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Arizona State University
School of Computing and Augmented Intelligence

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OpenIoTwx: A Low-Cost, Modular Platform for Real-Time Environmental Monitoring

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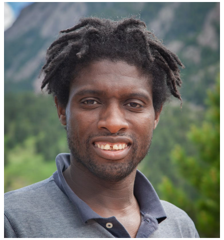
Motivation

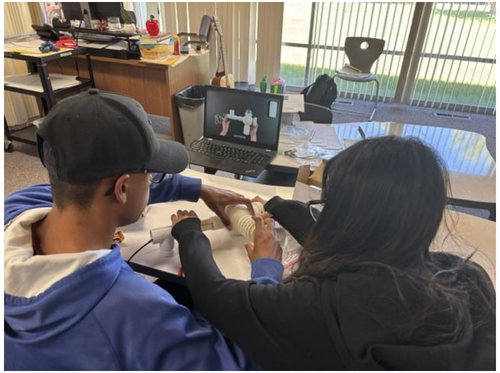
- Ground-level measurements complement satellite and model data by capturing real-time local conditions, especially in areas affected by extreme heat.

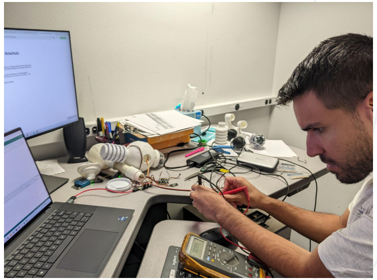
- However, many commercial weather stations are costly, difficult to customize, and require technical expertise.

- OpenIoTwx is a low-cost, modular IoT platform designed to simplify environmental monitoring.

History

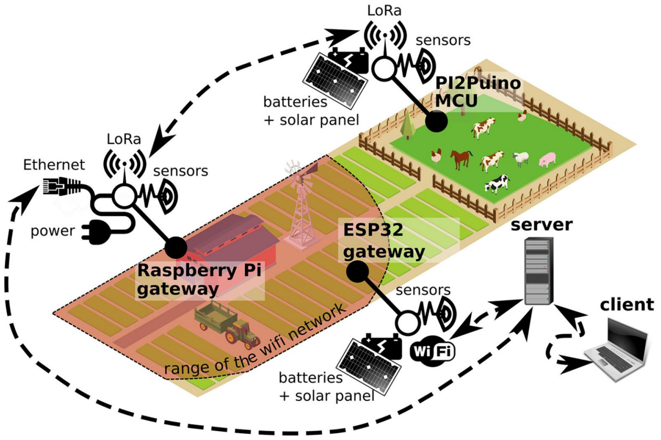






OpenIoTwx platform

- Low-cost, modular platform for real-time environmental monitoring.
- ESP32 Atom Lite / RP2040 collects data from connected sensors.
- Measurements are transmitted to a gateway, published through MQTT, and processed by cloud services.
- Sensors can be added or replaced without redesigning the station.



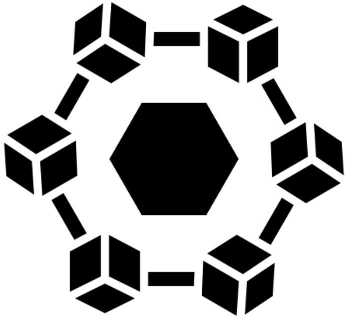
François Rebaudo et. al. 2023 *A low-cost IoT network to monitor microclimate variables in ecosystems*

Objective

- Develop a browser-based flashing and configuration wizard.
- Integrate RS485 wind speed and direction sensors.
- Design a modular 3D-printed globe thermometer.
- Estimate MRT using globe temperature, air temperature, and wind speed.
- Maintain compatibility with the existing OpenIoTwx cloud infrastructure.

