High Altitude Sensor Technology: HAST

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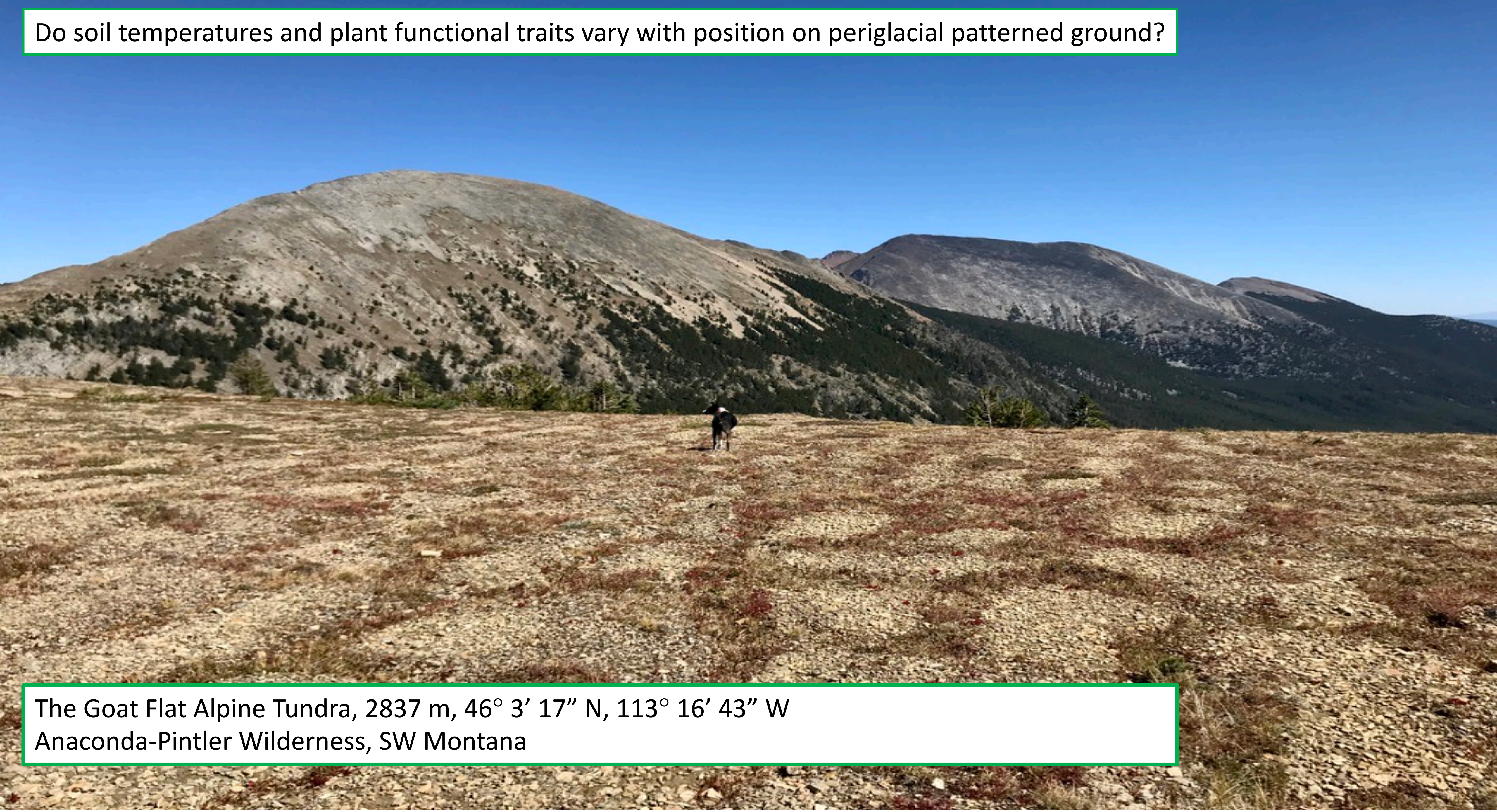
What is HAST?
A prototypical device for *in-situ* recording of soil temperature and humidity.
HAST logs data and sends it via Iridium satellites to a web host.

Rationale for HAST:
Soil temperature and moisture data are valuable in alpine ecology research on snowfields, periglacial patterned ground, plants and climate change.

Alpine sites are often inaccessible due to snow and terrain.
Data must be collected on site sensors.
Access to sensor data is limited even though sensors can record year-round.

With HAST, we have the potential for greater accessibility for year-round data series and improved understanding of climatic conditions in the alpine and other relatively inaccessible zones.

