Sensing Plant and Soil Temperatures in Snowy Alpine Environments: Part II

Martha Apple[1], James Gallagher[2], Kevin Negus[3], Jamison Ehlers[3]
[1]Biological Sciences, [3]Electrical Engineering, Montana Technological University, [2]OPeNDAP, Inc.

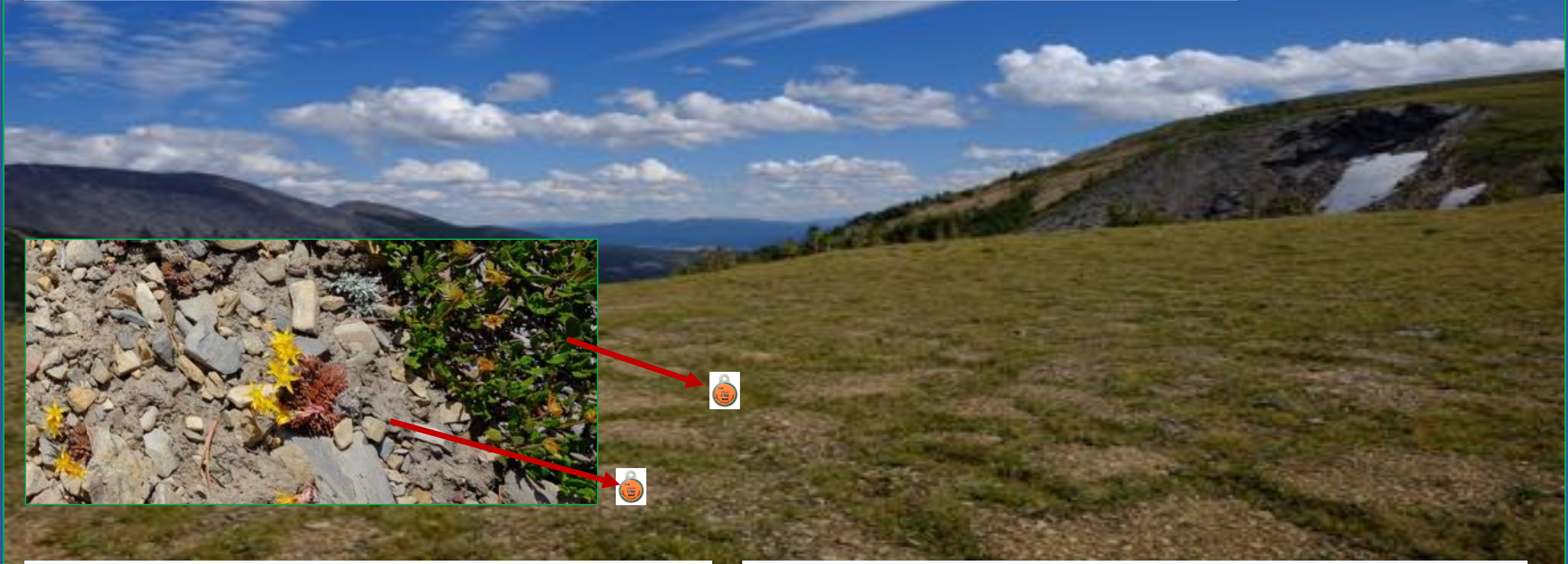
Alpine Plant Ecology and Environmental Sensing

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. FLIR (Forward Looking Infrared) images detect temperatures of plants and of patterned ground and snowfields.
5. We installed an array of soil temperature sensors but can only retrieve data at the sites.
6. Our alpine tundra sites are in the wilderness, have harsh winters, and are accessible only in late summer.
7. Research could be scaled up with wilderness-ready soil moisture sensors and with remote and year-round access to data.
8. 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:

