Project Details

Name of project: Sensors and Microclimate in Snowy Alpine Environments

Project lead and contact details:
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Proposed start and end date:
Start Date: March 1, 2020 or upon receipt of funds.
End Date: October 31st, 2020, or eight months after the receipt of funds.

Budget Requested: $8421.00

Budget Summary:
We request: 1) supplies to build and test multiple High-Altitude Soil Temperature (HAST) *master nodes* (that include temperature sensing and satellite modems) and *sensor nodes* that include temperature and moisture sensors; 2) funds for students to develop and test these sensors and modems with faculty supervision, and 3) transportation to alpine field sites, and 4) funds for student travel to an ESIP meeting.

Category	Cost ($)
Supplies to build multiple HAST and leaf sensors and satellite modems	2700
Student hourly wages for time to develop and test these sensors and modems Specifically, 2 students X 12 hours X 12 weeks X $12/hour	3456
Student benefits constitute 10% of wages during the summer	346
Travel to Research Field Sites (80 miles X 6 trips = 480 miles)	269
Student Travel to an ESIP Meeting. Specifically, Registration ($150) + Air Travel ($500) + Lodging (4 nights @ $200 = 800) + Meals (per diem)	1650
Total	8421.00

Project Outline

Project description
Alpine plants act as sentinels of climate change. The alpine tundra is markedly sensitive to climate change and it contains a wide range of microhabitats ranging from those imposed by position on periglacial patterned ground to those resulting from the gradient of distance from the edge of late summer snowfields. We are investigating the effects of microhabitat on the distribution of alpine plant species and their functional traits which interact with the changing climates of their environments and influence where the plants can live. To strengthen our knowledge of the effects of microhabitats and hence microclimatic variables on the alpine plants, we propose to develop, build, and test near real-time soil temperature and moisture sensors. These sensors must be unobtrusive, findable, underground (and under the snow) yet suitable for year-round *in-situ* deployment in the harsh and at times extreme conditions of the snowy alpine tundra. They must also be able to communicate with online data servers so that data can be obtained year-

round. While a variety of soil temperature and soil moisture sensors are available on the market, the sensors we propose to develop would differ by meeting all the criteria described above.

Our field sites in the alpine tundra of the Northern Rocky Mountains of Montana host an array of in-ground soil temperature sensors that can only be accessed during the short summer above the treeline. Sensor data can be obtained only by travelling and hiking to the field sites, locating and extracting the sensors, and downloading the data onto a laptop carried to the alpine tundra or by carrying the sensors back to the laboratory, downloading data, and returning to the alpine tundra to replace the sensors. Soil moisture sensors generally extend aboveground, and in the wilderness-designated field sites, aboveground sensors are not permitted. Even if allowed, aboveground soil moisture sensors would still be subject to high winds and tampering by inquisitive wild animals and by human beings. Belowground, *in-situ*, soil moisture sensors would enable determination of seasonal and storm-wrought variations in soil moisture using hourly measurements of soil moisture. The development of these sensors and their communicative abilities will expand the ability to gather data and expand our understanding of the effects of climate change on microclimate and microhabitat in the alpine tundra. These sensors may be deployable in other test cases, such as those conditions imposed by the arctic tundra and by glaciers.

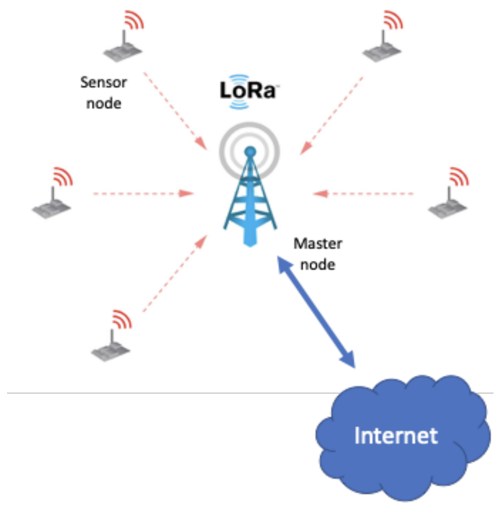

Figure 1. Conceptual deployment of Sensor Nodes using LoRa to communicate with a Master Node that pushes data to the Internet via satellite modem.

Project objectives, significance, and impact

The objectives of this project are to develop inexpensive yet accurate, research-grade, soil temperature and moisture sensors by taking advantage of the emerging open-source hardware movement to lower costs, to develop these sensors so they can be deployed year-round in extreme environments, to invent a way to easily locate underground sensors, and to develop year-round remote access to the sensor data. We require these sensors to operate in winter and under snow in harsh alpine environments, to be completely concealed underground so that they do not blow away, and to be constructed and deployed so that they will not be disturbed by weather or animals and so that they are unobtrusive and do not infringe upon the wilderness experience.

The significance of this scalable project is that its results will allow researchers to expand on what is possible and practical in environmental research on extreme and often inaccessible alpine and other environments. Existing solutions to this type of environmental application do not yet match this level of performance because, depending on configuration, they may not be suitable for year-round deployment and because, in the case of soil moisture sensors, the existing solutions extend above ground. In addition, the existing solutions do not make the collected data available in near real-time from these harsh environments.

The impacts of this project are that the ESIP community, and others, will gain increased access to soil temperature and moisture data from domain-based research in environments that are currently underexplored because of the complicated logistics in obtaining data from the field. The remotely-accessible data will be more readily available for analysis. This is important because the proposed soil moisture sensors will have the potential to provide year-round data on an hourly basis that will contribute to greater ecological relevance for domain-based research. The sensor networks that we envision will increase our capabilities for *in-situ* environmental monitoring and experimental research in harsh locations.

