Low-Cost Crowdsourcing Sensor Package for Drought-Related Decision Making

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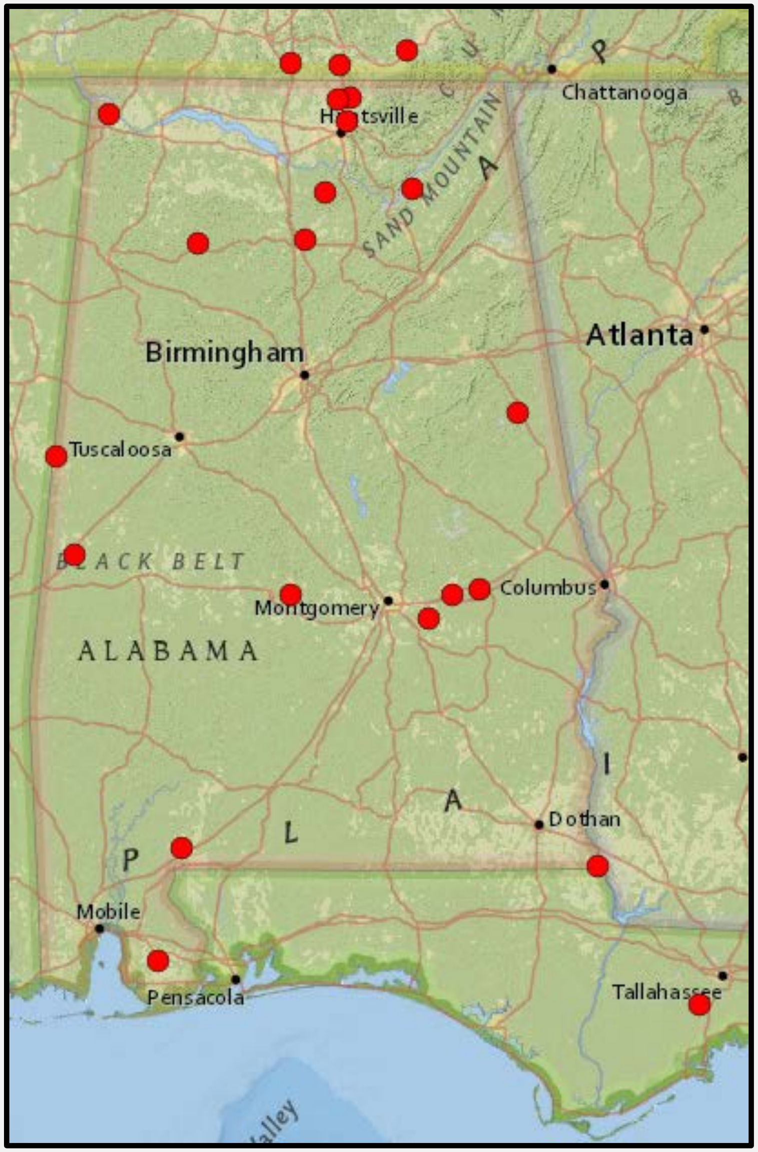
Motivation

- Drought-related decision making requires knowledge of crop stress, rainfall and soil moisture
- Soil moisture monitoring networks are sparse, for example the State of Alabama has ~16 soil moisture monitoring sites
- Satellite soil moisture retrievals are limited to 35-60 km resolution.