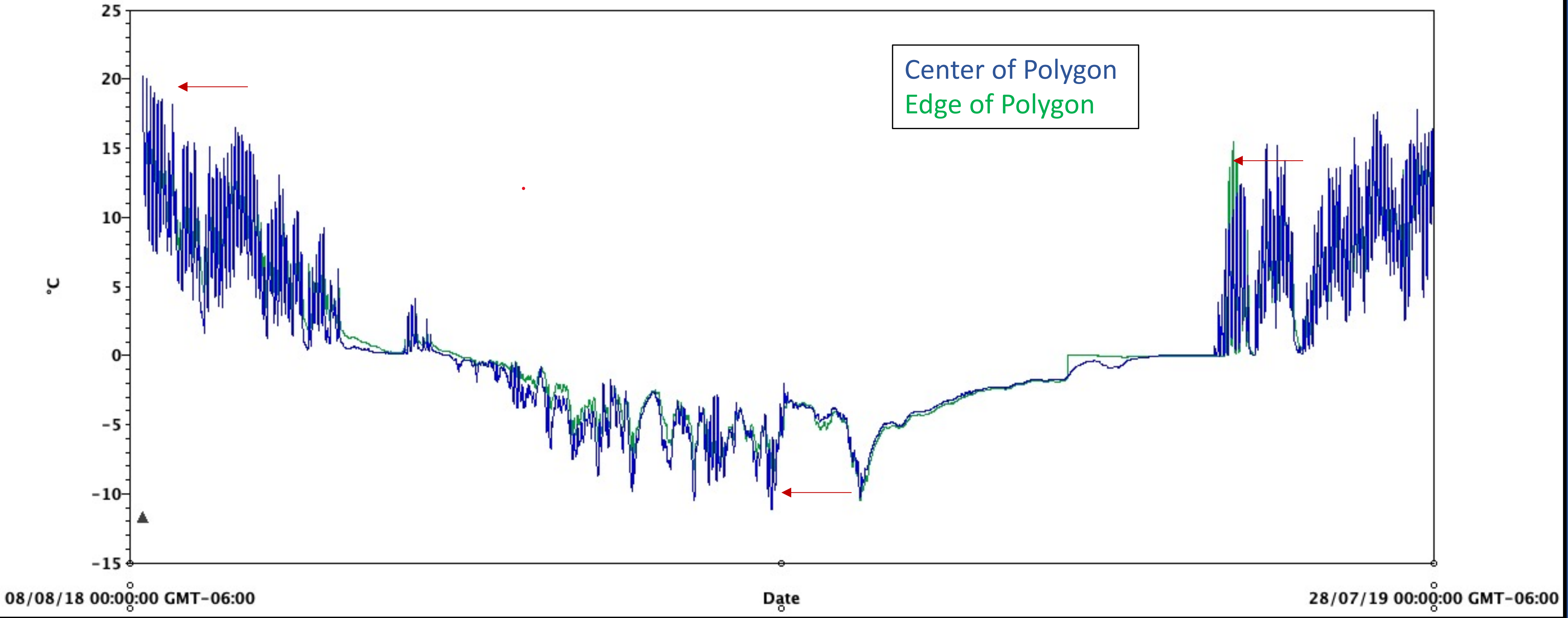
Surveyed the distribution of plant species and functional traits

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)

