MONTANA NSF EPSCoR

NEWSLETTER

SMART FIRES
YEAR 1
HIGHLIGHTS
2024

Prescribed fire. *Image courtesy of University of Montana*

DIRECTOR'S UPDATE

SMART FIRES' first year anniversary came and went in early August. The first year may have passed very quickly, but looking back on the project's accomplishments speaks volumes about the team's collective dedication, innovation, and sense of purpose. Many of these accomplishments are described in detail in this newsletter. Project highlights include:

- We welcomed two new computer science colleagues to Montana and to the team. Dr. Lucy Owen has joined the UM Computer Science faculty and is already starting to establish her research program applying machine learning to cognitive neuroscience. MSU hired Dr. Mike Wojnowicz as the inaugural Hambly Chair in Computer Science. He will start this role in January 2025. Dr. Wojnowicz's research focuses on developing interpretable, probabilistic models that blend the strengths of statistics and machine learning.
- A showpiece of the SMART FIRES project is a mobile sampling lab that will enable researchers to measure ground-level smoke properties at different locations relative to a prescribed burn. During the past year, Professor Lu Hu (UM) purchased a panel van and oversaw the retrofitting of the van's interior so that it could accommodate a suite of analytical instrumentation and sampling equipment, including new sensors being developed at MSU. The mobile sampling lab will provide the SMART FIRES team unique opportunities to understand the impact of prescribed fires on air quality.
- Prof. Kristen Intemann (MSU) reviewed wildfire-specific datasets and developed GIS maps of Montana and the continental US that identified communities most vulnerable to smoke exposure. These maps will be used to inform and guide how prescribed fire is used to manage ecosystems while being cognizant of prescribed fire's impact on people.
- Suzi Taylor (MSU) has begun working with Montana educators across the state to highlight professional development opportunities related to prescribed fire. Nathalie Wolfram (UM), Alex Sobin (UM), and colleagues with the spectrUM Discovery Area are developing exhibits and hands-on activities highlighting SMART FIRES activities and the science underpinning prescribed fire.

I can't acknowledge all the highlights here, but as you read through this newsletter, I hope you will feel pride and amazement at the breadth and scope of this project to which you are all contributing. Looking forward to what Year 2 brings!

—Professor Rob Walker,
SMART FIRES Project Director
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YEAR 1 HIGHLIGHTS

This special issue of the Montana NSF EPSCoR newsletter provides a summary of the Year 1 activities and progress for the RII Track-1 Sensors, Machine Learning, and Artificial Intelligence in Real Time Fire Science (SMART FIRES) Project. SMART FIRES, supported by the National Science Foundation under Award OIA-2242802, is a five-year, $20M project developing and deploying new technologies and research to better understand the behavior of prescribed fire and its impacts on Montanans.

The project's research is organized by four collaborative science areas that address prescribed fire and smoke: fire and smoke science, smart optical sensors, machine learning and artificial intelligence, and social science, economics and ethics related to decision makers and communities in Montana.

23 Faculty

23 Post Docs & Graduate Students

32 Partners and Collaborators

17 Undergraduate Students

22 Total Publications

SMART FIRES BY THE NUMBERS

YEAR 1 OUTCOMES OF MONTANA'S NSF EPSCOR RII TRACK-1 PROJECT

23 total faculty, **23** postdocs and graduate students, and **17** undergraduate students involved with the SMART Fires project in Year 1

22 PUBLICATIONS – Cumulative total number of publications released by SMART Fires researchers by the end of Year 1

32 PARTNERS AND COLLABORATORS – Total number of SMART Fires external partners and collaborating institutions in Year 1.

SMART FIRES PARTNERS AND COLLABORATORS

- University of Montana Forest & Conservation Experiment Station
- Lubrecht Experimental Forest
- US Forest Service Missoula Fire Sciences Laboratory
- Northern Rockies Fire Science Network
- Montana Department of Natural Resources & Conservation (DNRC)
- Montana Department of Environmental Quality (DEQ)
- Montana Idaho Airshed Management Group
- Blackfoot Challenge
- Montana Wildfire Smoke Program
  - Climate Smart Missoula
  - Missoula County Public Health Department
- NASA AERONET
- National Center for Atmospheric Research (NCAR)
- Resonon, Inc.
- Montana Photonics and Quantum Alliance (MPQA)
- SensorLogic
- Vision Aerial
- New Horizons Studio
- Hyundai America Technical Center, Inc.