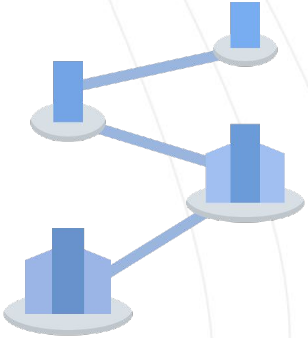
Design principles

Affordable



Modular

Accessible

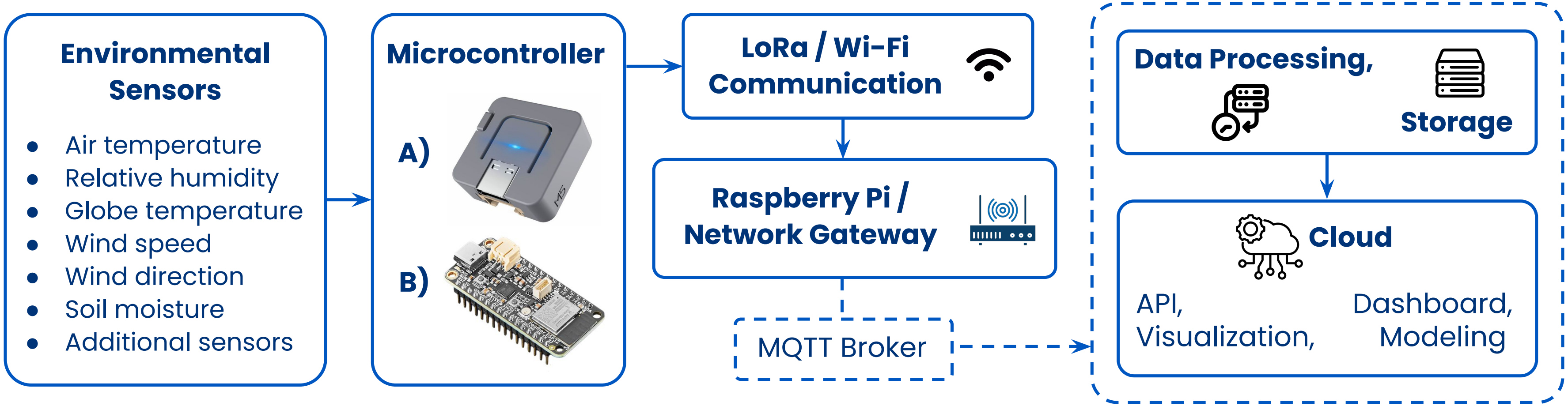


Scalable

Applications

- Weather and microclimate monitoring
- Outdoor heat-exposure assessment
- Air-quality monitoring and wildfire risk assessment
- Agricultural and ecological sensing
- Research and education

System Architecture



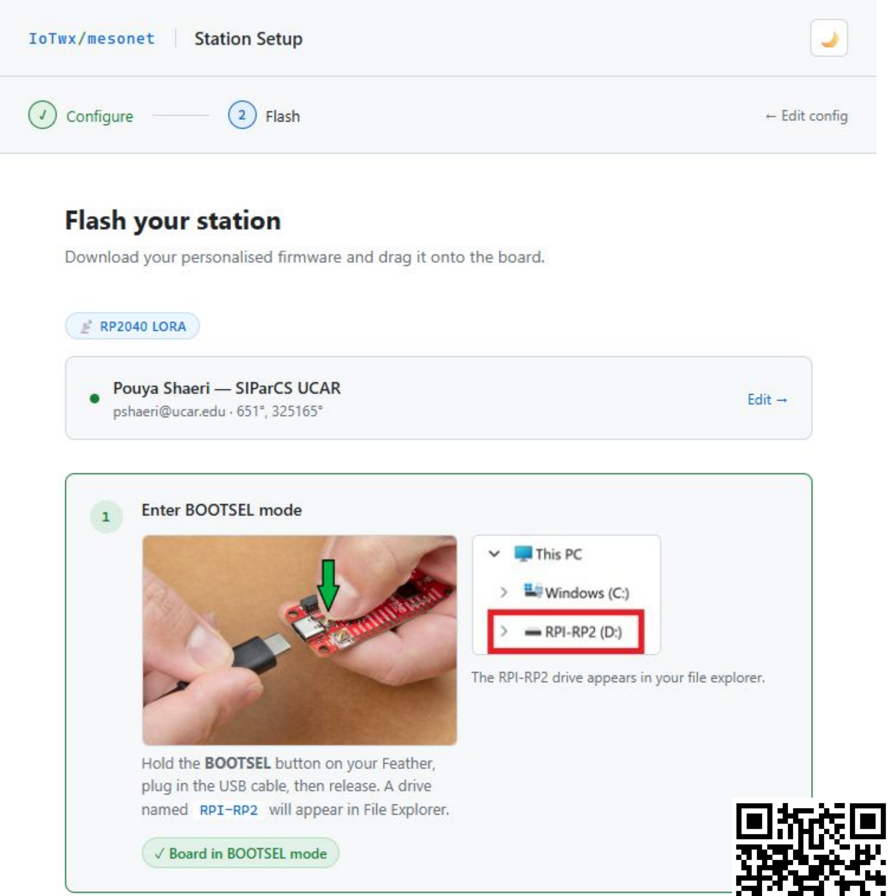
The OpenIoTwx System Architecture and Data Flow

Deployment workflow

1. The user selects the microcontroller and connected sensors.
2. Station, network, and sensor parameters are entered through the web wizard.
3. The microcontroller is connected by USB.
4. Compatible firmware is flashed directly through the browser.
5. Configuration information is written to the device.
6. The station collects and transmits environmental observations.
7. Measurements are processed, stored, and made available to downstream applications.

