IN027-05: A Sensor Network for Microclimatic Soil Variables on the Alpine Tundra

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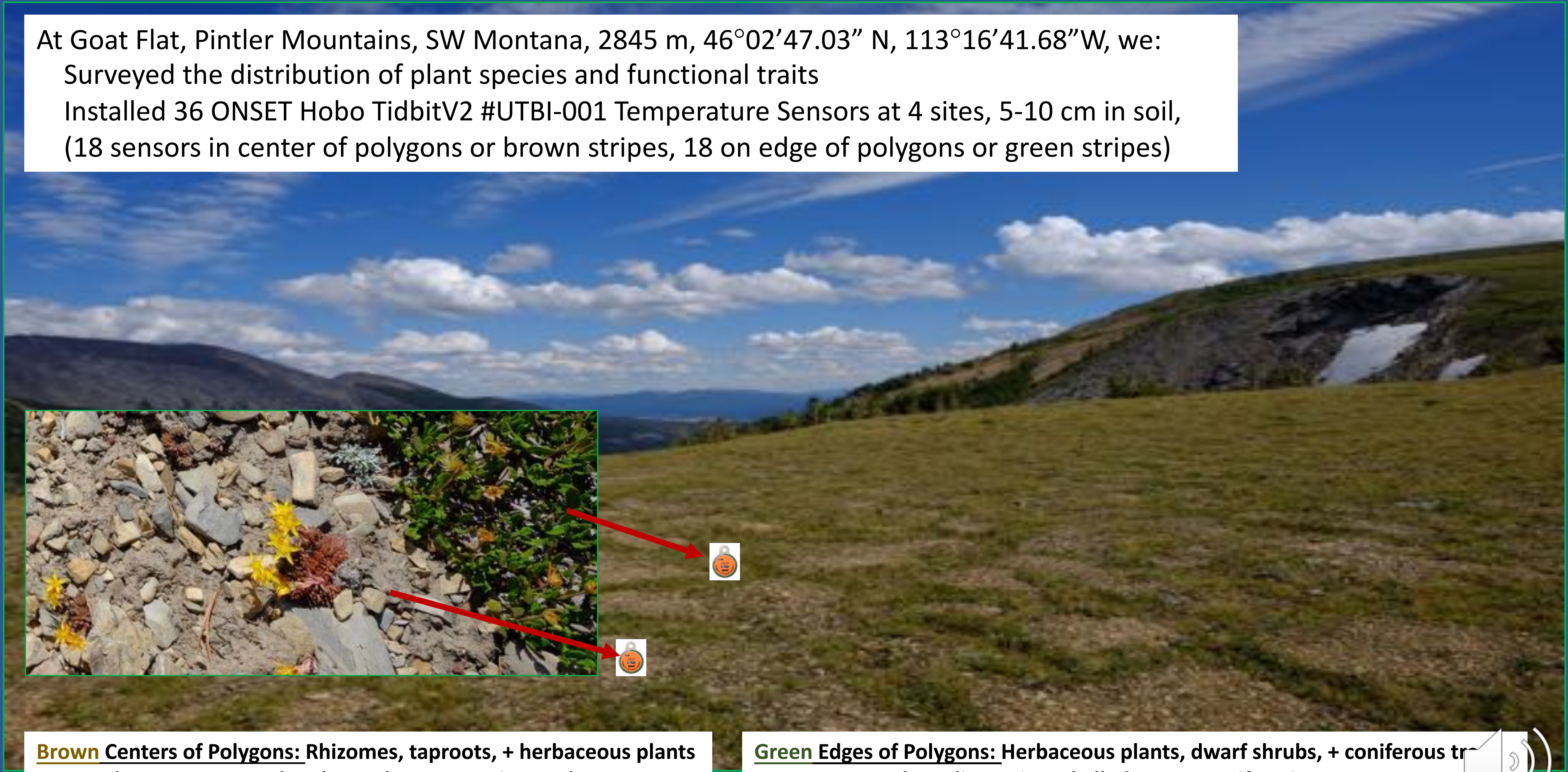
Alpine Plant Ecology and Environmental Sensing

1. Plant functional traits vary with position on periglacial patterned ground and near snowfields in the alpine tundra.
2. Periglacial patterned ground provides a mosaic of microhabitats.
3. Environmental sensing links plant functional traits with environmental signals.
4. We installed an array of soil temperature sensors but can only retrieve data at the sites.
5. Our alpine tundra sites are in the wilderness, have harsh winters, and are accessible only in late summer.
6. Research could be scaled up with wilderness-ready soil moisture sensors and with remote and year-round access to data.
7. We are developing a sensor system to send soil data to the internet via Iridium satellites.