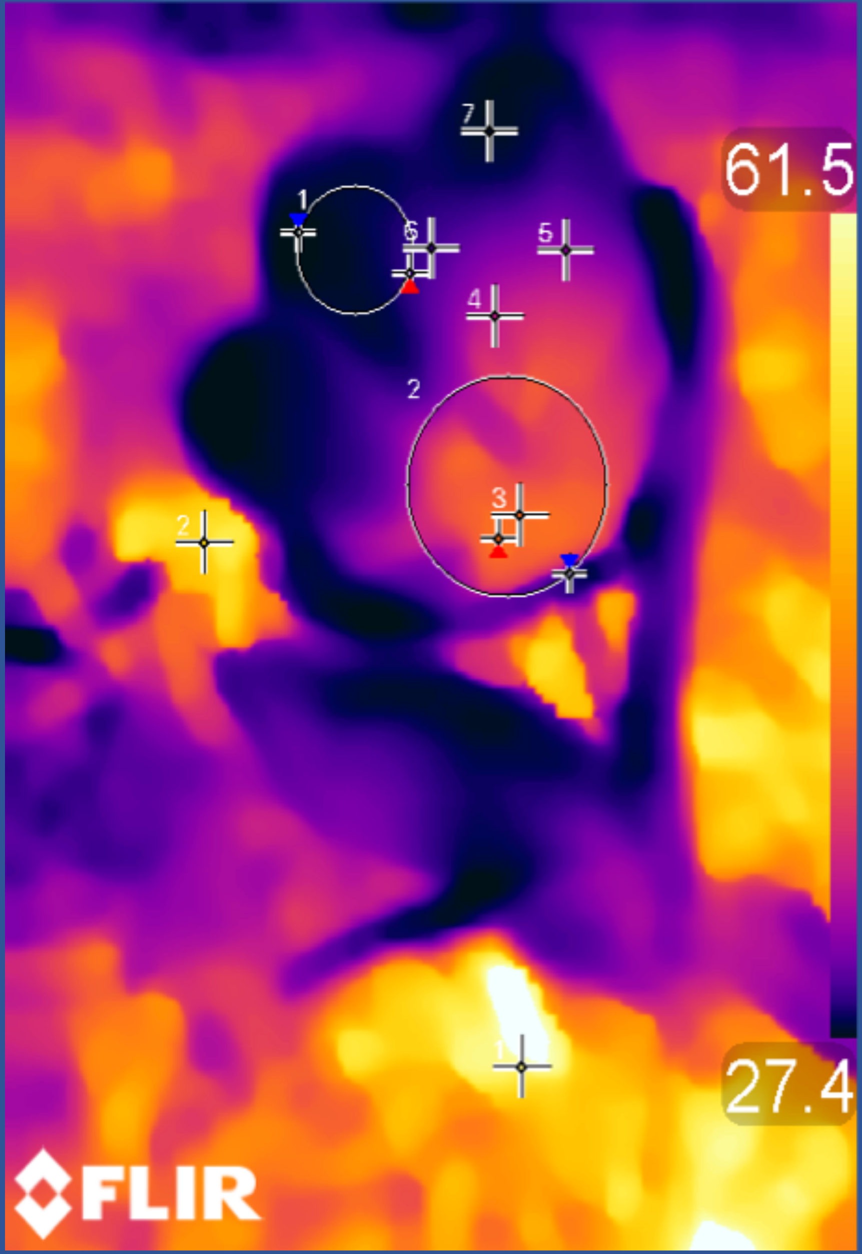


Brown Centers of Polygons: Rhizomes, taproots, + herbaceous plants
Astragalus sp., Carex, Sedum lanceolatum, Gentiana calycosa

Green Edges of Polygons: Herbaceous plants, dwarf shrubs, + coniferous trees
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