The SMART FIRES mobile lab can be used to sample smoke off-grid, while parked or driving, and can power over 5 kW of science equipment. *Image courtesy of Wade Permar.*

SMART FIRES RESEARCHERS AT UM BUILD MOBILE AIR QUALITY LABORATORY

SMART FIRES researchers at the University of Montana converted a 2023 AWD Ford transit van into a mobile laboratory capable of taking air quality measurements near prescribed burns, wildfires, and other remote pollution sources.

The van has enough space and power to house and deploy scientific instruments capable of taking comprehensive measurements of gas and aerosols in situ. It can use remote sensing to track and sample smoke from prescribed and wildfires. The mobile lab can be used to sample smoke while parked off-grid or driving, and can power over 5 kW of science equipment and two air conditioning units to manage the heat from the instrumentation, fires, sun, and more.

Dubbed the "Supervan," this mobile laboratory is a valuable piece of research equipment that will help the SMART FIRES Fire and Smoke Science (FSS) team better understand the production of remotely detectable fire radiative energy, prescribed fire emissions, and air quality impacts at local to regional scales.

Outfitting the mobile lab requires critical training in analytical chemistry and engineering for environmental monitoring. To this end the FSS team (specifically the Lu Hu/Bob Yokelson lab) has been responsible for all designs, implementation and deployment of scientific equipment-related tasks. The mobile lab represents a significant research infrastructure development for Montana.