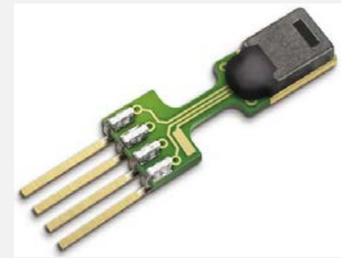


https://www.wcc.nrcs.usda.gov

Motivation

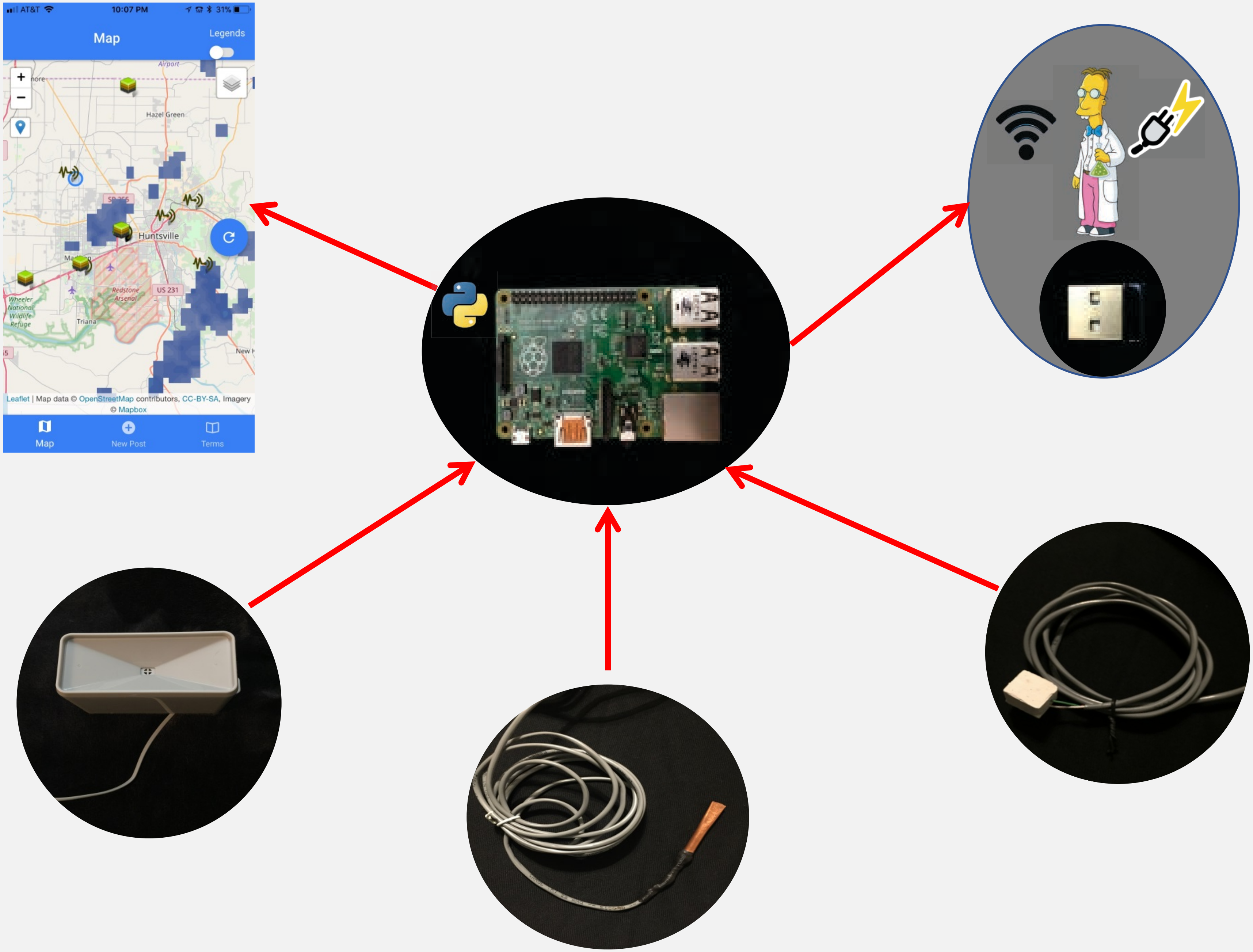
- Advent of inexpensive microprocessors systems and sensors presents opportunity for crowdsourcing of rainfall, soil moisture and soil temperature observations

- We examined the feasibility of developing inexpensive sensor nodes that monitor these variables and integrate the observations into mobile applications that assist decision makers