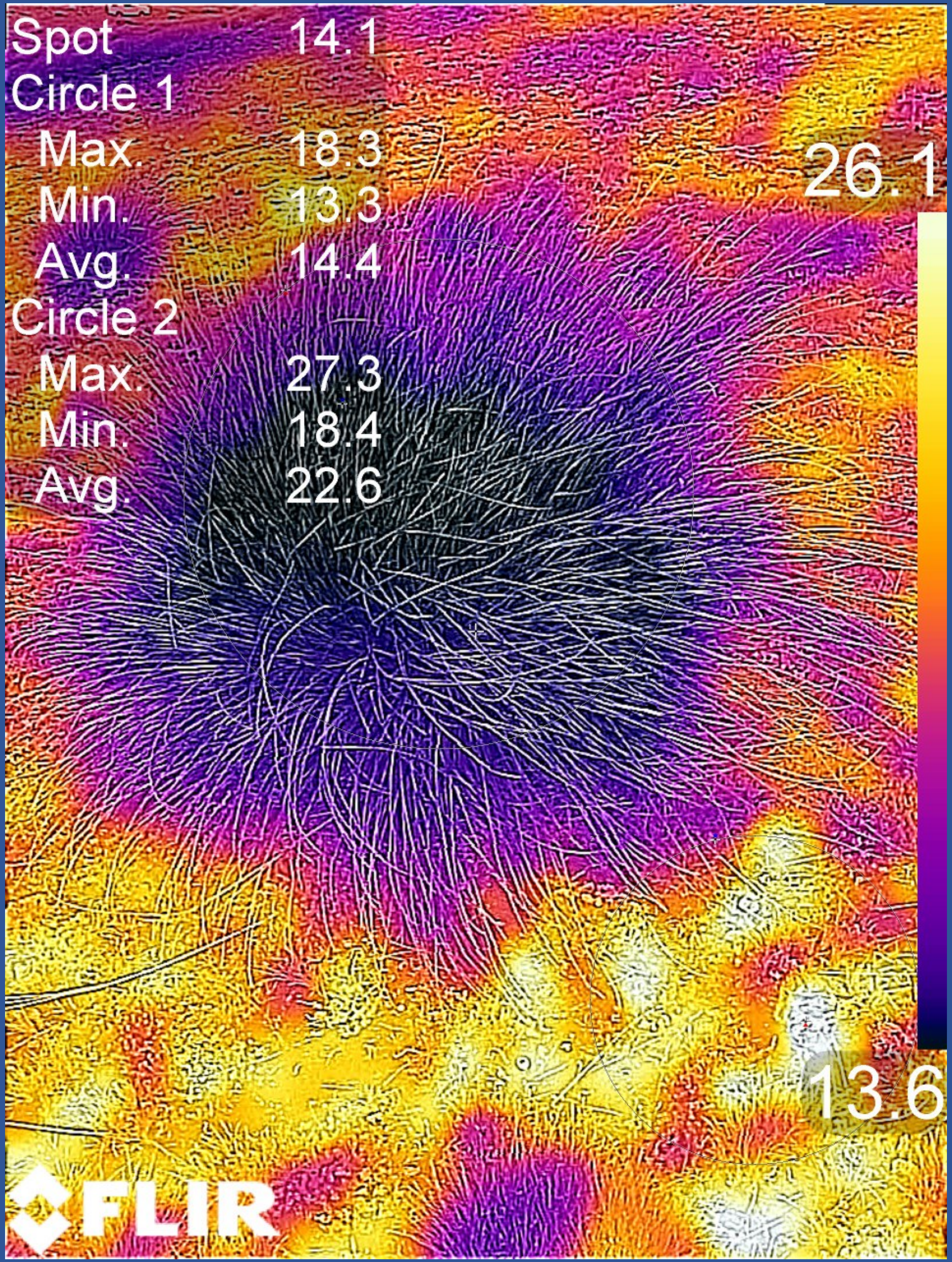


MEASUREMENTS (°C)

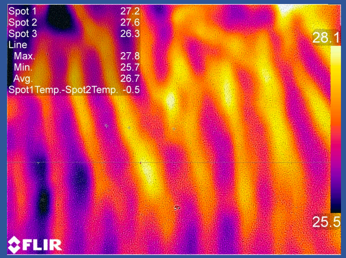
Spot 1 58.2
Spot 2 53.3
Spot 3 41.6
Spot 4 35.1
Spot 5 32.5
Spot 6 29.8
Spot 7 27.7