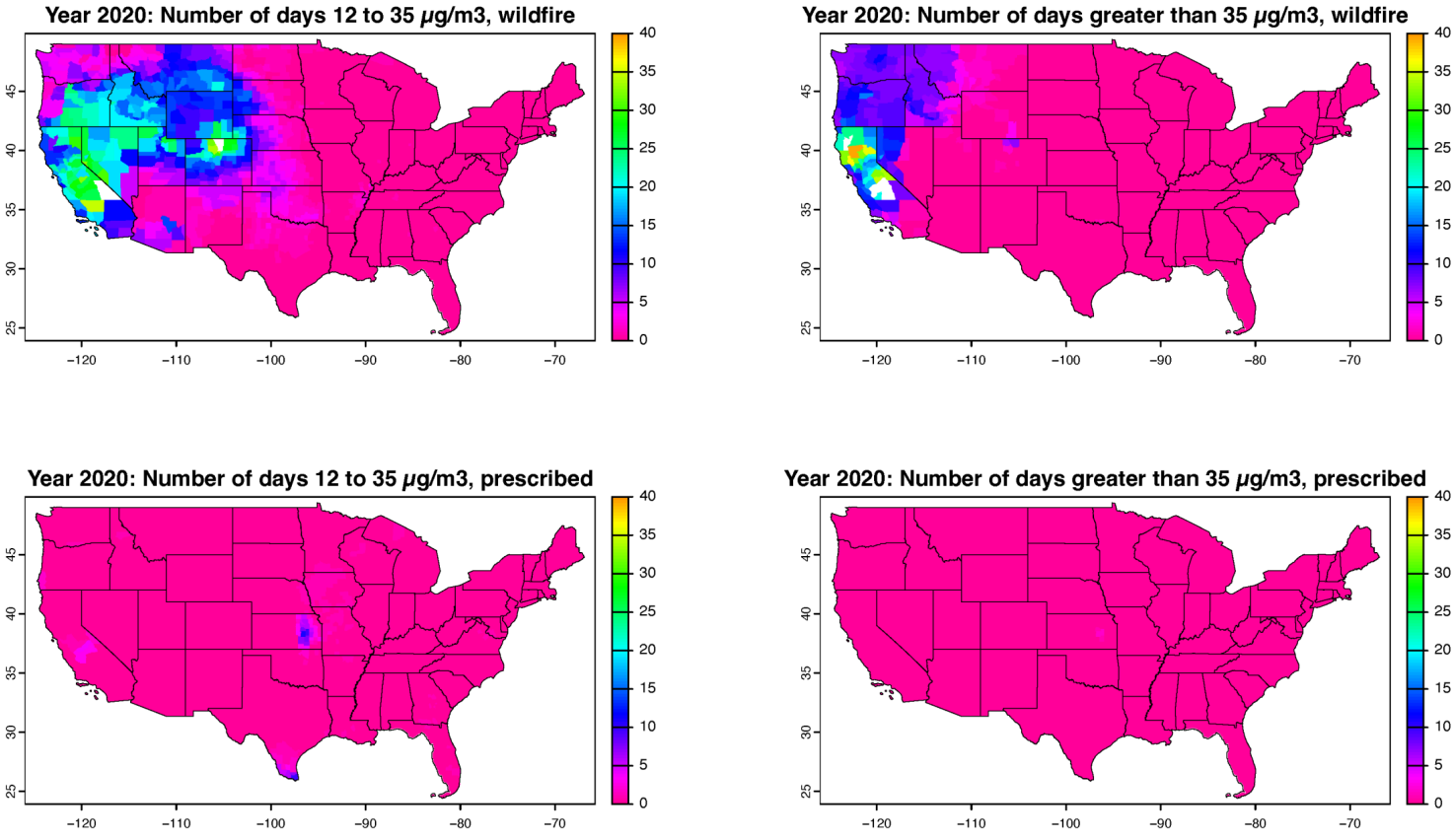
TEAM MAPS COMMUNITIES VULNERABLE TO SMOKE EXPOSURE

The Social Psychology, Economics, and Ethics (SPEE) research thrust directed by Libby Metcalf has spent much of year 1 developing GIS maps of Montana and the continental United States to identify and analyze the communities most vulnerable to smoke exposure.

This research, led by Kristen Intemann, will help decisionmakers identify where resources are needed and ensure that prescribed burning can be done in ways that do not make smoke pollution worse for vulnerable communities.

Smoke from fires creates particle pollution (PM 2.5) that, at certain levels, can lead to a variety of health problems, including cardiac arrest, strokes, and premature death. The research identifies communities across Montana and the U.S. that, on average, have the highest number of smoke days that exceed the EPA limit and communities that also have a significant number of days of "moderate" smoke pollution, which may still have some health impacts, particularly for sensitive groups.

Below is a map displaying the average number of days at the EPA levels for "unhealthy" (greater than 35 µg/m3) and "moderate" (between 12-35 µg/m3) for counties and census tracts across the U.S. from both wildfires and prescribed burns. The team found that unhealthy levels of smoke are far more likely to be caused by wildfires than prescribed burns and that certain communities that are highly vulnerable to the health impacts of smoke are also those with the greatest wildfire smoke exposure.



Maps displaying the average number of days at the EPA levels for "unhealthy" (greater than 35 µg/m³) and "moderate" (between 12-35 µg/m³) for counties and census tracts across the U.S. from both wildfires and prescribed burns. *Image courtesy of Kristen Intemann.*

HIGH SPECTRAL RESOLUTION LIDAR

Researchers at Montana State University have spent the last two decades developing laser-based remote sensing instruments for probing the lower atmosphere and are now using this knowledge for the Smart Optical Sensor research thrust.

This year, part of the SOS team's research, directed by Joseph Shaw, focused on developing a high spectral resolution lidar. The HSRL utilizes the spectral properties of light scattered in the atmosphere to provide information regarding the concentration of atmospheric aerosols, including smoke.

The image at right shows a high spectral resolution lidar built during the past year. The high spectral resolution lidar will provide information on the height and thickness of a smoke plume and help characterize the smoke. The instrument is currently undergoing testing on MSU's campus.

Dylan Maxwell, a graduate student in Electrical and Computer Engineering, working on the initial alignment and testing of the High Spectral Resolution Lidar for aerosol profiling. *Image courtesy of Kevin Repasky.*

