Pathfinding Partnerships Award

For research that engaged four or more distinct research entities in Colorado (with at least two being federally-funded labs) whose results leveraged the resources and strengths among partnering organizations – and demonstrated the power of collaboration.

CIRES

Rapid-Response Science in Service to Communities After the Marshall Fire

NAME OF PRINCIPAL INVESTIGATOR(S):

- CIRES Fellow Joost De Gouw and Associate Director for Science Christine Wiedinmyer
- NOAA CSL's Steve Brown
- NOAA NWS Meteorologist (Denver/Boulder) Robert Kleyla
- NOAA GSL's Darrel Kingfield and Curtis Alexander

Please note that four other people were key to this project: CIRES' Bart Croes and CU Boulder's Nina Vance, Mike Hannigan, and Colleen Reid. At full count, over 20 people from multiple institutions partnered to serve the community with research and information.

NOMINATION'S DESCRIPTION OR ABSTRACT:

This nomination recognizes the quick-response science and service conducted by a set of pathfinding partners before and after the Marshall Fire roared through Superior and Louisville, Colorado, at the end of 2021. We call out teams of researchers who set to work immediately, collaborating seamlessly to figure out how to serve citizens in the short term as well as in the long term. Partners from CIRES, CU Boulder's Mechanical Engineering and Geography departments, the NOAA Chemical Sciences Laboratory, the NOAA Global Systems Laboratory, the NOAA National Weather Service, and the Cooperative Institute for Research in the Atmosphere (CIRA) helped ordinary people make extraordinary decisions, and their ongoing research promises to help guide wildfire response and mitigation long into the future.

DESCRIBE THE BACKGROUND CONTEXT SHAPING THE NEED AND INTEREST IN THIS RESEARCH.

In the early morning hours of December 30, 2021, veteran National Weather Service meteorologist Bob Kleyla was getting a bad feeling as he looked at his computer screen in the Denver/Boulder forecast office. The High-Resolution Rapid Refresh, or HRRR (https://www.weather.gov-/news/200210-rapid-model), NOAA's best short-term weather model, predicted sustained high winds with gusts exceeding 90 miles per hour from a classic downslope windstorm at the base of the foothills near Boulder and Jefferson counties—where trees, grass, and shrubs were tinder-dry after six months of drought and record warmth. Worse, the HRRR was also showing high winds could spread further east toward the dense housing of eastern Boulder County. Kleyla decided to issue a high-wind warning and used GSL-developed Hazard Services software to send out the high-wind alert seven hours before the fire started and winds picked up.

It was the beginning of what would prove to be several harrowing weeks for the communities of Superior and Louisville, Colorado, and for the scientists, weather forecasters, and other experts who not only serve those communities but live in them, too. The Marshall Fire destroyed an estimated 1,084 structures, mostly homes. Two people died.

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Organized by CO-LABS, each year's event spotlights the men and women creating our future through brilliant technological and engineering discoveries in aerospace, energy, agriculture, public health, weather prediction, wildlife ecology, communication, earth science and dozens of other fields of research right here in our communities.

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DESCRIBE THE BACKGROUND CONTEXT SHAPING THE NEED AND INTEREST IN THIS RESEARCH. (CONTINUED)

More than anything, people needed information, both before and after the fires. They needed accurate weather forecasts and information about current conditions. They needed to know what was in the air—outdoors and indoors—and how to best clear that air before moving back home. In this context, NOAA OAR and NWS, CIRES, CIRA, CU Boulder's Mechanical Engineering and Geography, and NWS experts responded to many of those information needs, by drawing on strong existing partnerships, building new ones, and collaborating widely to provide state-of-the science information to people and communities—and advance the state-of-the-science, itself.

- Context for forecasting and warning innovations:
In the hours before the Marshall Fire started, NWS forecasters knew there was a potential for a damaging wind event. That knowledge was based on research technology that had recently been transitioned to operations: The High-Resolution Rapid Refresh weather model. HRRR was built in Boulder, the result of a decade or more of research and development stemming from collaborations among federal and cooperative institute experts in NOAA's Global Systems Laboratory (GSL).

The NWS forecasters were responsible for informing the public (and emergency responders) that conditions were developing with the potential to become deadly. To sound the alarm, the forecasters used GSL-developed software that streamlines the process of issuing watches and warnings.

