# WeatherChimes

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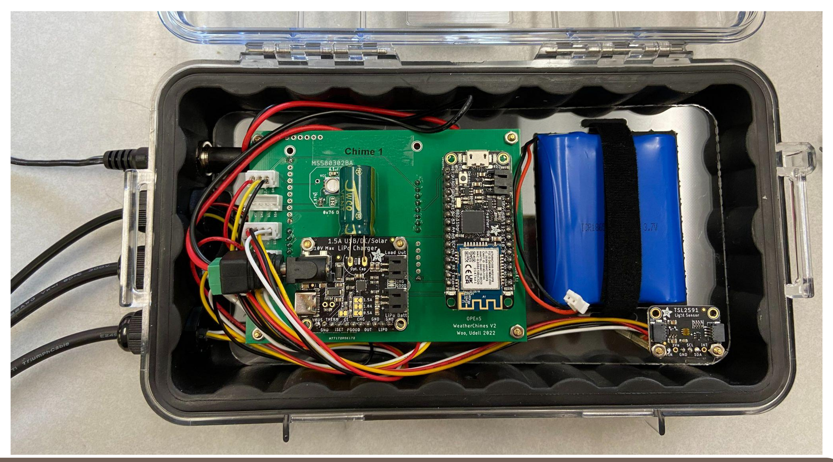
OPEnS

## ABSTRACT: Open IoT Weather Station and Data Sonification System

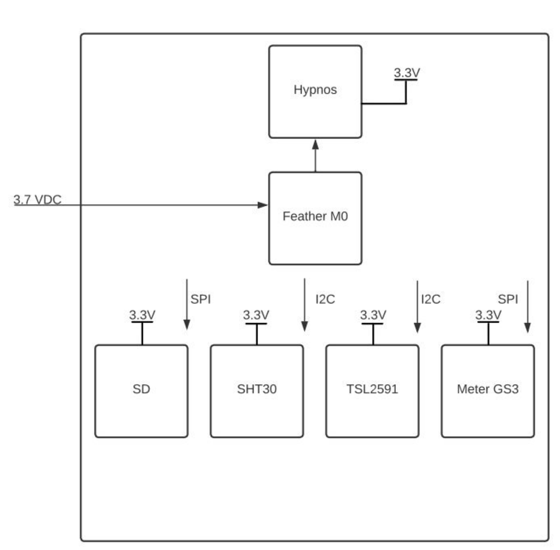
WeatherChimes is an open-source Arduino-programmable, low-cost hardware and software suite that enables real-time access to in-situ environmental sensor data (including light, temperature, relative humidity, and soil moisture) anywhere with a WiFi or 4G internet connection. It also provides applications that translate the data into alternative sensory signals (sound, music, digital art) that enable new insight into natural phenomena and new modalities to monitor and explore these data spaces. Each *Chime* can measure soil moisture, soil temperature, air temperature and humidity, and solar luminosity, and log data over user-specified intervals online to MongoDB. The Chime is intended to last for 27 days at 15-min sample periods. Addition of a solar cell was accomplished, which can extend operation indefinitely A WiFi-only version of an older model is currently "under review for publication" through HardwareX

*Completed WeatherChimes device >>*



## PURPOSE

Each Chime can measure soil moisture, soil electrical conductivity, and soil temperature (Meter GS3); air temperature and humidity (SHT31/SHT30); and solar luminosity (TSL2591), and log data at user defined intervals to the cloud database: MongoDB. Beyond the sensors used in this paper, the Chime is capable of using a variety of analog, digital, I2C, SDI-12, and other serial sensors via footprints on the Printed Circuit Board (PCB) .
WeatherChimes logs real-time sensor data to an internal SD memory card and via network to the MongoDB online database. Typical IoT systems conclude their operation chain at the database layer for plotting and downloading data reports. WeatherChimes goes a step further by incorporating novel data sonification and visualization applications that pull data from MongoDB using NodeJS into a platform called Max8.