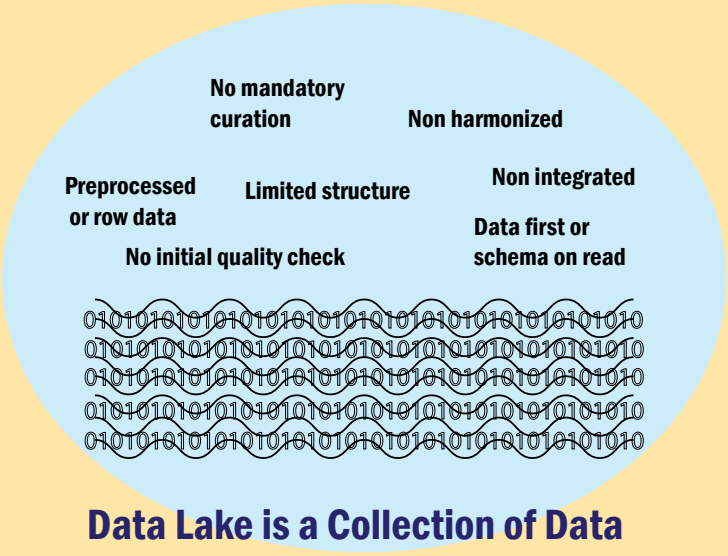
DATA LAKE

The cyberinfrastructure team has implemented a data lake as part of their goal to ensure effective data management for SMART FIRES. The data lake is an internal data storage solution for big data and connects SMART FIRES researchers to MSU's Blackmore data storage facility.

The data lake enables centralized and scalable project data storage; data sharing; ease of access across the Montana University System; and automated nightly backups. The data lake is accessed via services that enable high-speed transfer of large datasets.

For multi-disciplinary research teams sharing big data –large files or lots of small files – typical storage solutions can perform poorly or fail. Increasingly large datasets can create technical bottlenecks. The data lake is intended to mitigate bottlenecks and accelerate research.

The data lake provides researchers with a high-performance storage solution that can be easily accessed from anywhere with a network connection, regardless of institutional affiliation. The SMART FIRES data lake aligns with data management best practices and keeps research data secure, enabling researchers to focus on the research.



Data Lake is a Collection of Data

NEW HIRES – DR. LUCY OWEN AND DR. MICHAEL WOJNOWICZ

Dr. Lucy Owen and Dr. Michael Wojnowicz have been hired at UM and MSU respectively as computer science professors focusing on machine learning. Short interviews below introduce the two new members of the team. To learn more about our new colleagues or learn how they found their way to their current careers, longer versions of the interviews are available on the SMART FIRES website.

DR. LUCY OWEN

What is your specialty?
I am a computational cognitive neuroscientist. I'm really interested in brain network dynamics.

How did you end up researching the brain?
I started as a studio art major and a chemistry minor. I thought I would go into medicine, but I took a gap year and worked on a dude ranch, and I tried my hand in New York City as an artist for a while, all while thinking that I would go back to med school. But then I started tutoring in math and science, and I really fell in love with teaching. I got really interested in how people learned and remember and what made for efficient and effective teaching. I enrolled in a master's of neuroscience and education at Columbia University and that was my avenue into research. It was there that I got more and more interested in the brain specifically, which led me to pursue my PhD at Dartmouth College.

How did you get into computer science?
My PhD research focused on modeling brain data at high temporal and high spatial resolutions. It also honed my interest in machine learning and software design.

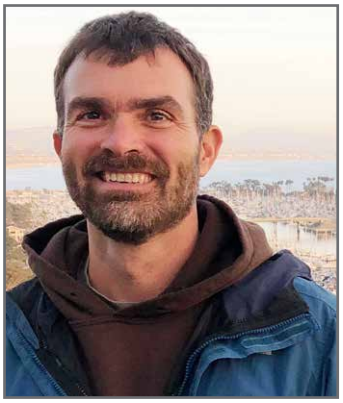
How will your expertise apply to SMART FIRES?
As a cognitive neuroscientist, I am familiar with ways in which we can use sparse and missing data to make predictions. I have experience with several machine learning techniques that I think could be useful in fire mapping.

Specifically, I have used Gaussian processes in several of my projects. For my graduate work I used Gaussian process regression to predict whole brain activity from a subset of electrode locations by leveraging neural similarities across patients. My work has shown how you can use assumptions like spatial smoothness and covariance across people to make accurate predictions about missing data. Additionally, for my internship at Facebook Reality Labs we used Gaussian processes for adaptive psychophysics experimentation. Although the goal for the project was to develop faster and more efficient ways of performing human psychophysics experiments, I think these tools and ML technique like them might be useful in prediction and prevention of wildfires in several ways.

I think these tools could help predict the spread of wildfires by developing a model of factors that contribute to wildfires. Another way would be to leverage the uncertainty in the data to best inform sensor placement to help in the prevention of wildfires. Additionally, generational changes to forests due to fires and other long-term changes would be interesting to explore. Understanding the relationship between these variables and modeling them across time is something well suited to my previous work in timeseries modeling.