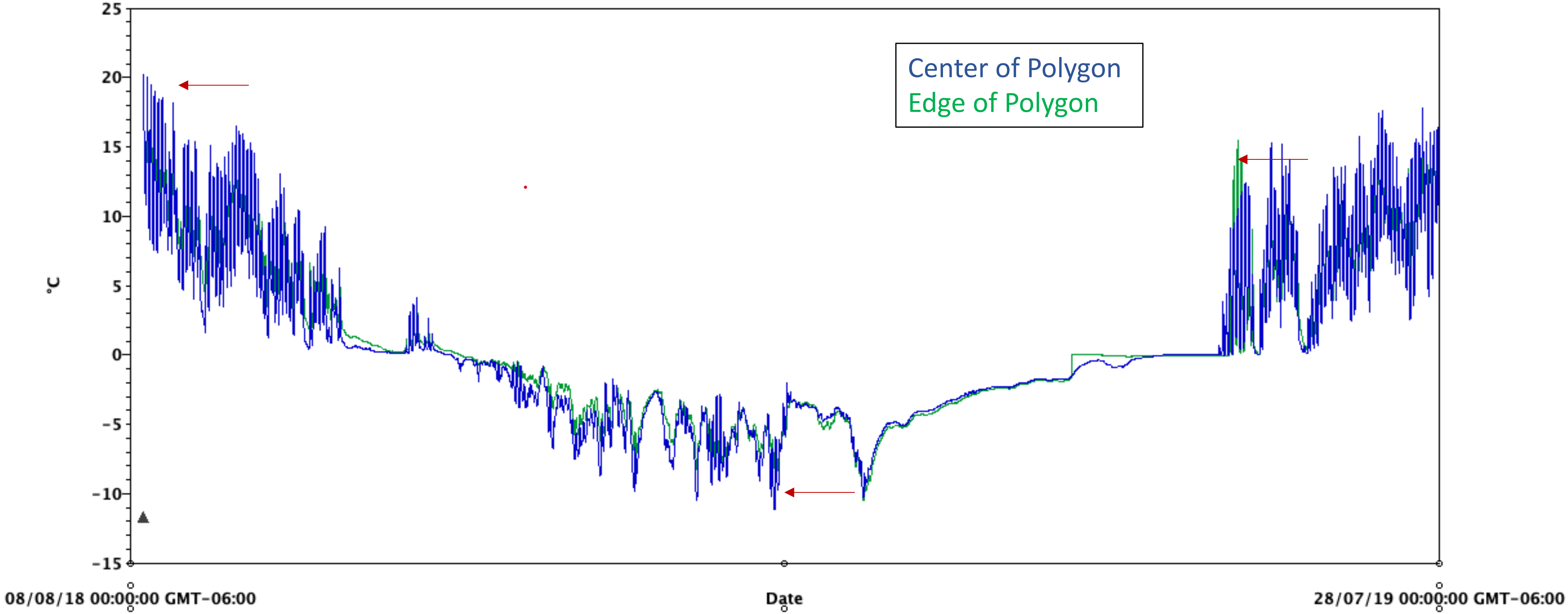
At Goat Flat, Pintler Mountains, SW Montana, 2845 m, 46°02’47.03” N, 113°16’41.68”W, we:

- Surveyed the distribution of plant species and functional traits
- Installed 36 ONSET Hobo TidbitV2 #UTBI-001 Temperature Sensors at 4 sites, 5-10 cm in soil, (18 sensors in center of polygons or brown stripes, 18 on edge of polygons or green stripes)



Brown Centers of Polygons: **Rhizomes, taproots, + herbaceous plants**
Astragalus sp., Carex, Sedum lanceolatum, Gentiana calycosa

Green Edges of Polygons: **Herbaceous plants, dwarf shrubs, + coniferous tr**
Dryas octopetala, Salix arctica, Phyllodoce empetriformis,