*Block diagram of WeatherChimes electronics*

*A Chime installed outside Sitka Sound Science Center*

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***Website/Projects:***
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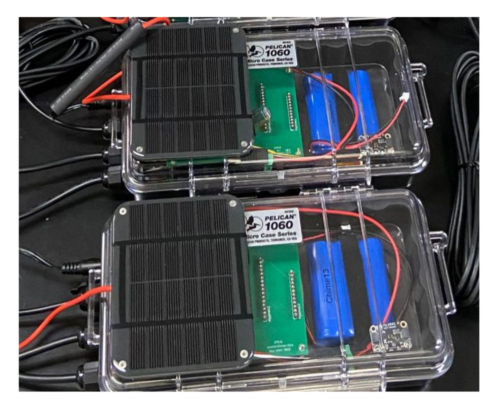
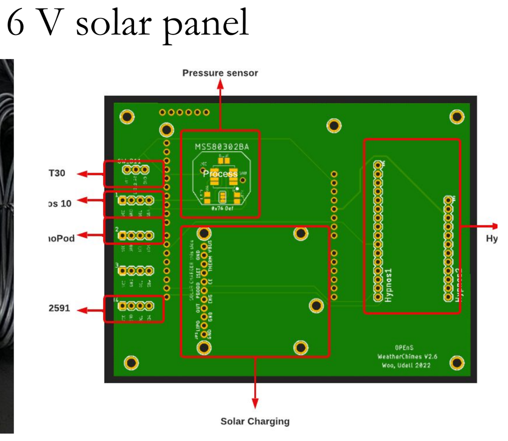
## COMPONENT BREAKDOWN

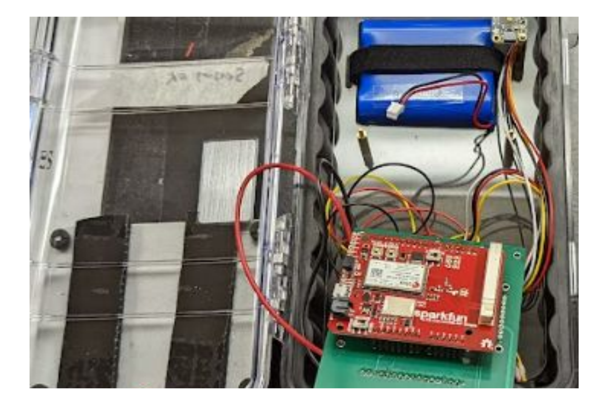
- Adafruit Feather M0 WiFi - Microcontroller used to execute code and orchestrate other components.
- LTE board - 4G capabilities for real-time data
- Hypnos - PCB used for time keeping, data-logging and power management.
- TSL2591 - Collects infrared, visible and full-spectrum light.
- Teros 12- collects soil electrical conductivity, soil moisture (volumetric water content) and temperature.
- SHT30 - Collects temperature and humidity.
- 10500 mAh Battery - Provides power to the unit.
- 3D printed components - Base plate for holding components together.
- Pelican case - Used as a waterproof container for electronic components.
- Osmopod - Measures pressure and that can be used to calculate the water levels
- Solar Panel - 6 Watt, 6 V solar panel