What are you most excited about with your new position?
I really like to teach. Specifically, I find adapting to so many different students and types of learning to be a rewarding challenge. The neuroscience of learning is how I got into my field in the first place.

What do you do outside of work?
Hiking, reading, gardening, and painting.



DR. MICHAEL WOJNOWICZ

What is your specialty?
I work in the space between statistics and machine learning.

Statistical models are nice because they're interpretable, probabilistic, and reliable to train. But they can struggle with large, complex datasets. On the other hand, machine learning models are great for large, complex datasets, but many of them are black boxes which are hard to interpret, and the training process can be unreliable and resource intensive.

My research is about developing new methods which blend the best of these worlds.

How did you end up in that area?
My academic training was focused on statistics and mathematics, but I spent six years working at a cybersecurity company building malware classifiers on huge datasets and building intruder detection models from active real-time sensors. In both cases, we needed models that had all of the properties I was talking about before -- expressive but interpretable, scalable but reliable. After a while I came back to academia so I could focus on research. I did a postdoc in machine learning at Tufts, and right now I'm doing a postdoc in biostatistics at Harvard. My research addresses problems from the same perspective as before – models must have the properties that we needed in industry. Most recently, at Harvard, we've been developing new methods along these lines for early cancer detection.

How will your expertise apply to SMART FIRES?
SMART FIRES is right up my alley.

The selection problem of finding where you would want to place a controlled burn is similar to other selection problems that I've worked on throughout my career. For example, in cancer research, you're looking along the chromosome and you're trying to see if there are places in the chromosome where there's something weird happening called copy number alterations. If you see that, it's an early clue that someone might have cancer. I've also worked on selection problems in other areas of research - stroke recovery, malware analysis, and soldier performance.

Another thing is that I'm very interested in is spatiotemporal problems where you have irregular time stamps or irregular spatial locations. Sensors don't necessarily give information in regular time and aren't always synced with each other. This problem came up at the cybersecurity company when we were developing models for intruder detection based on how people use their computers. I've recently been developing some new methods for such data that again blends techniques from statistics and machine learning.

What are you most excited about with your new position?
I am excited to work on SMART FIRES, to teach classes related to probabilistic modeling of data, and to work with talented colleagues and students.

What do you do outside of work?
First and foremost, hanging out with my friends and family. I have a 9 and a 7-year-old so I'm lucky enough that they usually still want to hang out with me. My hobbies have been changing recently because we've been moving around, but I enjoy hiking and racquetball. My goal is to learn how to skate ski.

HEADWATERS TECH HUB

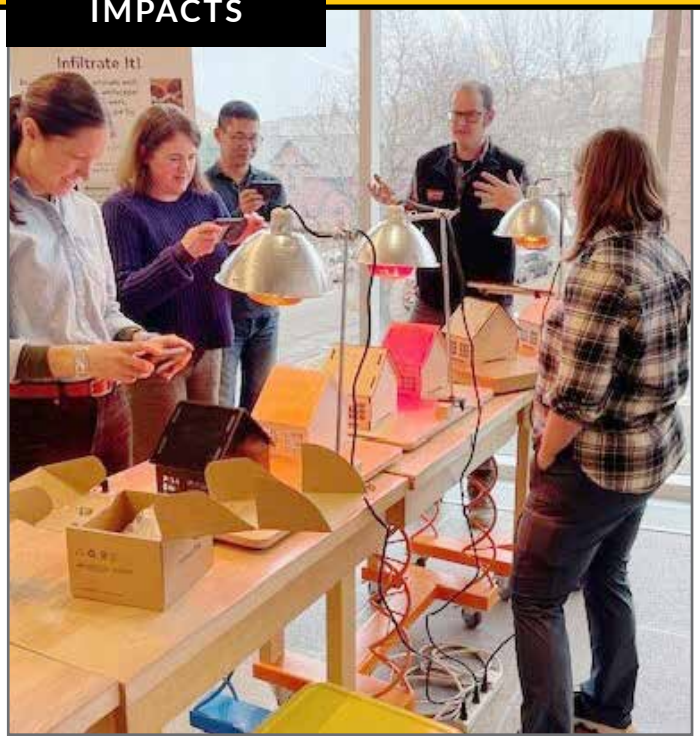
A key element of the SMART FIRES project is to bring together world-class expertise at UM in fire science with world-class expertise at MSU in optical remote sensing systems. A new statewide initiative called the Headwaters Tech Hub was selected for $41 million of funding from the Economic Development Administration in July 2024.