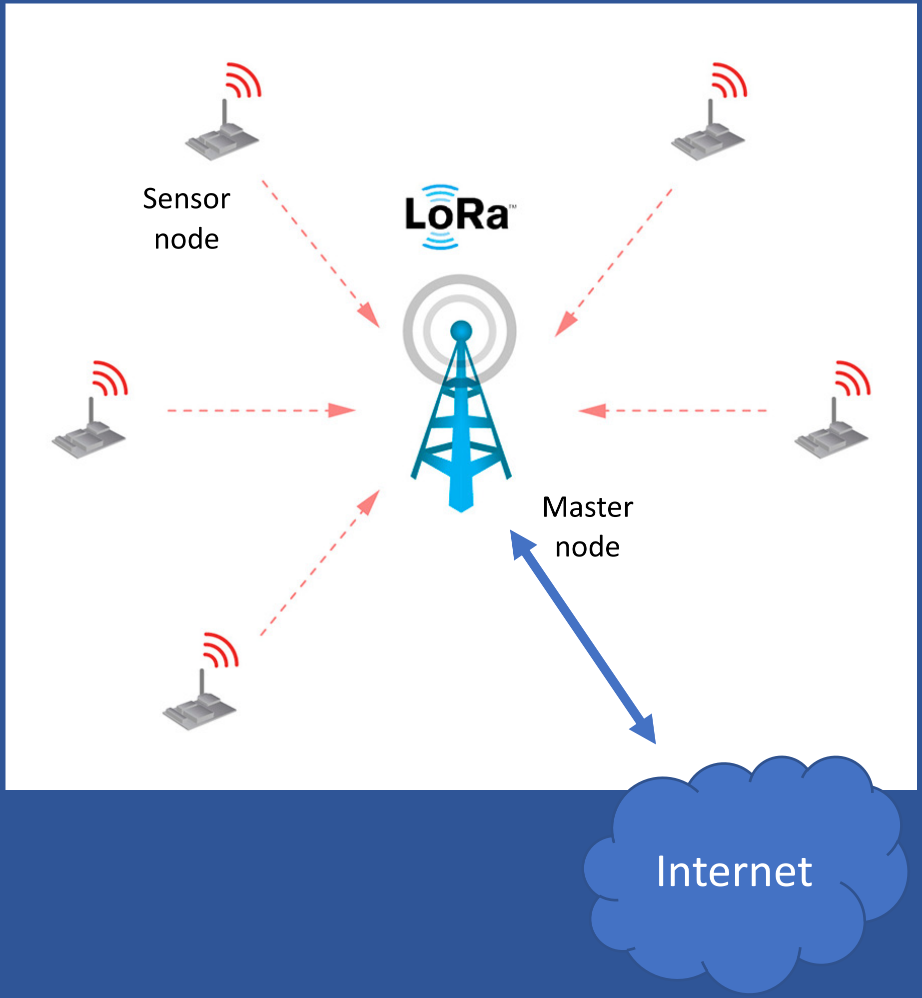


Center of Polygon
Edge of Polygon
25
20
15
10
5
0
-5
-10
-15
°C
08/08/18 00:00:00 GMT-06:00
Date
28/07/19 00:00:00 GMT-06:00

In the sensor development project :

- We are developing prototype soil moisture sensors for year-round use on the alpine tundra
- Sensors will be underground and not susceptible to wind and animal damage
- Sensor data should be remotely accessible throughout the year
- Data will be gathered from ~10 locations at the study site
- Data will be sent to a data store accessible via the Internet.