Circle 1
Max. 29.4 Min. 27.3 Avg. 28.1

Circle 2
Max. 42.0 Min. 28.6 Avg. 38.2



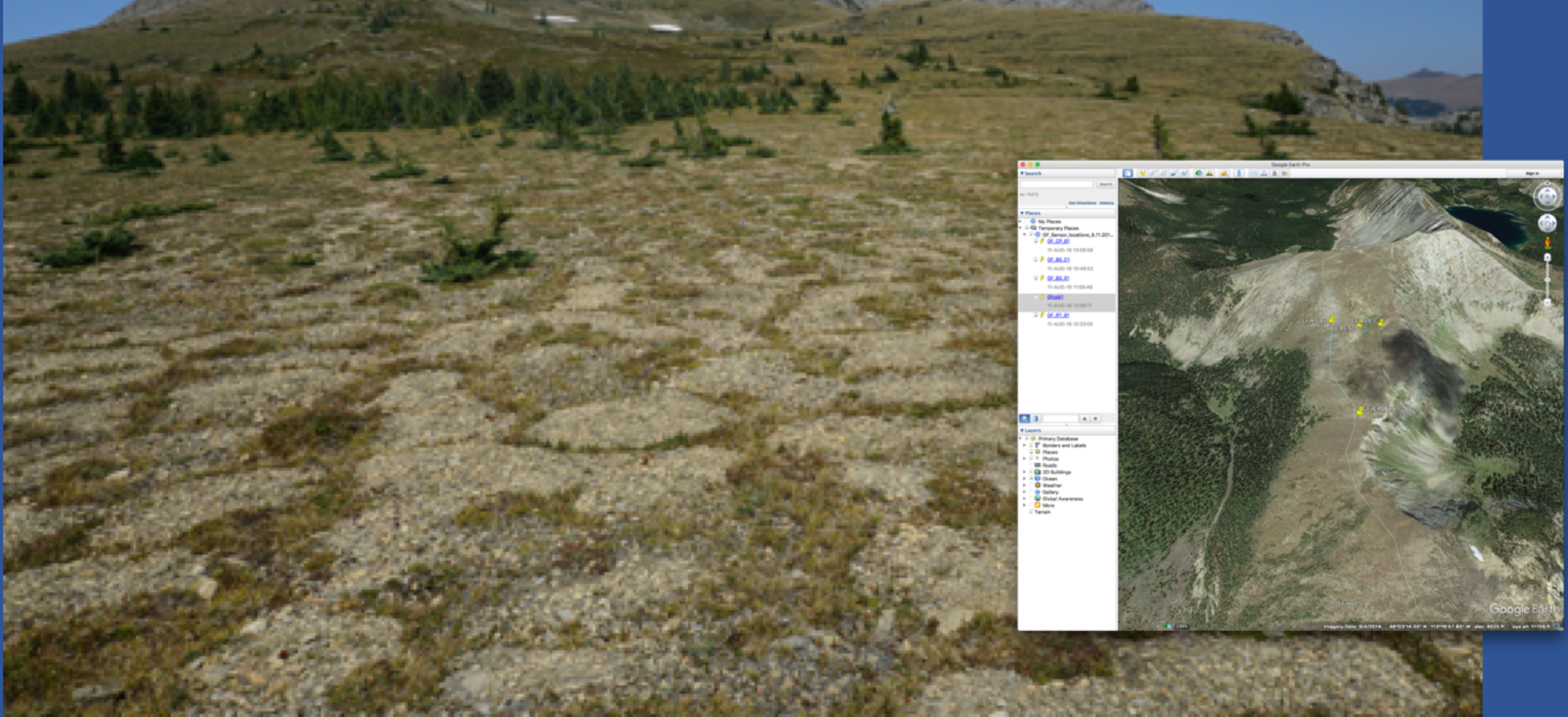
Tussocks at the GLORIA Alpine site on Mt. Pisa in New Zealand are cooler than the surrounding plants and ground.



Pacific Ocean Beach Sand

With the ESIP lab program:

- 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.