(left) Arduino Mini. (right) SHT75
(bottom) Raspberry Pi

Sensor System Overview



Soil Temperature Sensor- DS18B20

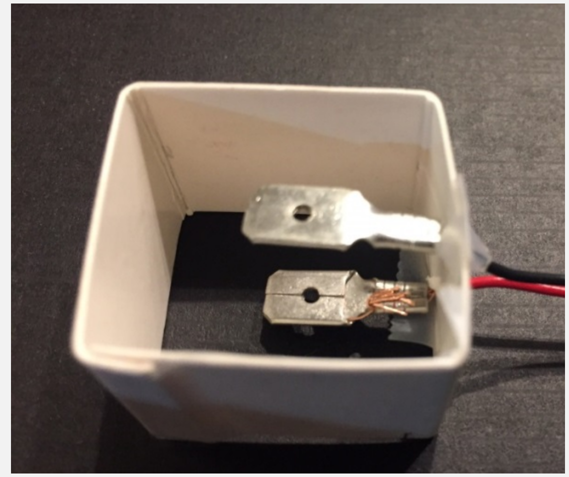
- Soil temperature sensor is constructed from one wire digital temperature sensor DS18B20.
- Sensor is soldered to a 3 wire cable and each lead of the chip is insulated heat shrink tubing.
- The sensor is then placed within copper tubing and the other side of the tube is hammered to make it water proof.
- The end of the tube where the chip is inserted is water proofed using silicone and then enclosed within heat shrink tubing (Cost ~ $5)

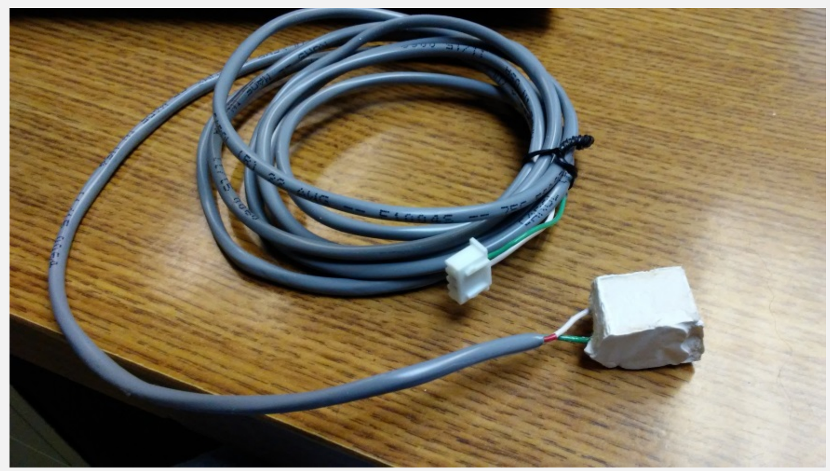
Rainfall - Argent Data System Tipping Bucket Rain Gauge

- COTS sensor, with 0.011 inch resolution (Cost ~$11).
- Tips are sensed as switch activation and counted by the Pi

Design – Gypsum Sensor

- Gypsum blocks moisture content in equilibrium with surrounding soil.
- Measure voltage across probes and convert to resistance.
- Resistance of gypsum block inversely proportional to soil water content.
- Sensitivity greatest in dry soil conditions such as during drought.





(top) Gypsum mold. (bottom) Gypsum sensor.