Do soil temperatures and plant functional traits vary with position on periglacial patterned ground?



The Goat Flat Alpine Tundra, 2837 m, 46° 3’ 17” N, 113° 16’ 43” W
Anaconda-Pintler Wilderness, SW Montana


Late Summer Snowfield, Goat Flat Alpine Tundra
Snowfields used to last through the summer but now they do not.
What are the soil temperatures where snowfields are retreating?

CURRENT FIELD METHODS:

On the Edges and Centers of Polygons,

- **Soil Temperature:**
  - **Hobo-Onset Temperature Sensors (UTBI-001), n = 12**
  - **5-10 cm beneath the soil surface**
  - **Temperatures recorded hourly, 2018-21.**

- **Plant Species and Functional Traits:**
  - **Surveyed their distribution in quadrats**
  - **Recorded percent cover,**
  - **Calculated relative percent cover (RPC)**
  - **RPC = % cover species or trait/total % cover of quadrat.**


When sensors are set 5-10 cm beneath the soil on patterned ground, how is it possible to relocate them to retrieve data?

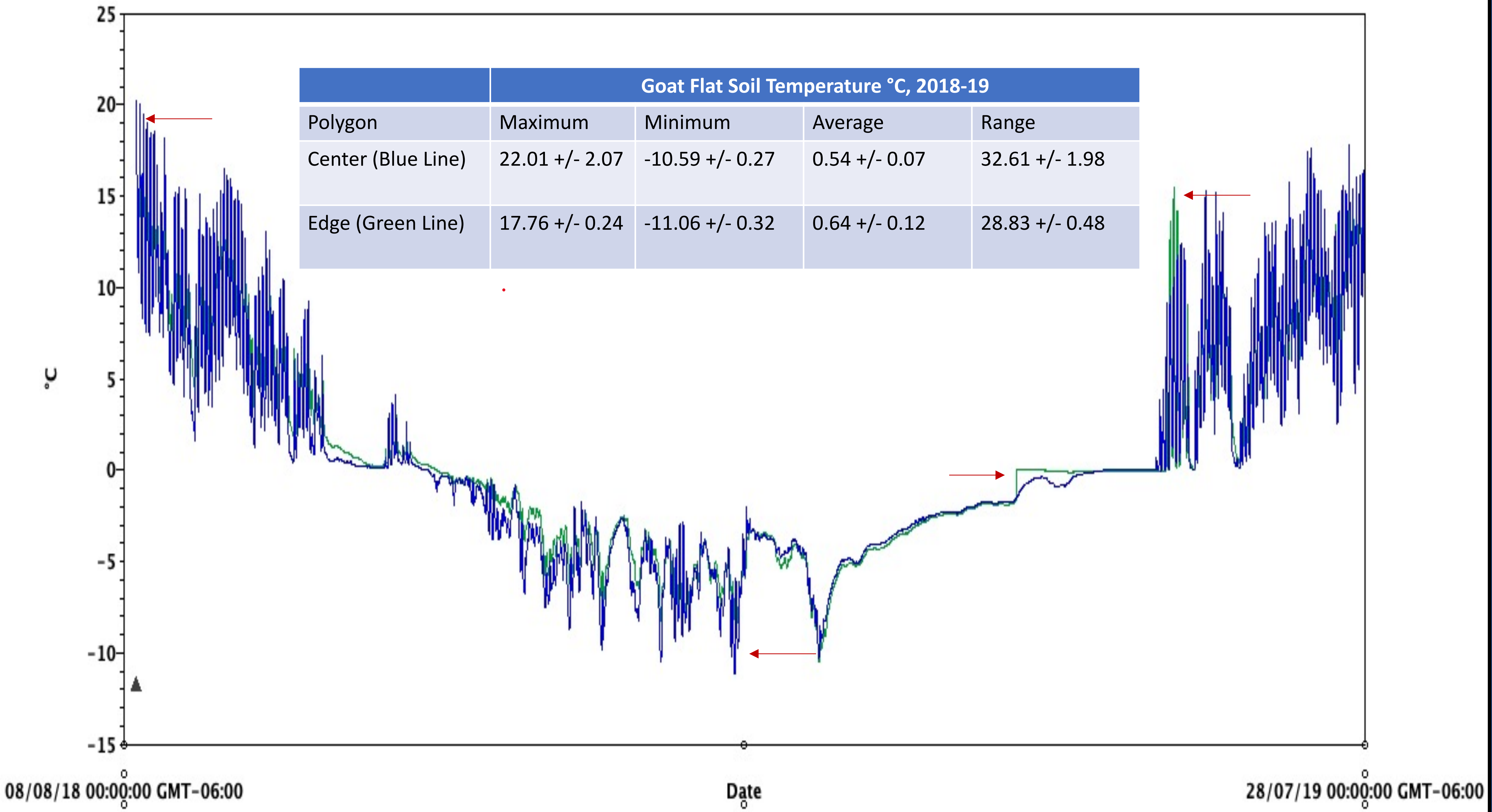
RESULTS:

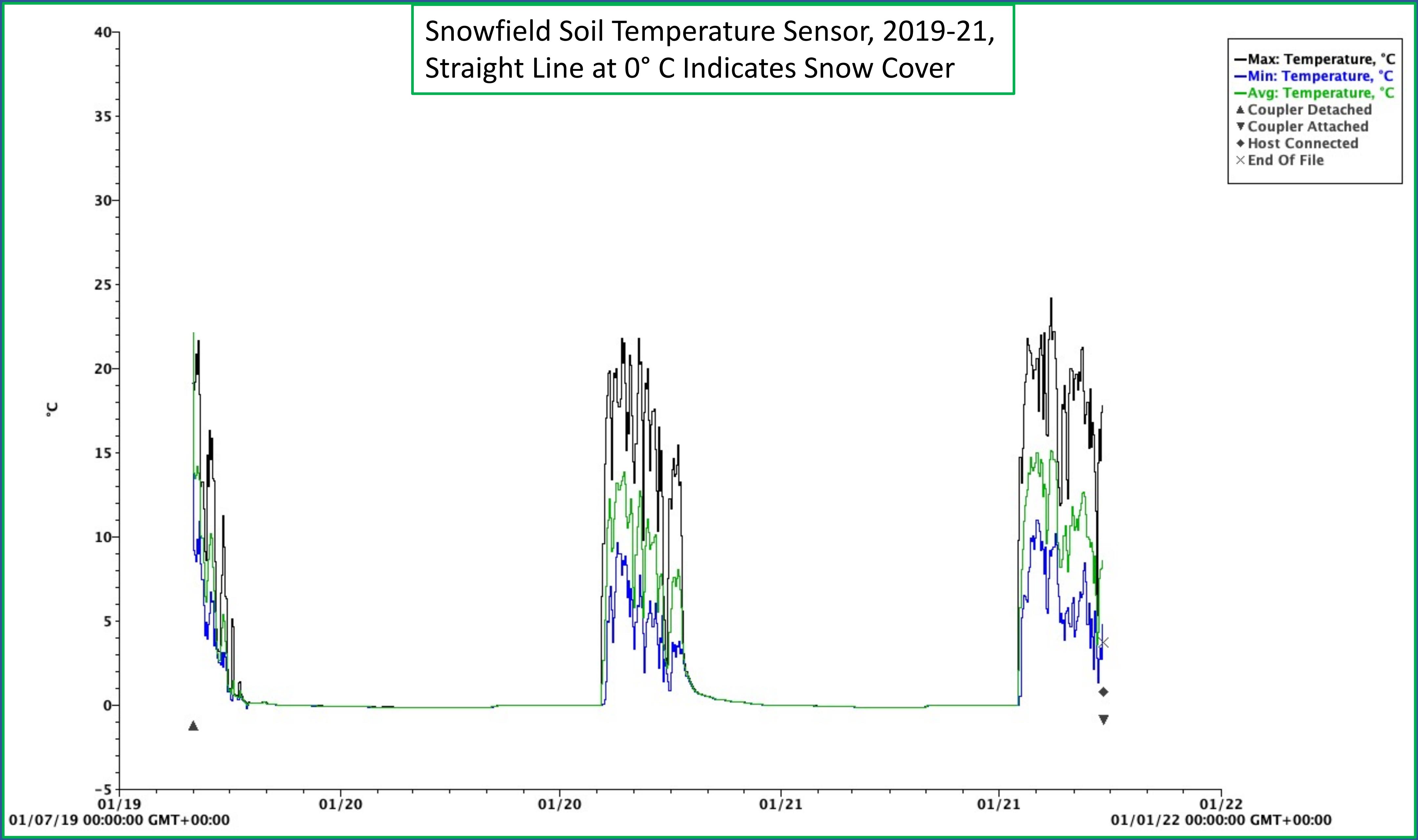
- **Edges of polygons:**
  - **Total percent cover was high**
  - **Higher RPCs:**
  - **Dwarf shrubs**
    - ***Dryas octopetala* and *Salix arctica***
  - **Tree seedlings**
    - ***Picea engelmanii***