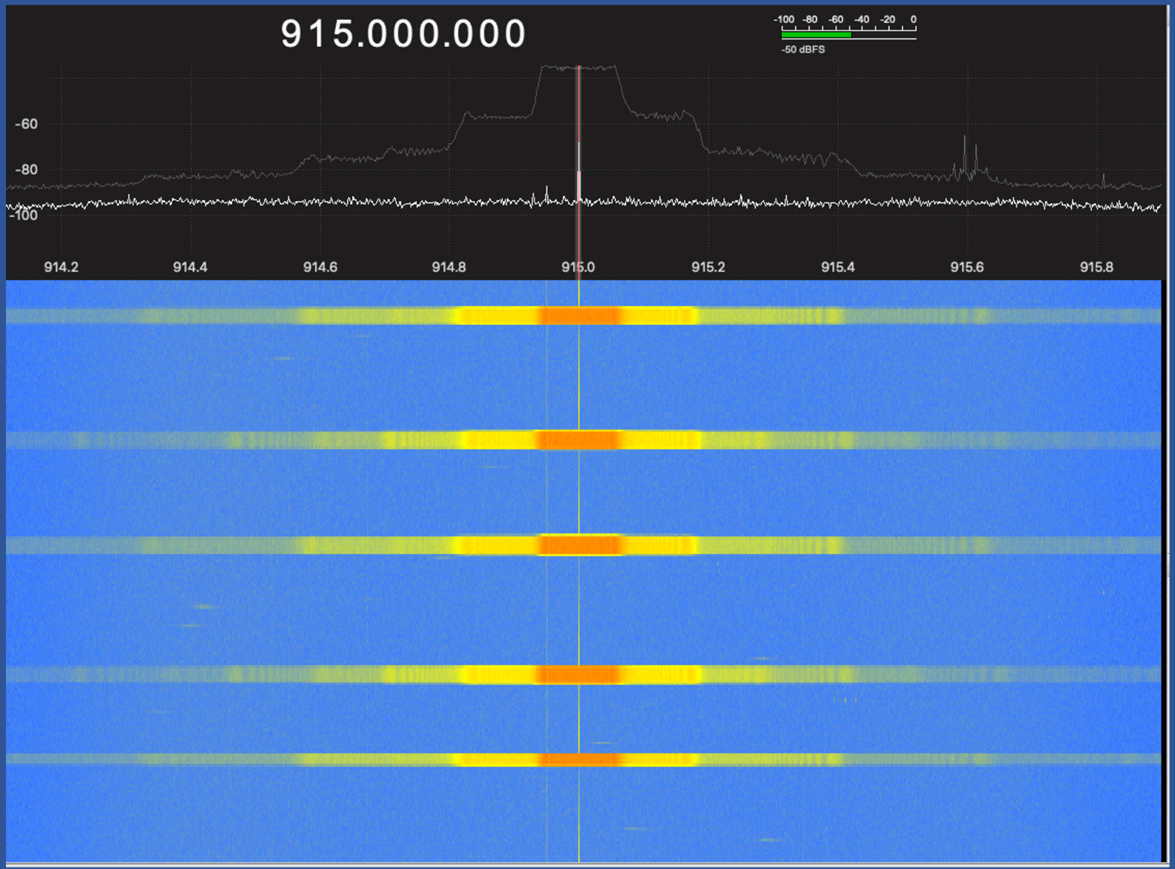


Current sensor design

- Hardware simplification – Use RocketScream boards for all nodes
  - Integrated real time clock, faster processor, more memory, LoRa, battery power features and low power modes
  - Simpler than discrete components – decrease development time
- Build significant local storage into node
  - Using ruggedized SD memory cards; vast storage potential
- Adopt a mesh network architecture
  - Each leaf node will send its own information, listen/store from nearby nodes and selectively re-broadcast information from nearby nodes
  - More robust than a star architecture
- See poster: High Altitude Soil Testing: Increasing Accessibility of Data from Remote Locations, *Jamison Ehlers; Martha Apple; Kevin Negus*