The Tech Hub aims to expand and strengthen the technological ecosystem in Montana so that we can achieve even greater commercialization of photonic remote sensor technology. Examples of the technology range from lidar systems for 3D measurements of gases and aerosols (e.g., wildfire smoke) to hyperspectral imagers for drone-based characterization of fire fuels and automated sorting in food processing plants.

Though the projects differ, both SMART FIRES and the Headwaters Tech Hub have smart photonic sensors as core technologies. While the Headwaters Tech Hub is oriented toward commercialization, its funding will benefit optic and photonic research in Montana and the SMART FIRES project. TechHub director Tim VanReken spent nearly a decade as an EPSCoR program director with the National Science Foundation.

The new Montana Headwaters Tech Hub will continue the development of the state's optical sensing technology. *Image courtesy Headwaters Tech Hub.*

The Tech Hub's funding will be used to help hire new faculty and to purchase significant new equipment for educating students and for developing, calibrating and testing advanced optical sensing systems. The Tech Hub will also develop several different outdoor testbeds where sensors can be tested for both research and commercialization. One of those testbeds will be at the Lubrecht Experimental Forest, where plans are already underway to conduct some of the prescribed fire experiments in the SMART FIRES project.



spectrUM associate directors Nick Wethington and Caitlin Ervin engage faculty members Libby Metcalf, Katrina Mullan, Bob Yokelson, and Lu Hu with a climate resilience exhibit as part of the design of a SMART FIRES exhibition. *Image courtesy of University of Montana.*

spectrUM DISCOVERY AREA FIRE SCIENCE EXHIBITS

In the first year of SMART FIRES, spectrUM engaged over 20,000 Montanans of all ages with exhibits and hands-on activities related to fire and smoke science and the technologies and data involved in researching, managing, and making everyday decisions related to fire and smoke.

The University of Montana's spectrUM Discovery Area is developing a hands-on exhibition to engage K-12 students and the public with key SMART FIRES research and workforce development themes, including fire and smoke science, sensor technologies, artificial intelligence and machine learning, and the human and community dimensions of living with prescribed and wildfire in Montana.

Last winter, staff collaborated with SMART FIRES faculty at spectrUM's Missoula museum to explore existing fire science exhibits and activities and brainstorm new resources as well as extensions of existing ones. spectrUM also hosted an art and poetry exhibition, *Brushstrokes of Change*, curated by teachers at Missoula's Big Sky High School. It featured paintings and haikus by the school's 250 sophomores on the themes of climate and resilience, including to wildfire. Student participants were recognized in signage and at a community gallery event in May.

SMART FIRES SHARES RESEARCH WITH TEACHERS AT STEM SUMMER INSTITUTE

Each year, the Science Math Resource Center at MSU co-hosts the STEM Summer Institute, an annual conference for more than 170 K-12 educators from around the state. This summer, SMRC led a workshop that introduced educators to the SMART FIRES project. It included presentations by Dr. Kevin Repasky from the Smart Optical Sensor thrust and Will Jardee from the Artificial Intelligence and Machine Learning thrust.

Educators also engaged in a discussion on how they could integrate SMART FIRES citizen science initiatives–such as placing air quality sensors in schools around Montana–into their classrooms. Many expressed interest in the project and contributed ideas on how SMART FIRES research could align with Next Generation Science Standards. Most conference participants also visited the SMART FIRES exhibit booths run by SMRC and spectrUM to learn about citizen science and other educational opportunities. spectrUM's booth included the Smoke Box, which demonstrates how smoke contributes to air quality as well as how quickly a homemade box fan filter can clear a cubic meter of smoke.

Suzi Taylor and Jack Pearson welcome educators to the SMART FIRES booth at the STEM Summer Institute. *Image courtesy of Montana State University.*

As each teacher can reach dozens of students or more each year, outreach at the STEM Summer Institute is significant. Integrating the citizen science initiative into classrooms and supporting teachers with other educational resources will provide localized STEM activity and connections to university research.

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