*Solar panel velcroed on Pelican 1060 case*




*Top view of the PCB*

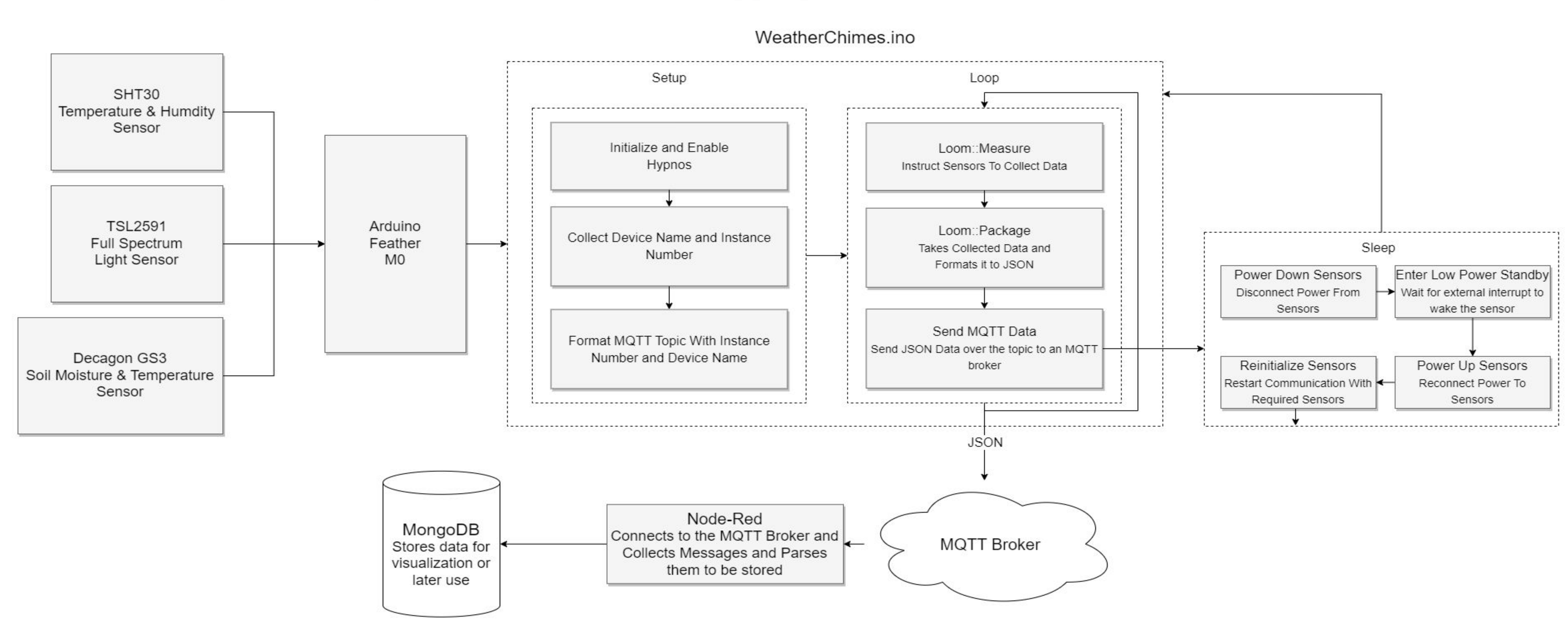


*4G LTE board on the underside of the PCB*

## METHODS: OPERATION

The WeatherChimes system operates by:

1. Locating an area where the device enclosure can receive enough sunlight for the light sensor and solar panel.
2. The SHT sensor should be installed ideally vertically to the ground to measure and log data properly. The Teros 12 sensor needs to be inserted horizontally into a 6 in. hole with the long side of the white sensor body vertical and the cable at the top.
3. The barrel jack for the solar panel needs to be plugged into the solar charger.
4. The Osmopod can be dropped into a bucket of water to measure water levels.
5. After battery is plugged in, verifying that the WiFi light on the Feather & Hypnos LED flashes. Log into MongoDB to verify data with appropriate values.

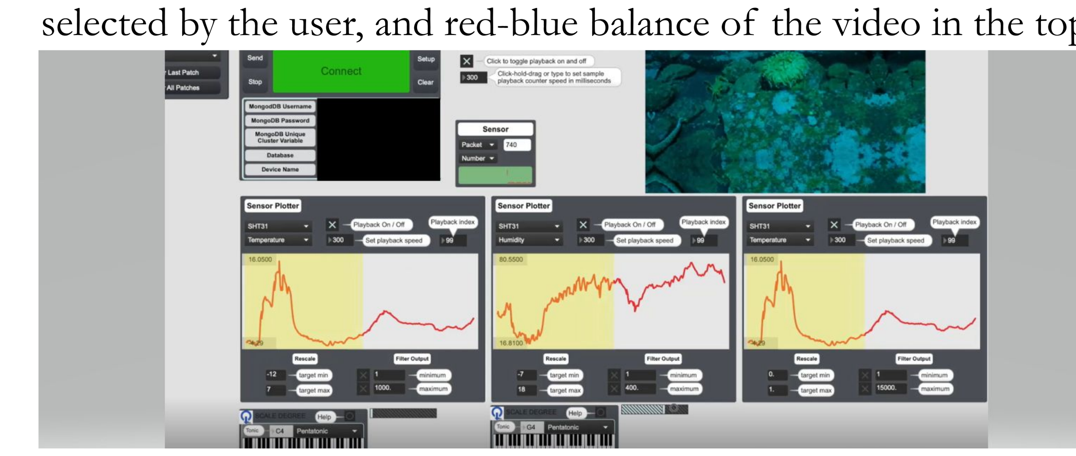



*Data handling flowchart for WeatherChimes*

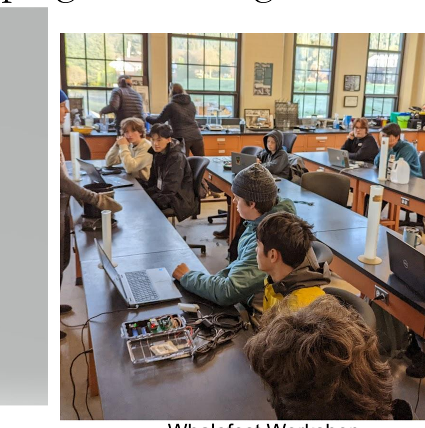
The Feather WiFi first requests data from the sensors and locally stores that data. After sensor information has been collected, the Feather will initiate a message to a remote MQTT server that is being run locally on an OSU server utilizing the Mosquitto broker. Once we have the data from the broker within Node-Red we can parse from the database and collection name and push to MongoDB. Once the data is within MongoDB, Max8 (by Cycling'74) allows us to handle all communication between Max8 and MongoDB, which opens up numerous possibilities for manipulating and utilizing the data received.