Sensor Network: Topology



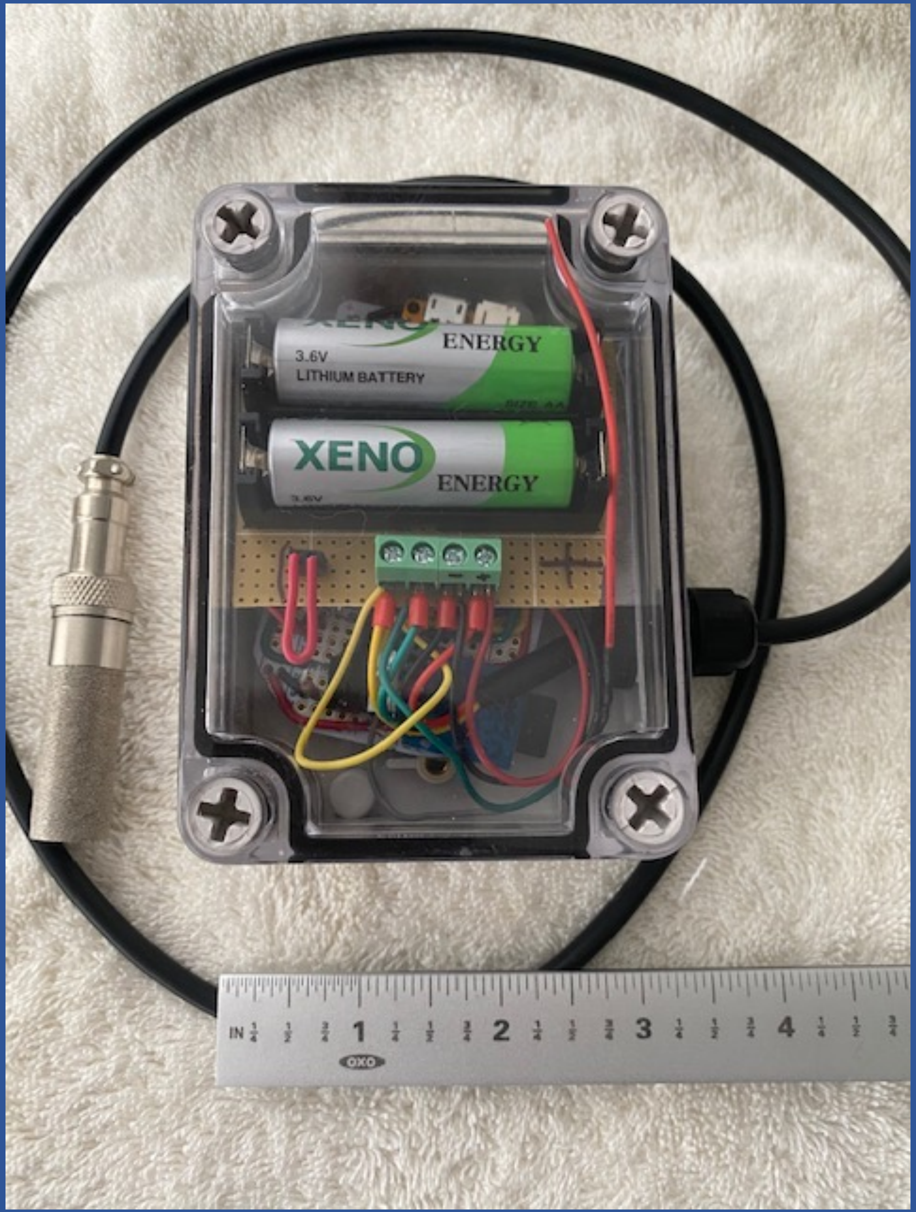
- Main/Sensor star and/or mesh topology
- Sensor nodes
  - Collect data (temperature, soil moisture, etc.)
  - Use LoRa radio to send data to Master
- Main node
  - Receives data from sensors using LoRa
  - Will include temperature, etc., sensing
  - Forward data to ‘Application Server’ via Iridium satellites and the Internet.
- The rest of this presentation will cover the sensor node

Current sensor design

- Two prototype versions; one using a Printed Circuit Board (PCB)
- A prototype is deployed alongside a traditional sensor system for comparison, and it recorded/transmitted 270,000+ readings.
- The prototypes use Lithium Thionyl-Chloride (Li/$SOCl_2$) batteries.
- The prototypes use an off-the-shelf temperature and humidity sensor.
- Using the RadioHead* LoRa library, which provides support for datagrams and mesh networking.
- A next step will be to deploy several of the PCB-based sensor prototypes and experiment with network topologies.
- Source code at: github.com/jgallagher59701/Soil_moisture

*www.airspayce.com/mikem/arduino/RadioHead/

Current sensor design – initial prototype



Current sensor design – PCB version

Issues with sensor design/implementation

- Changed emphasis to faster-prototyping instead of low-cost because of issues with ‘cheap’ hardware. *We will optimize for low cost once we have a reliable prototype.*
- Switched to a fabricated PCB to reduce size, decrease build time (30 mins versus 5 hours), and increase reliability. *In the future, these can be populated by a fabrication service.*
- Combining the LoRa radio and an SD Card has been problematic. *Issues with the SPI* bus or the SD card maybe be the cause of intermittent sensor node failures.*
- While the RocketScream™ MCU[†] claims a 40µA sleep current, in practice we see 187µA due to the SPI bus devices.
- Modifications to the antenna design improved LoRa RSSI[§] by 36 dB (measured using the LoRa transceiver units)

* SPI: Serial Peripheral Interface
† Microcontroller Unit
§ Received Signal Strength Indicator