Design – Gypsum Block Calibration

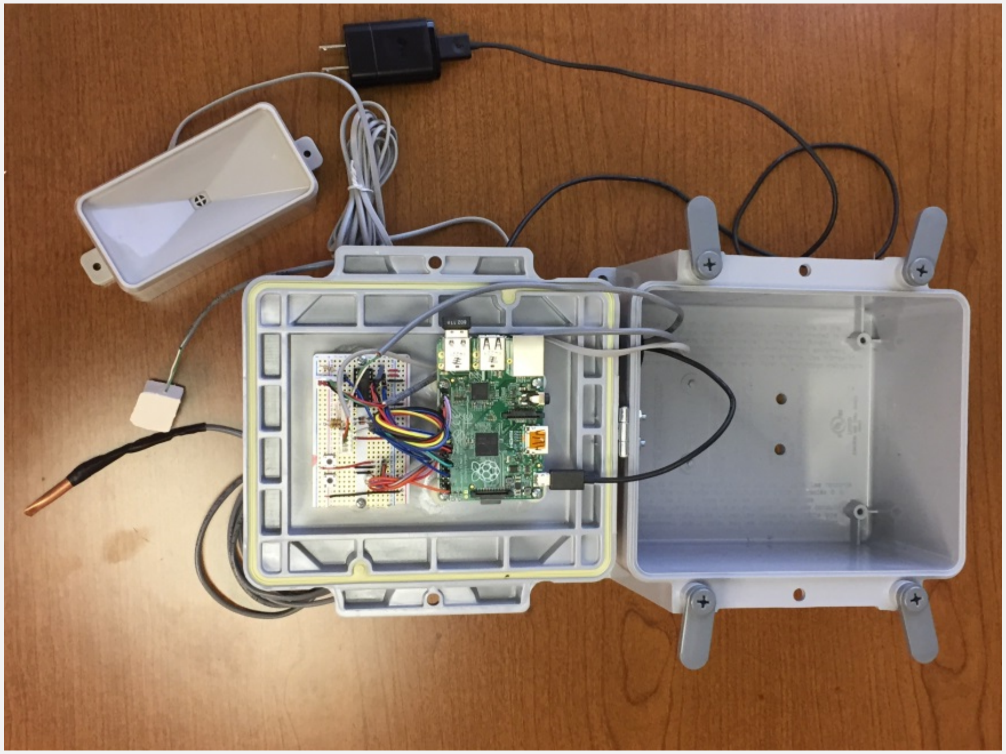
- Resistance of gypsum block is both a function of temperature and moisture. Following Keyhani (2000), resistance of the gypsum block for standard temperature of 15 ^{0}C: $R_{15} = \frac{R_T}{K_1 R_T + K_2 T + K_3}$, where K_1, K_2 and K_3 are constants, R_{15} and R_T are resistances at 15 ^{0}C and arbitrary temperature of T ^{0}C respectively.

- The constants K_1, K_2 and K_3 can be determined using six resistance measurements made for constant soil moisture conditions. Three of these measurements are made at temperature of 15 ^{0}C and the other three for a differing temperature. A system of linear equations may be used to solve for K_1, K_2 and K_3

- Volumetric soil moisture is given by $W = aR_{15}^{-b}$, where the constant a is dependent on soil type and $b \sim 0.156$