- **Centers of polygons:**
  - **Total percent cover was low**
  - **Higher RPCs for:**
  - **Drought tolerant CAM * plants**
  - **CAM = Crassulacean Acid Metabolism**
    - ***Sedum lanceolatum*, *Sedum roseum***
  - **Clonal mechanisms:**
    - **Stolon production**
    - **Vivipary (clones instead of seeds)**
    - ***Polygonum viviparum***


Polygon centers:
Higher Relative Percent Cover
Sedum lanceolatum, a CAM plant,
Polygon edges:
Higher Relative Percent Cover
Dryas octopetala, an evergreen dwarf shrub

	Goat Flat Soil Temperature °C, 2018-19			
Polygon	Maximum	Minimum	Average	Range
Center (Blue Line)	22.01 +/- 2.07	-10.59 +/- 0.27	0.54 +/- 0.07	32.61 +/- 1.98
Edge (Green Line)	17.76 +/- 0.24	-11.06 +/- 0.32	0.64 +/- 0.12	28.83 +/- 0.48




Snowfield Soil Temperature Sensor, 2019-21,
Straight Line at 0° C Indicates Snow Cover
Max: Temperature, °C
Min: Temperature, °C
Avg: Temperature, °C
Coupler Detached
Coupler Attached
Host Connected
End Of File
°C
40
35
30
25
20
15
10
5
0
-5
01/19
01/20
01/20
01/21
01/21
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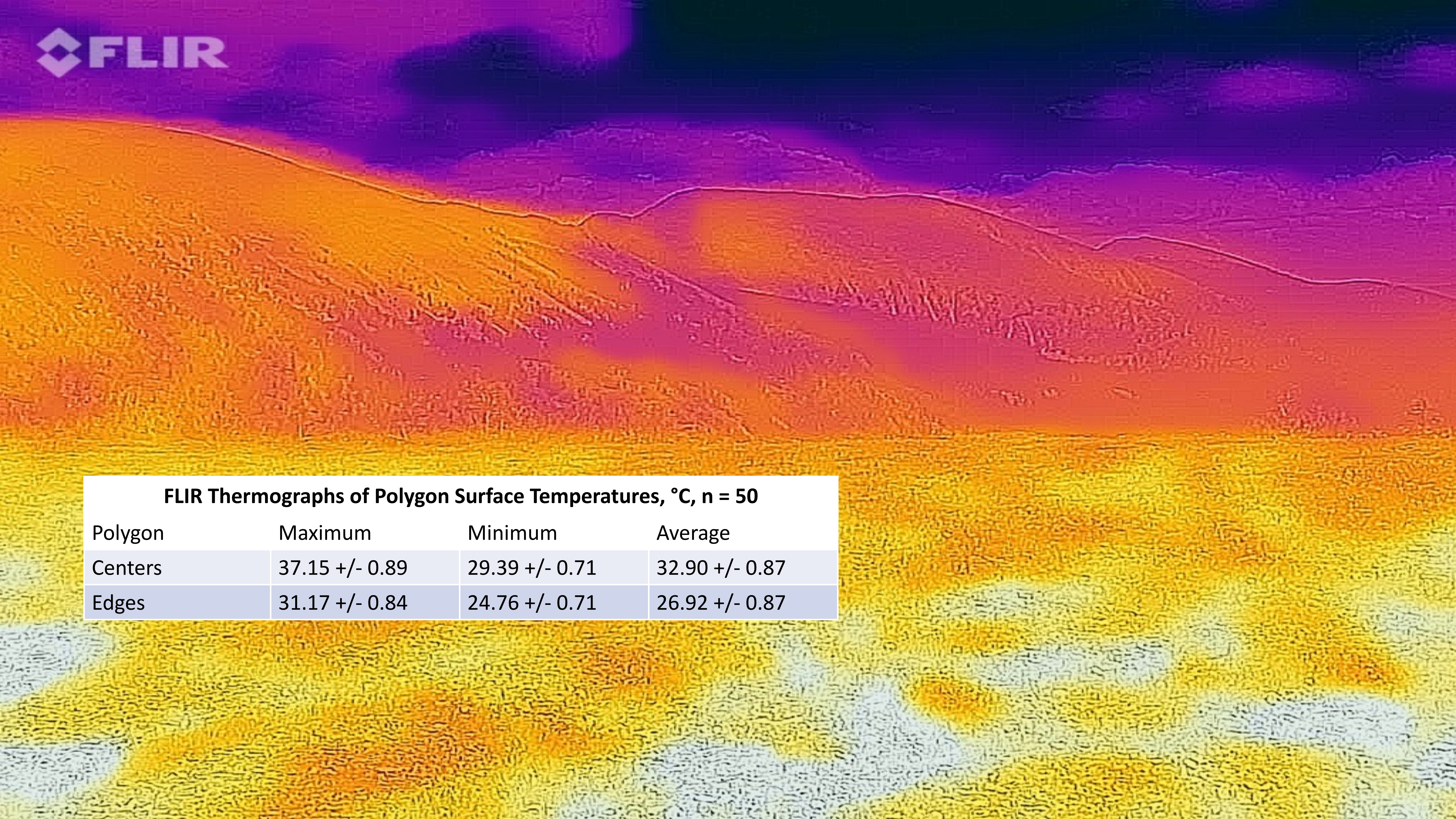
01/01/22 00:00:00 GMT+00:00