Field testing – Site

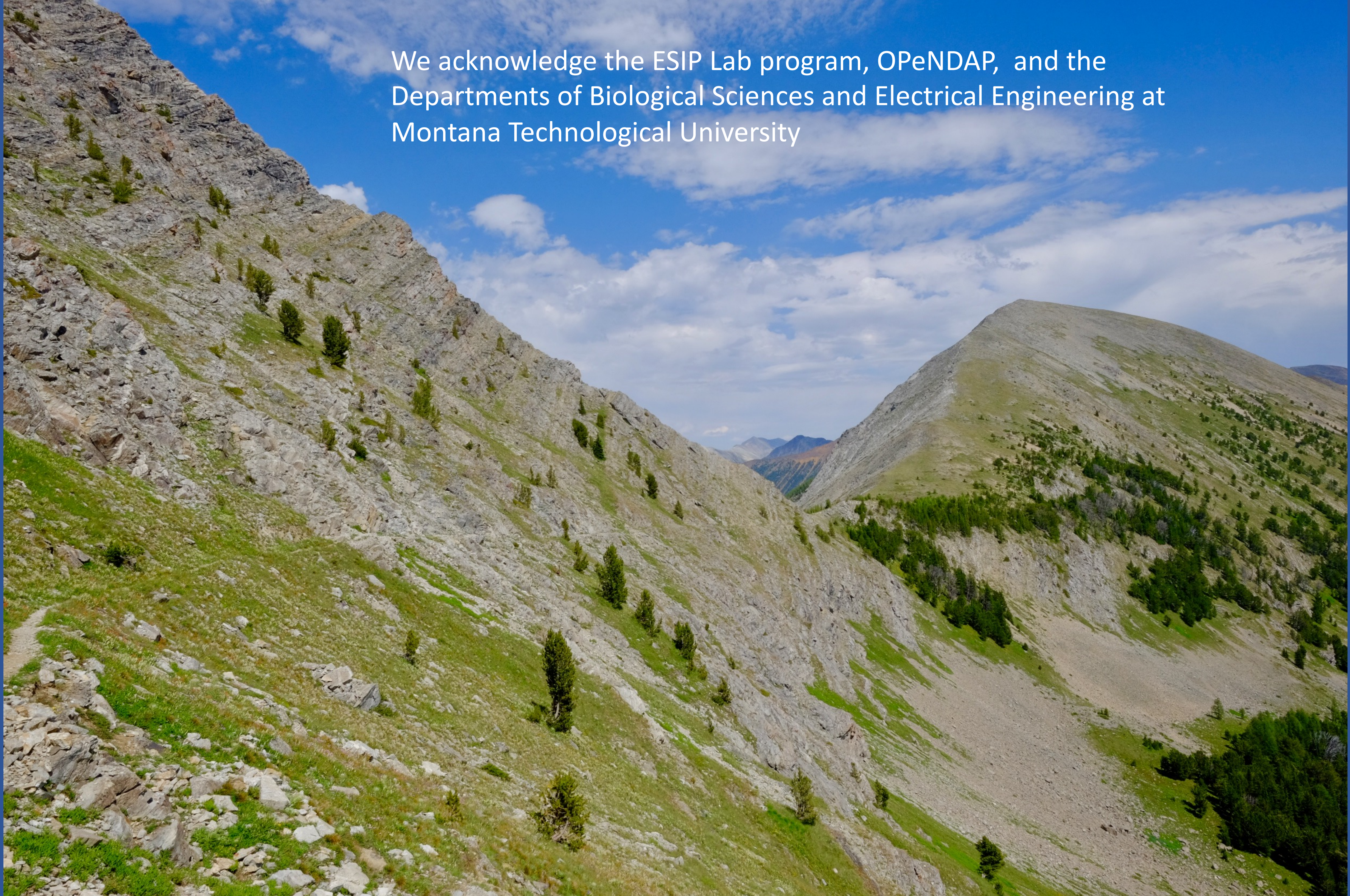
Field testing – Sensor node

Field testing

- Sensors have been tested at three field sites:
  - Butte, Goat Flat, Mt. Fleecer (Montana)
- The case and sensor are rated IP-68/66
- The nodes’ RSSI was reduced by ~40 dB when they were buried.
- *Will a radome help reduce signal attenuation by the soil? A radome will make air space around the antenna.*
- We used a combined temperature/humidity sensor – off-the-shelf and environmentally hardened.
- *Will a relative humidity sensor buried in the soil be a viable proxy for near-surface soil moisture?*

Summary

- Improving access to sensor data can increase the potential for scaling up research, collaboration, and communication.
- Sensor data can help explain the distribution of plant species and their functional traits.
- Prototypes using PCBs are ~10 times faster to build than nodes made using perf boards and are the only reasonable way to build an even modest sized collection of sensor nodes.
- Next steps for the sensor nodes: deploy multiple nodes and run them through the winter.



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