Description of key project steps and timeline

Timeline for key project steps:

1 March – Start the project by hiring students to work with Apple, Negus, and Gallagher to build the initial set of sensor and central nodes and to test them near campus. Document the project, timeline and goals using a repository in the ESIP GitHub organizational account.

1 May – Complete sensor calibration.

30 June – Complete the final hardware prototype.

Late July – Field site will likely become accessible

1 August – Field testbed deployment and soil characterization.

1 September – Continued field testbed deployment and soil characterization.

Late September – Snow will likely block access to the field site.

31 October – Final Report for the Project in the ESIP GitHub organizational account.

Field-testable sensors are to be ready by early summer, 2020 so that they can be deployed when the snow will likely have melted enough so that the field site will become accessible, likely by late July.

This project will proceed as a combined hardware and software project, building on earlier prototyping work that resulted in a proof-of-concept (POC) system. The POC design and deployment combined sensor hardware and software that demonstrated data could be collected and sent to a data server on the Internet in near real-time using low cost open-source hardware components. The sensor nodes were based on the ATmega 328p Microcontroller Unit (MCU) with temperature and soil-moisture sensors and an RFM95w LoRa transceiver. The sensor node communicated with a 'master' node that forwarded the data to a CHORDS (ref) server.[1]

The initial POC work employed a simple master node that enabled testing the sensor nodes. The students led by Negus have developed a POC master node based on Arduino MCU ecosystem and satellite modem technology that can receive data from the sensor nodes and forward them to data servers (e.g., CHORDS, ERDDAP) fill the role of a Master node.[2]

The project we propose is to build a scalable prototype system based on the POC design. There are several steps needed to produce a system that will be robust enough to be generally usable. We believe that the development of a *prototype* is achievable in an eight-month timeframe and that such a prototype can be used effectively for use by people who understand its limitations.

Figure 1 illustrates the basic architecture of our proposed sensor network consisting of a set of sensor nodes and one master per field deployment. This architecture is also commonly known as a 'star' network topology.

Milestones for the Project:

- Build an initial set of sensor and central nodes
- Devise a means to locate buried sensors
- Test prototype deployments in several testbed environments

Description of additional funding currently supporting this work

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[1] Gallagher and Apple presented work on the POC system at the Summer 2019 ESIP meeting and at a subsequent EnviroSensing Cluster telecon. The software and design artefacts are available via GitHub at https://github.com/jgallagher59701/Soil_moisture

[2] Negus et al. 2019, have written a white paper describing their current progress.

The Montana Technological University Department of Electrical Engineering is currently funding three undergraduate students who work with Professors Apple and Negus to develop a means to access sensor data remotely. This one-academic-year-long project will result in a student-generated poster presentation at Montana Tech's Spring Research Fair (TechXpo) and is funded for approximately $3,000.

Outreach

What groups/audiences will be engaged in the project?
The groups/audiences that will be engaged in this project include the ESIP EnviroSensing cluster, domain scientists, the Montana Native Plant Society, students in engineering, computer science, and biological sciences at Montana Tech, and the CirMount Mountain Research group.

How will you judge the project's impact?
We will judge the project's impact by calibrating the sensors to determine their effectiveness, by assessing the accessibility of data from the sensor network, by feedback from interested parties at scientific meetings, by the interest of groups wishing to implement sensor networks and by mountain science and climate change data generated from this project.

How will you share the knowledge generated by the project?
We will share the knowledge generated by the project by making presentations at ESIP meetings, at AGU, and by relaying knowledge to colleagues in the EnviroSensing and mountain science communities. We will also prepare written accounts of the knowledge generated by the project and these accounts can take the forms of the final report, white papers, and manuscripts for submittal to peer-reviewed journals.

Description of who (agencies/individuals) should be aware of this project, i.e. potential outreach targets
Agencies/individuals who should be aware of this project include: The ESIP EnviroSensing cluster, ESIP in general, the National Forest Service which issues permits for research on the Alpine Tundra Wilderness areas of Montana and other remote regions, the MtnClim/CirMount group of mountain scientists, the MTech faculty and students, the Montana Native Plant Society, and SensorSpace at the University of Montana. This project extends to a general audience because of its engagement with the open source hardware movement and IoT groups. Our use of GitHub and online JIRA servers in an open project management system provides transparency to the work delineated in this project.

Project Partners (as applicable)

Description of project partners (agencies/individuals) and their involvement
Project partners are Professors Apple (Biological Sciences) and Negus (Electrical Engineering) of Montana Technological University and James Gallagher of OPeNDAP. At Montana Tech, Professors Apple and Negus will work with students to develop and construct an array of sensors and satellite modems. James Gallagher of OPeNDAP will be working closely with the Montana Tech group to develop this system. The sensor 'leaf nodes' will use LoRa technology to communicate with the satellite modem that will forward data onward to CHORDS or ERDDAP servers.

How will this project engage members of the ESIP community?
This project will continue to engage the ESIP community via the EnviroSensing cluster by conveying news of its progress to the EnviroSensing cluster and to all other members of ESIP through participation and presentations at ESIP Meetings and telephone conferences and by developing collaborations with members of the ESIP community who are interested in field testing the sensor arrays that are developed with this project.