioned across sampling locations to collect spatially distributed data
- Detected gradients linked to environmental factors like sunlight exposure, algae presence, and organic debris



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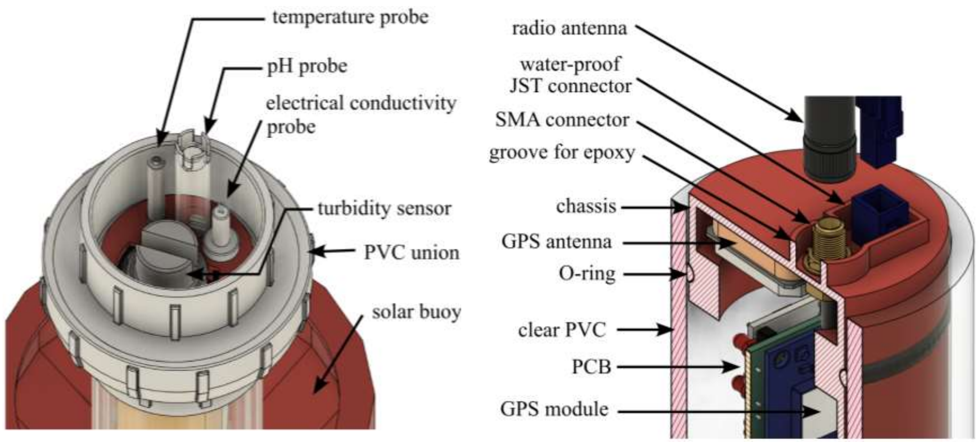
- A water quality sensing node equipped with GPS and wireless communication
- That is sustained by solar power
- Within reasonable accuracy compared to industrial sensors
- Future works will focus on developing a cluster of such sensing node that enables spatial and temporal mapping of large water bodies



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Thank You for Your Time

GitHub Repository

github.com/ARTS-Laboratory/In-Situ-Water-Quality-Sensor

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