Web-based device setup

- Select the microcontroller and firmware
- Configure station, network, and sensors
- Flash the device directly through USB
- Reduce the need for programming experience



Wind sensor integration

- Measures wind speed and direction
- Validates and converts sensor responses
- Adds wind data to the transmitted payload
- Supports future third-party sensors

Globe Thermometer and MRT

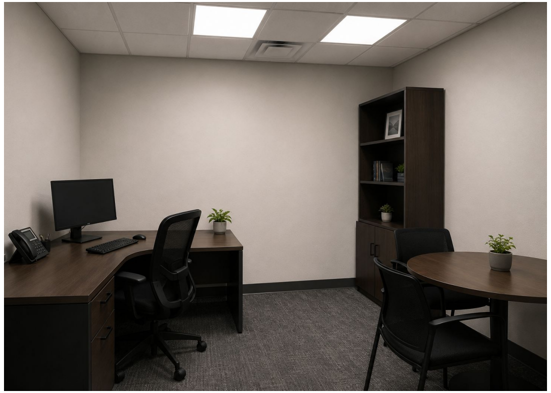
A 3D-printed globe thermometer was designed to measure globe temperature and estimate MRT using air temperature and wind speed.

$$T_{\mathrm{MRT}} = \left[(T_g + 273.15)^4 + \frac{1.1 \times 10^8 v_a^{0.6}}{\varepsilon_g D^{0.4}} (T_g - T_a) \right]^{1/4} - 273.15$$

Data | Sensor Table

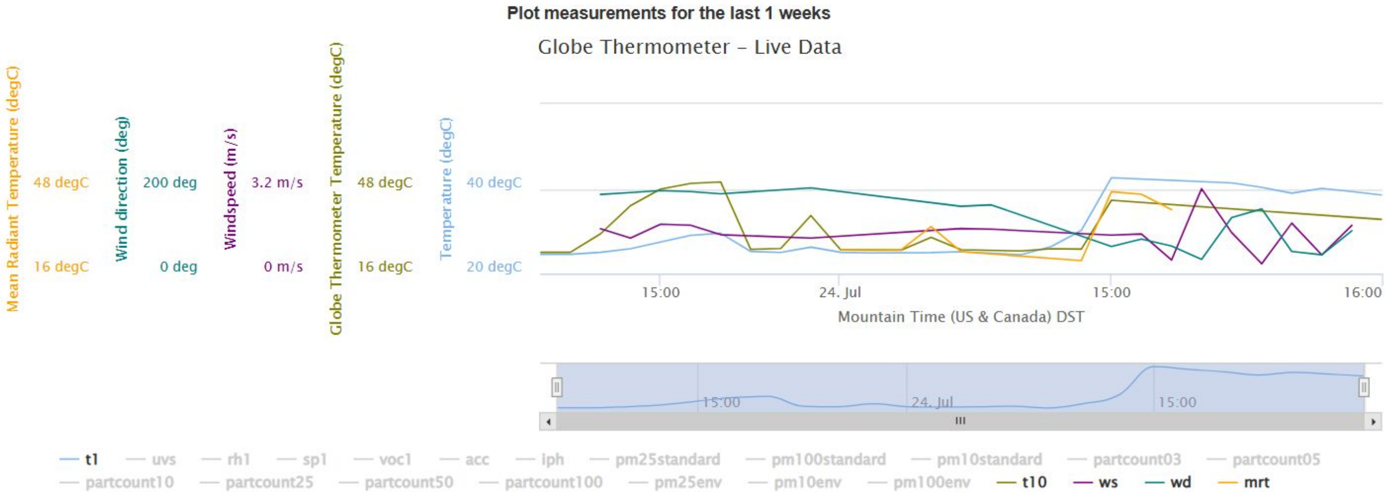
Sensor	**Measured Variables**	**Interface**
Si7021	Air Temperature, Relative Humidity	I2C
BME680 (Ambient)	Temperature, Humidity, Pressure, Gas Resistance, Altitude	I2C
BME680 (Globe)	**Globe Temperature, Globe Humidity, Globe Pressure, Globe Gas Resistance**	**I2C**
TMP117	High-precision Air Temperature	I2C
LTR390	UV Index, Ambient Light	I2C
PM25AQI (PMSA003I)	PM1.0 / PM2.5 / PM10, Particle Counts	I2C
SCD40	CO2, Temperature, Relative Humidity	I2C
PA1010D	GPS Latitude/Longitude, Timestamp	I2C/UART
RG15	Rainfall (event, accumulated, total), Rain Intensity	UART
WS302 Anemometer	**Wind Speed, Wind Direction**	**RS485/Modbus**