## Whalefest Workshop (Sitka, Alaska)

WeatherChimes was demonstrated at the Whalefest Workshop at the Sitka Sound Science Center November 2022. Participants used 13 kits connect to MongoDB using our custom applications in Max8, which establishes a connection with specific MongoDB data clusters based on credentials provided by the user. The Max8 Sensor Plotter interfaces below show plots for the SHT30 air temperature (left and right graphs) and relative humidity (middle graph) data over the requested 48-hr period. Keyboard boxes translate the graphs into melodies based on a musical scale and key selected by the user, and red-blue balance of the video in the top right of the figure.

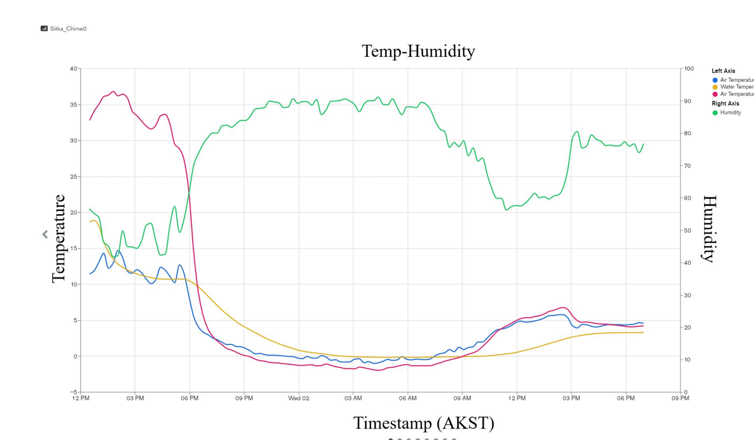


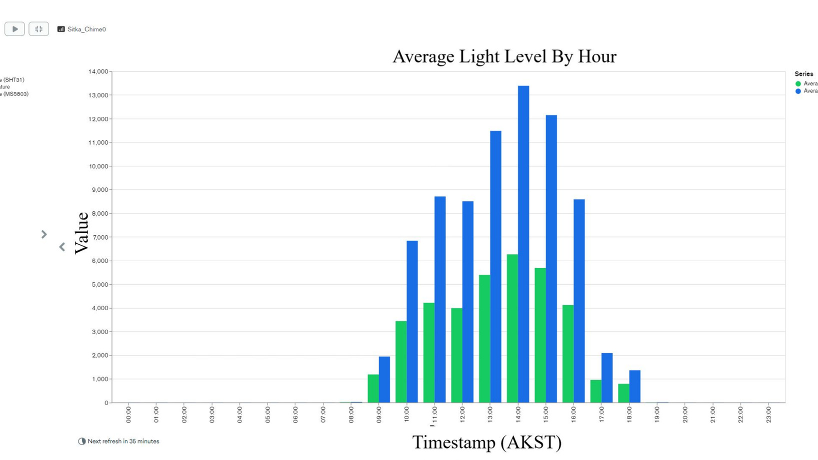
WeatherChimes interface showing data plots from the Sitka Sound Science Center



Whalefest Workshop

## RESULTS: MongoDB Charts




## CONCLUSIONS: FUTURE DIRECTION

WeatherChimes demonstrates an open-source option for advancing in-situ data-driven science, automating measurement tasks, uploading and accessing data directly over servers online to decrease the need to interact with field sites to retrieve data and monitor system performance. It also extends these applications to represent and explore data through other modalities for educational purposes. Workshop participants reported the sonification and visualization exercises provided an insightful and engaging introduction to environmental sensors and experiencing their interrelationships using multiple senses. One user shared that hearing something like temperature expressed as a melody turned observing data on a plot into a "time-based experience," becoming more aware of nuances of movement as the temperature unfolded. Another participant shared that being able to choose the scale of the melody to determine if it sounded happy or sad prompted them to think carefully about the meaning we ascribe to data and why we use data to communicate with others. Further exploration is needed to determine if integrating sonification and alternative visualization tools also yield insights into data research that could not be as easily perceived from a graph at a glance, to help researchers relate with and ascribe meaning to the data in new ways

## ACKNOWLEDGMENTS

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