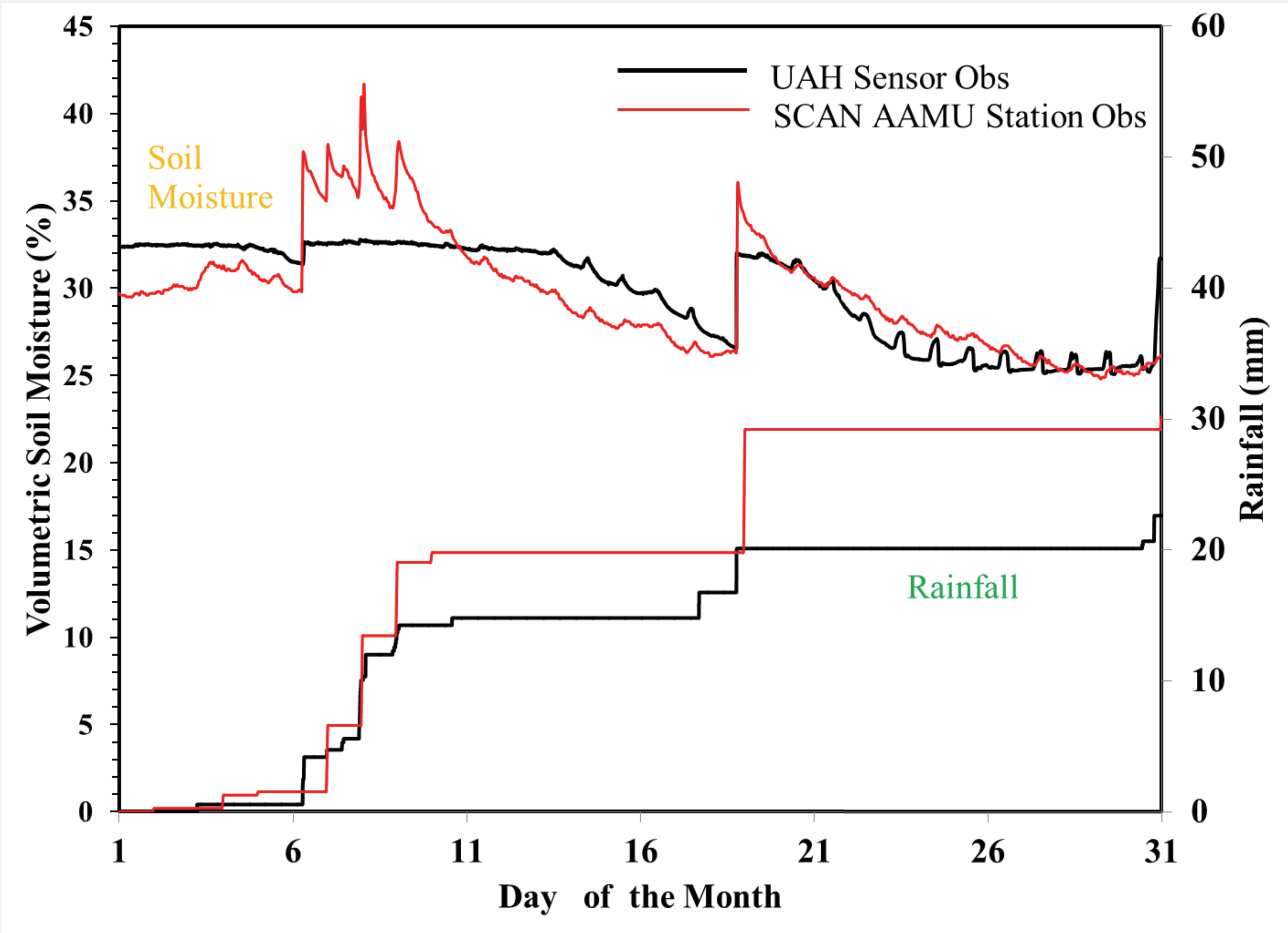
Design - Station

- The Raspberry Pi ($35) and sensor circuity are placed in a hinged NEMA enclosure ($10) and cables are routed through a waterproof cable gland ($3).
- System connects to internet using WiFi and periodically uploads data to Amazon Cloud Services