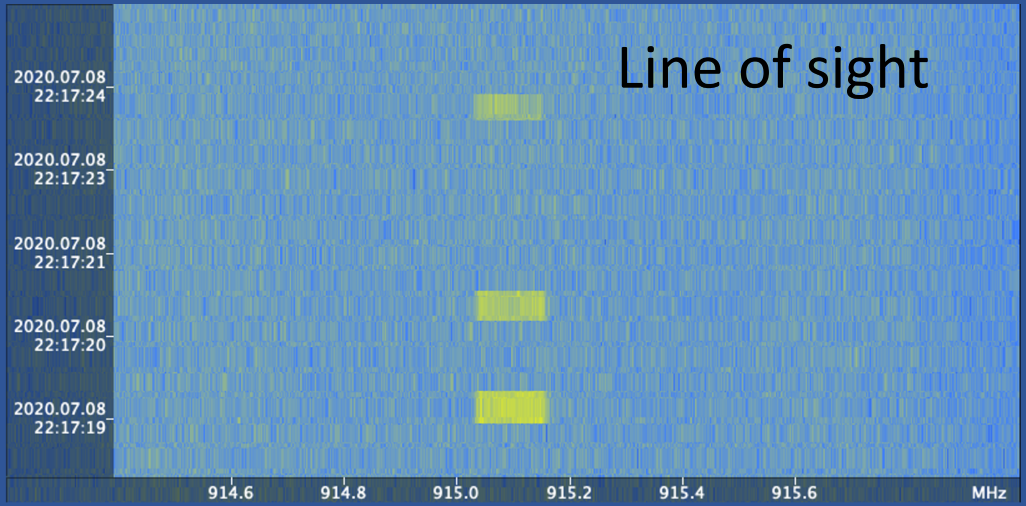
Experiments with LoRa

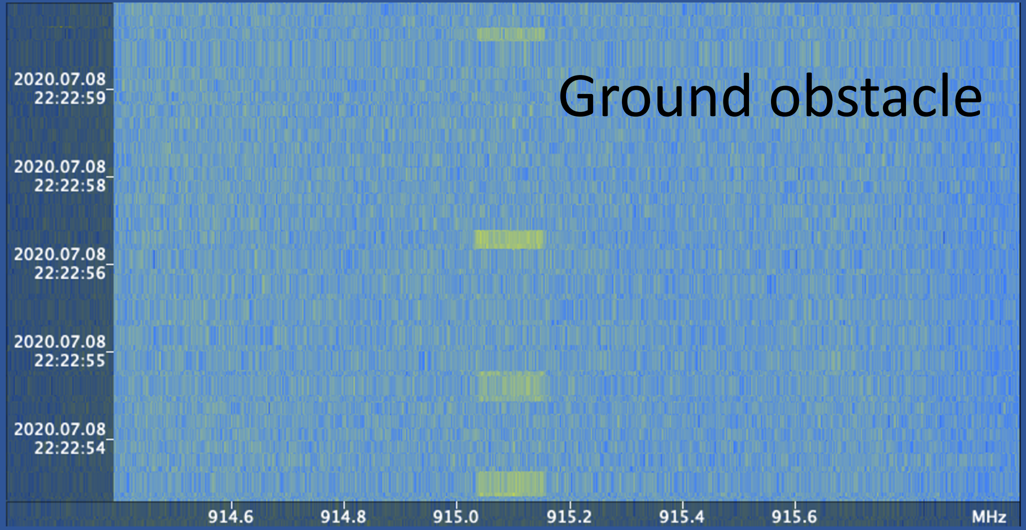
- Tests run using moderate settings
  - Bandwidth (BW) = 'Chips' per symbol
  - Coding rate (CR) = Extra information sent for error correction
  - Spreading factor (SF) = Number of chips used for each bit ($R_c = R_b * 2^{SF}$)
- Our tests:
  - BW = 125kHz, CR =1, SF = 7
  - Transmission power = 13 dBm
- Message length 57 bytes (93 bytes in transmission frame)
- Time on air: 107.78 ms



Field Experiments with LoRa

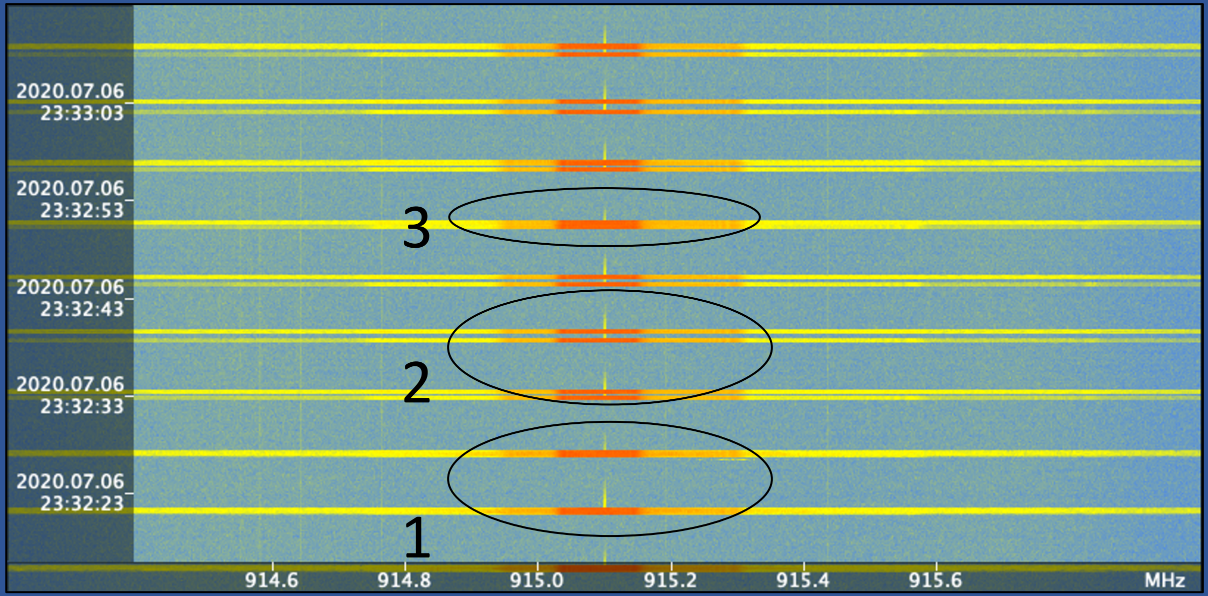
- Nodes separated from receiver by ~200 and ~300 ft
- Used BW = 125 kHz, CR = 1, SF = 7
- Transmission power = 13 dBm
- Signal strength
  - Line of sight: -95 to -120 dBm
  - Ground Obstacle: -102 to -120 dBm