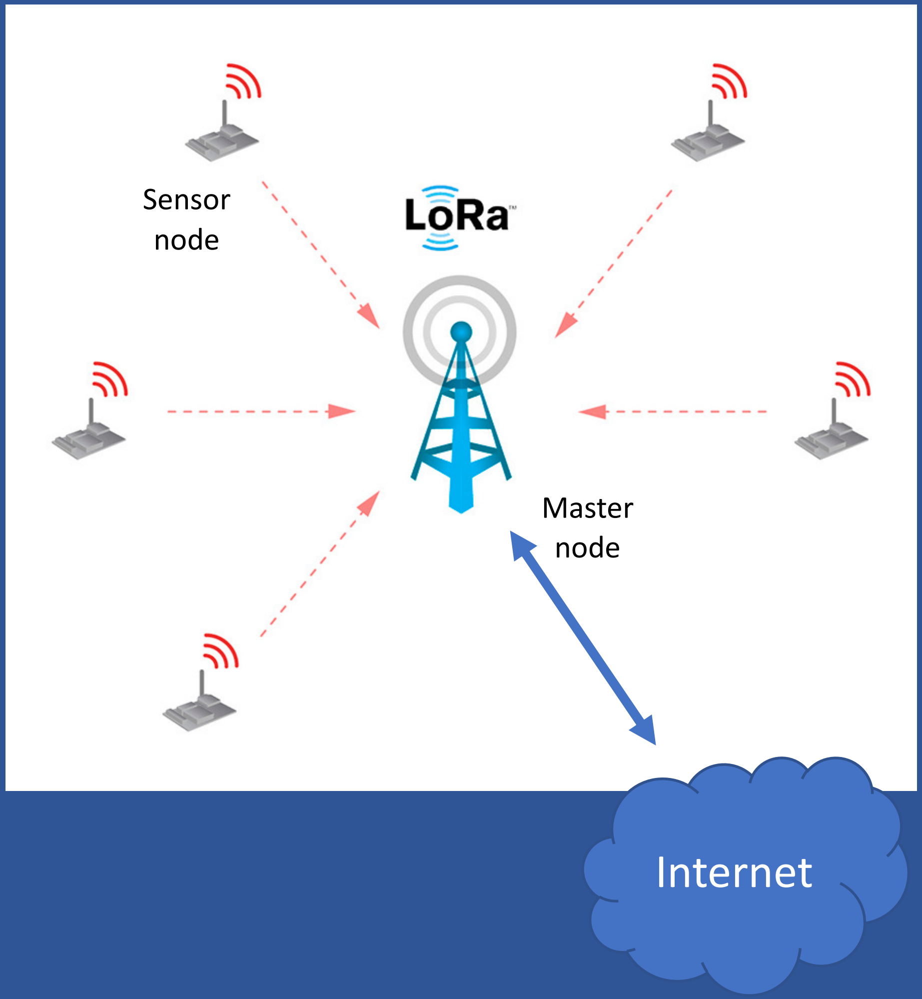


FLIR Thermographs of Polygon Surface Temperatures, °C, n = 50

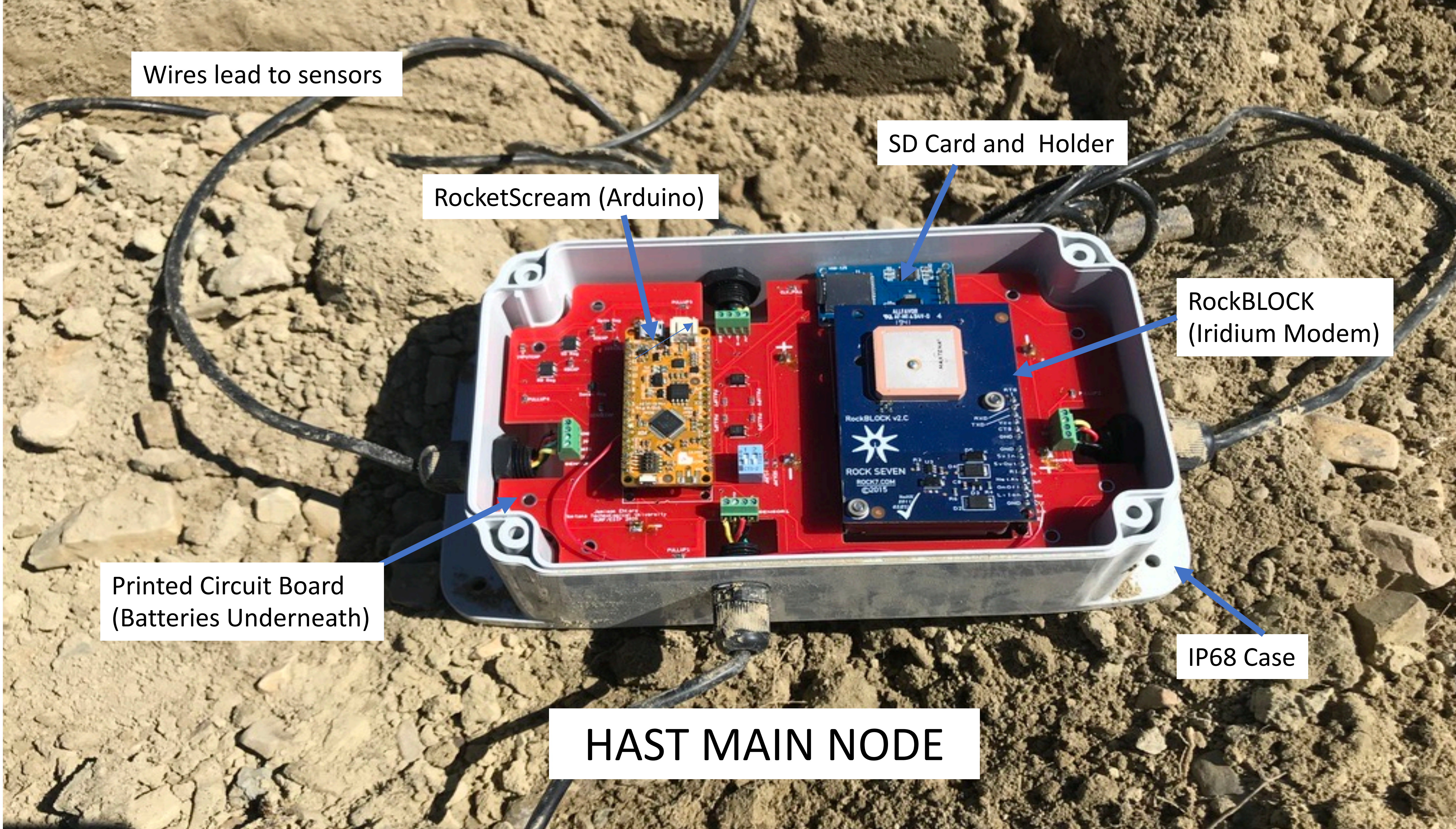
Polygon	Maximum	Minimum	Average
Centers	37.15 +/- 0.89	29.39 +/- 0.71	32.90 +/- 0.87
Edges	31.17 +/- 0.84	24.76 +/- 0.71	26.92 +/- 0.87

HAST!

HAST 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.


Wires lead to sensors
SD Card and Holder
RocketScream (Arduino)
RockBLOCK
(Iridium Modem)
RockBLOCK v2.C
ROCK SEVEN
Printed Circuit Board
(Batteries Underneath)
IP68 Case
HAST MAIN NODE

In the HAST System main node:

The RocketScream controls the main node, providing power management, a real-time clock, and the Arduino coding libraries to operate each of the other components. The usual operating mode (standby) of the microcontroller will draw around 20 uA, increasing to 20 mA when active.