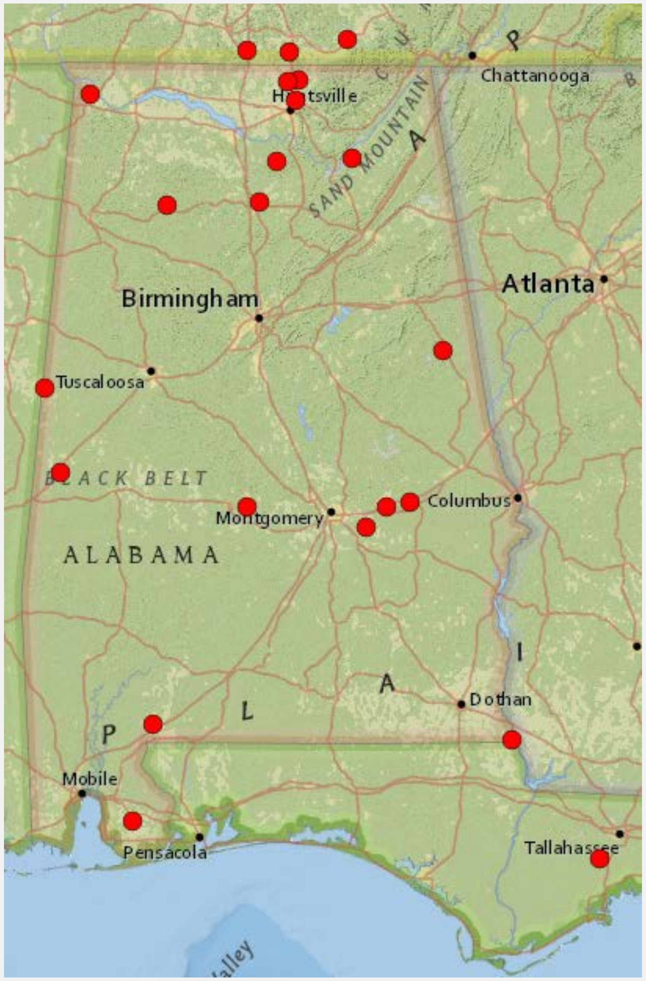


Soil Moisture Station

Comparison to Observations from local SCAN Station November 2017



Network

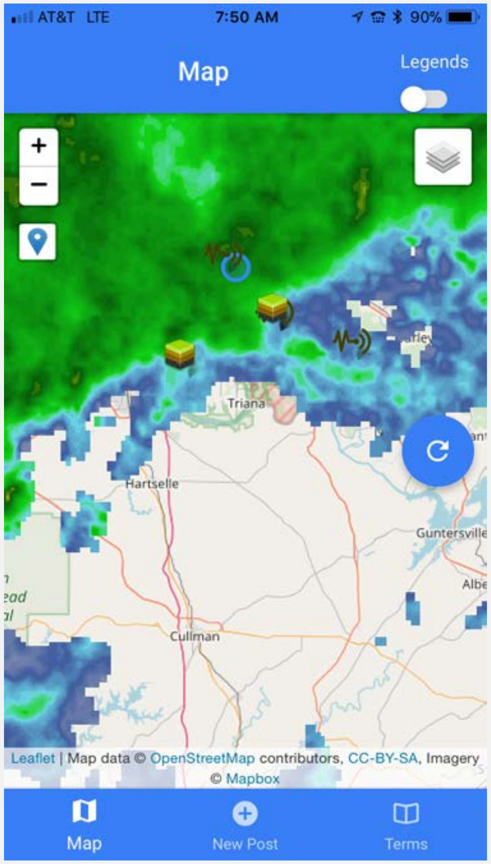


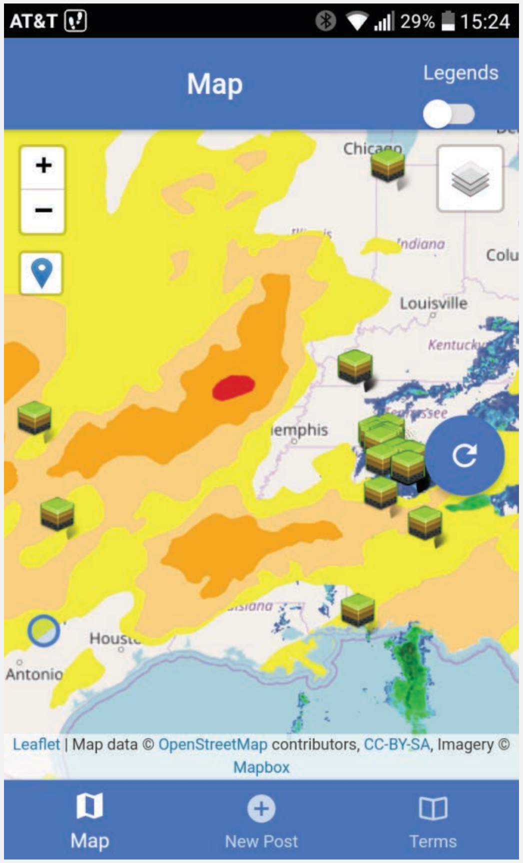
Locations of SCAN network soil stations.

- Soil Climate Analysis Network (SCAN) hosts 16 stations in Alabama.
- Our preliminary goal is 30+ stations across Alabama.
    - Currently have six near Huntsville.
    - 30 stations cost less than $4000 (~$130 per station).
- Commercial soil monitoring stations are more than $200 each.