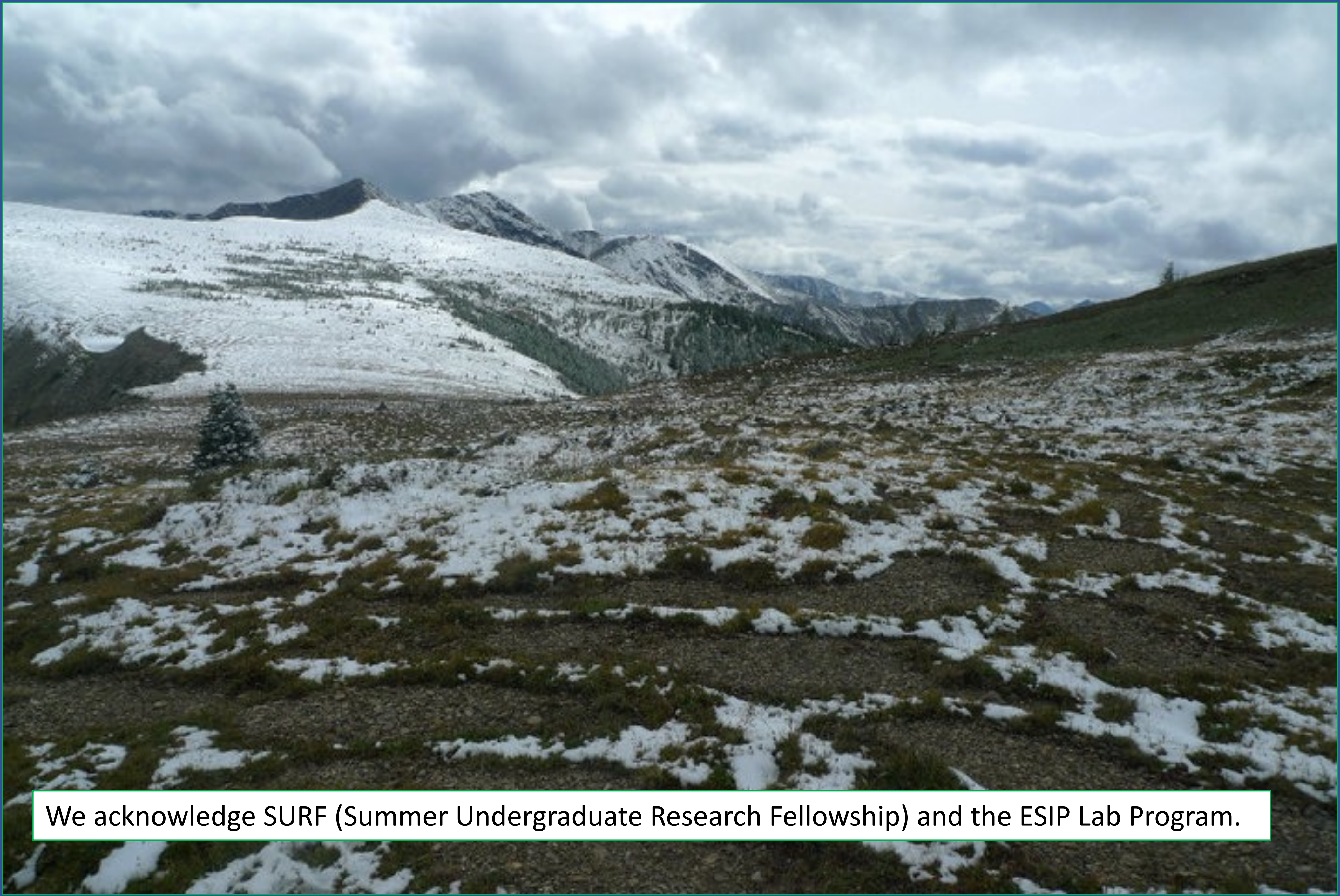




LoRa Channel Activity Detection

- Adding Channel Activity Detection reduced collisions from unsynchronized nodes
    - #1 - Nodes started at the same time - Transmissions collide
    - #2 - CAD added - one node waits for the other to complete transmission
- It's not perfect...
    - #3 - CAD may fail
- Tests indicate it provides a benefit





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