The RockBlock is a satellite modem, able to connect to a moving satellite in orbit around Earth, and can send an email containing a “Twitter length” string of data

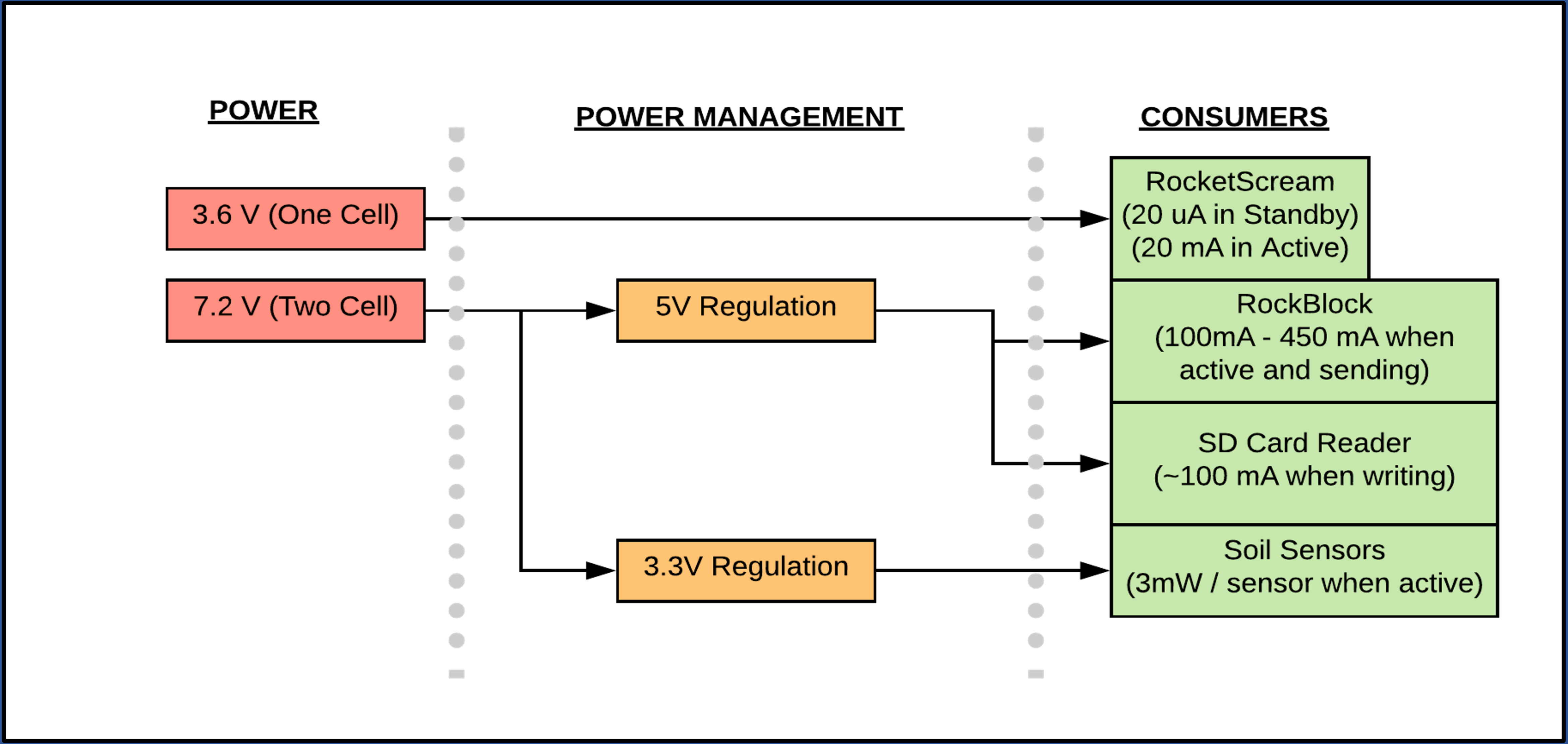
The SD card reader stores data onto a temperature rated SD card, if the RockBlock is unable to establish a satellite connection.

The SHT10 sensor reads temperature and soil humidity. For the final system, multiple sensors will be implemented.

The lithium-thionyl batteries were chosen for their constant voltage performance over time, as well as their projected battery life. They are non-rechargeable.

The IP68 rated cable glands and NEMA case were chosen for their safety rating of dust ingress and moisture incursion protection.

The clear acrylic dome decreases the attenuating effects of dirt and snow on the radio energy.