Experimental Setup & Results

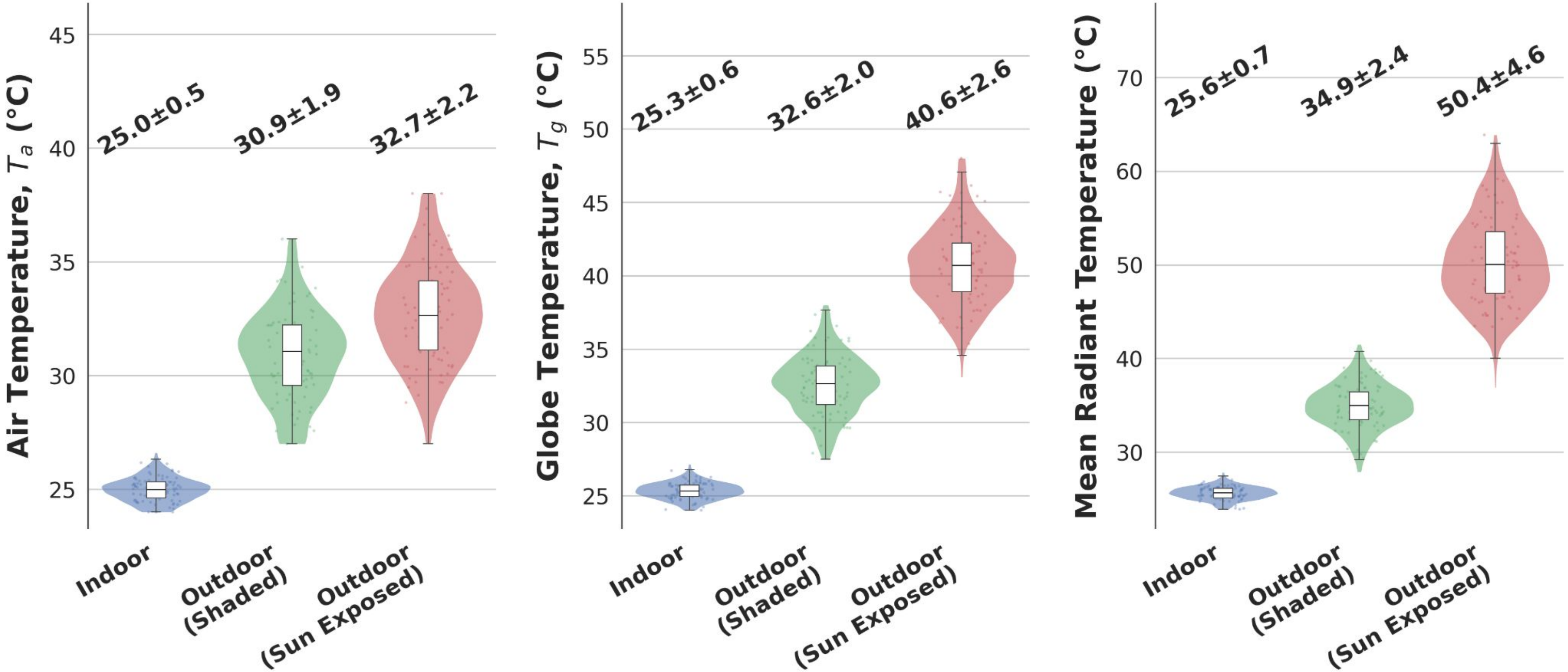
Scenario A	Scenario B	Scenario C
		
Indoor	Outdoor Sun Exposed	Outdoor Shaded

SYSTEM DEMONSTRATION

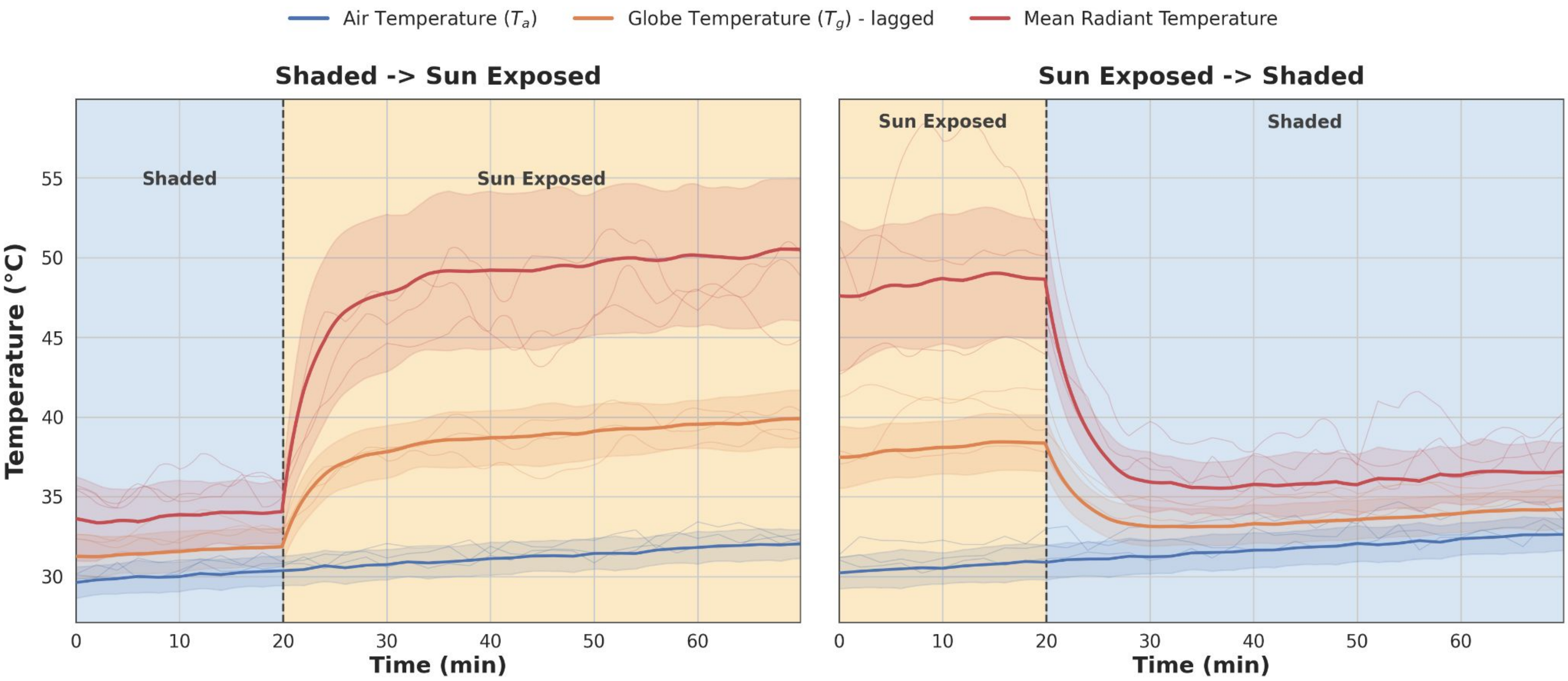
- Environmental measurements were successfully collected and transmitted through the IoT pipeline.
- The data payload included air temperature, globe temperature, wind speed, wind direction, and calculated MRT.
- Measurements were stored and displayed through the OpenIoTwx cloud services.



Radiant Divergence: Air, Globe, and Mean Radiant Temperature Across Exposure Conditions



Thermal Lag of the Globe Thermometer During Shade–Sun Transitions



Future Works

- Deploy OpenIoTwx stations in Arizona communities affected by extreme heat and heat stress.
- Web app flashing tool integration into CIRRUS mesonet data management system
- Integration with GDEX and expand the codebase to support additional environmental sensors.
- Calibrate and validate the globe thermometer and wind sensor against reference instruments.
- Improve weather resistance and long-term outdoor reliability.

Conclusion

- This project developed a browser-based wizard for flashing and configuring OpenIoTwx devices,
- integrated RS485 wind sensing and third-party sensors, and added a 3D-printed globe thermometer for MRT estimation.
- These improvements make the platform more accessible for research, education, community monitoring, and heat-exposure studies.

Thank you

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