Broader Impacts - Collaboration

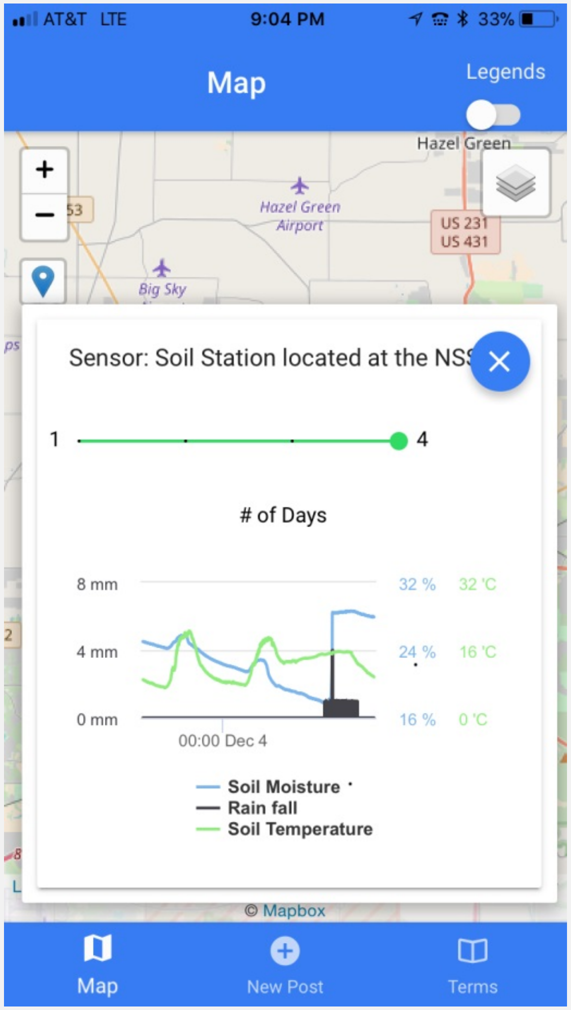
- Partnership with NASA Short-term Prediction Research and Transition (SPoRT) Center
  - Integration into drought monitor data stream
  - Inclusion in NASA "Drought Information Supported by Citizen Scientists" (DISCS) smartphone app.