Power Use of Main Node

Current leaf node sensor design – PCB version

Current leaf node sensor design

- A prototype leaf node has been deployed alongside a traditional sensor system for comparison, and it recorded/transmitted 270,000+ readings.
- The leaf node design uses:
  - Lithium Thionyl-Chloride (Li/$SOCl_2$) batteries.
  - Off-the-shelf temperature and humidity sensor (SHT-30).
  - The RadioHead* LoRa software library, providing support for reliable networking.
  - An SD card for redundant data storage
- Source code at: github.com/jgallagher59701/Soil_moisture

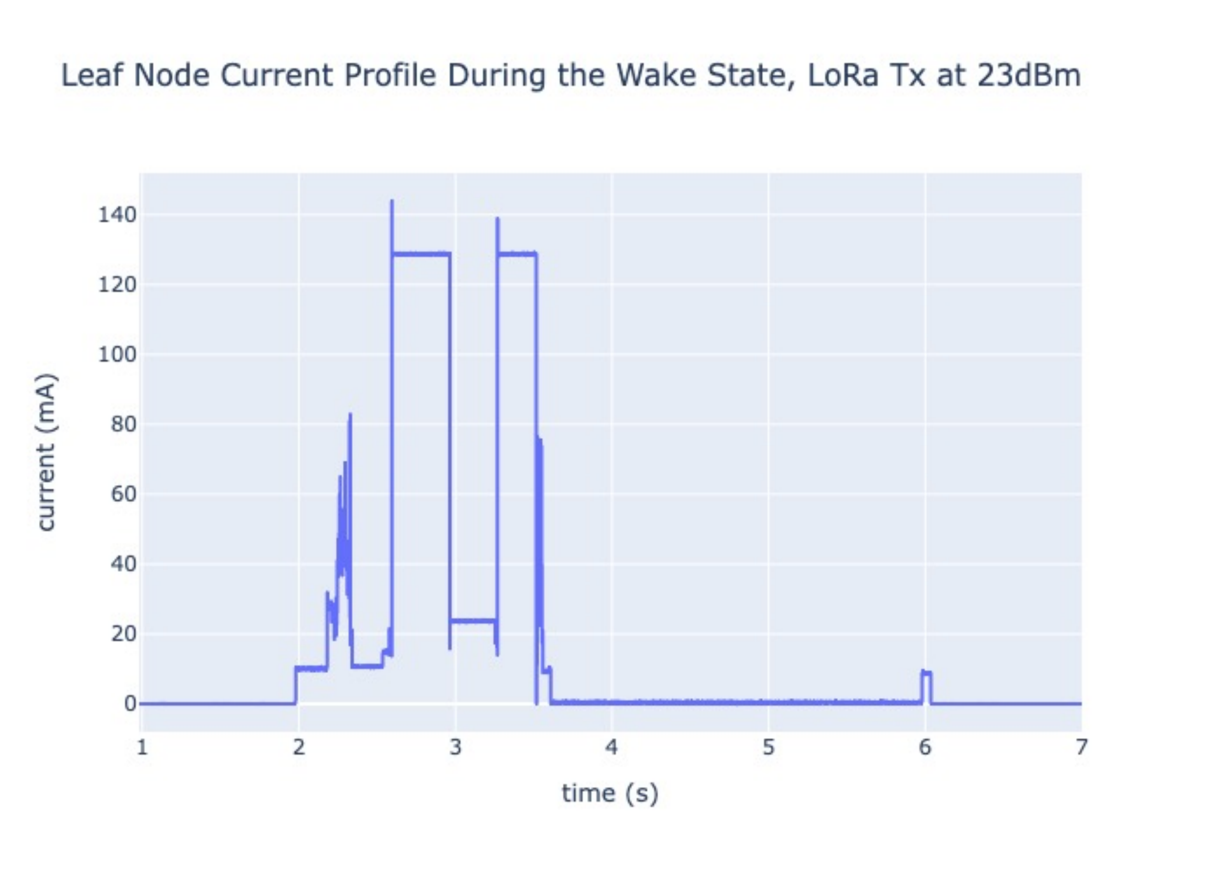
*www.airspayce.com/mikem/arduino/RadioHead/

Leaf node deployment

This prototype unit has been left at the site to over-winter. Other nodes are deployed in Butte where they can be more easily accessed and monitored.

Leaf node power consumption

- Wake-state power use shown at right
- Sleep power use is 18.5µA
- Estimated best-case battery life is 11.8 years (hourly sensor readings and data transmission)*.



*Jupyter notebook: https://github.com/jgallagher59701/HAST_leaf_node_data/blob/main/Compute_Leaf_Node_Current_2.ipynb

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