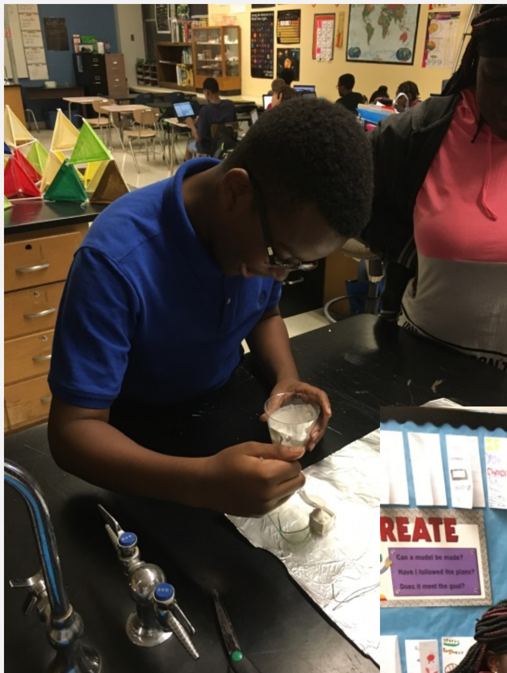


Broader Impacts - DISCS

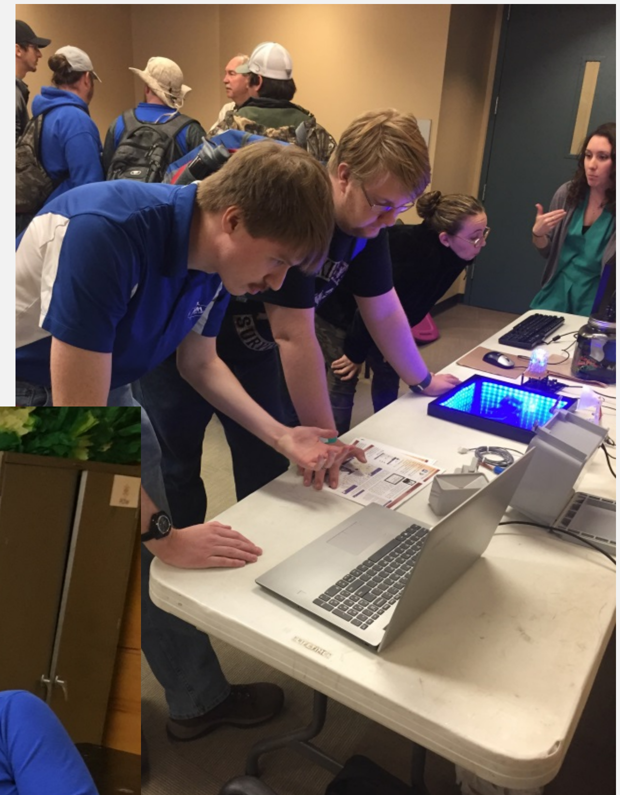
- App developed by NASA SPoRT
  - Available for iOS and Android.
  - Crowd-sources agricultural monitoring
  - Dissemination of drought related observations such as cumulative rainfall and soil moisture.
  - Capability to link station data feeds for public viewing.

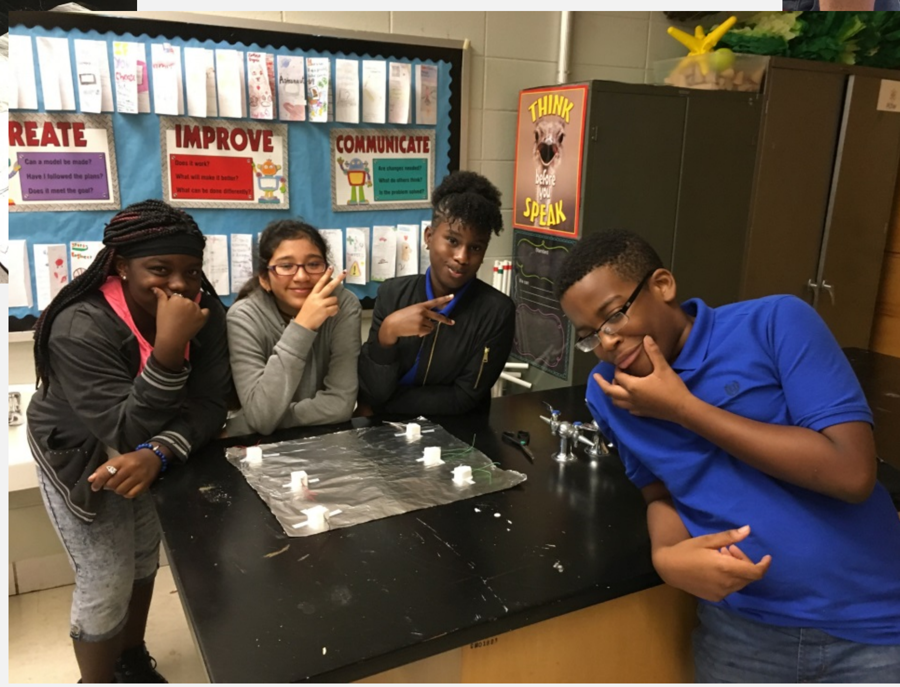


Broader Impacts - Outreach



(left) Student creating soil moisture sensor.
(bottom) Students posing with finished sensors.
(right) University outreach program to local schools.





Broader Impacts - Outreach

- Public availability of NASA DISCS app increases outreach opportunities at local schools.
- Students have ability to monitor *their* station in real-time.
  - Tie-ins with physical science education
  - Opportunity to measure hydrological cycle components such as rainfall and soil storage to deduce runoff.
  - Multiple sensor attachment points allow for experimentation with soil cover. Does bare soil or vegetation produce more runoff?
- Ability to see other schools' stations emphasizes science as a team effort.
- Hands-on learning enhances skills that bring the student to a STEM career.

Conclusions

- Low cost sensor nodes for soil moisture monitoring have been developed.
- Initial results show ability of sensor nodes to realistically capture soil moisture drying trends
- The system is automated and the data is available operationally though decision support tools
- Due to low costs, it is possible to construct high density networks
- The network is being utilized for STEM education in schools.

Acknowledgements

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