After the fire started, the forecasters relied on NOAA NWS research, itself, into how people respond to alerts and warnings. Often, people need confirmation from another source to understand the urgency of a situation and take action. The National Weather Service Twitter account provided that confirmation for many community members.

- Context for post-fire service and research innovations:
Immediately after the fires, community needs shifted. The air was smoky and acrid: Was it safe to breathe? What about homes still standing that had been drenched in smoke for hours: Was it safe to return? NOAA, CIRES, and CU Boulder researchers realized they had the tools to provide the community—including themselves—some of the answers. Leveraging existing partnerships and creating new ones, teams of investigators quickly inventoried and then deployed existing equipment to measure critical components of air quality (toxic substances, volatile organic compounds, ozone, etc.) indoors and outdoors. They obtained a rapid "Innovative Research Program" grant from CIRES to start the research, and then another from the National Science Foundation, to dig in and try to understand the atmospheric and human health impacts of a suburban fire. And importantly, they shared results in real time with state and local entities, including Boulder County and the Colorado Department of Public Health and the Environment.

DESCRIBE THE COMPELLING FACETS OF THE, OR THIS TEAM/PERSON'S, RESEARCH AND WHAT WAS THE ULTIMATE KNOWLEDGE AND INSIGHT DISCOVERED.

FORECASTING AND WARNING
NWS meteorologists across the United States rely on the hourly-updating High-Resolution Rapid Refresh (HRRR) model each day to produce weather forecasts. HRRR provides hourly forecasts of weather conditions at resolutions of less than two miles. It can predict dozens of weather elements in 3D from the surface of the Earth up to 80,000 ft in the atmosphere every hour out to 18 hours. Every six hours, the forecast extends another 48 hours. A NOAA GSL team led by Curtis Alexander transferred the latest version of HRRR into NOAA operations in December 2020.

Early in the morning on December 30, 2022, HRRR signaled the potential for a life-threatening wind storm in the foothills of Boulder County. Based on that information, NWS meteorologist Bob Kleyla used Hazard Services, a new software system being developed by GSL's team led by Darrel Kingfield to streamline the forecast and warning process, and issued a high-wind warning with gusts exceeding 90 miles per hour. The other models Kleyla consulted were less confident, but his years of experience had taught him to trust the HRRR in situations like this. Unfortunately, the forecast was verified.

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TWITTER STREAM

The Boulder/Denver office of the National Weather Service, led by Meteorologist-in-Charge Jennifer Stark, used Twitter highly effectively on December 30 and beyond, to highlight the extremely high-risk situation and evacuations (no doubt saving lives), and to point people to resources. @NWS-Boulder has 80.2K followers, expanding the reach of accounts like Boulder's Office of Emergency Management (71.7K). Over the course of December 30 alone, public engagement with @NWSBoulder's Tweets grew from a few dozen retweets and likes to thousands per tweet.

- An 8 am tweet warned about high winds.
- At 11:33, a wind gust hit 105 mph; the office wrote "Stay safe out there everyone!"
- By noon, the office had tweeted about multiple fires, warned the situation was high-impact and serious, urged people to abide by evacuation orders, and began sharing city and emergency management Twitter accounts.
- After 1 pm, the office was using ALL CAPS and hashtags, e.g., "If you are in Louisville, this is a life threatening situation. LEAVE NOW!" These messages inspired action. One Louisville resident reported that Tweet was a jolt of reality; she'd assumed the situation wasn't too bad, that rumors were rife.

POST-FIRE RESEARCH AND SERVICE

SERVICE

Immediately after the fires, CIRES and CU Boulder researchers led by Christine Wiedinmyer began assembling useful information for communities and residents on mitigating post-fire smoke impacts in homes. Team members responded to a constant stream of emails and calls from residents and so on January 4, they published on CIRES's website an online guide to cleaning and airing out living spaces, based on published research (https://cires.colorado.edu/news/how-mitigate-post-fire-smoke-impacts-your-home). They described the source of the smell, the value of air purifiers, the importance of opening windows, and more—and they translated all information into Spanish. Boulder County Public Health posted the guide on the County's Marshall Fire Website, Boiler County Office of Emergency Management posted and shared it, and scientists from CIRES, Mechanical Engineering, Geography, BCPH, and the Colorado Department of Public Health and the Environment began meeting or communicating daily, to update it. The webpage drew more than 20,000 unique views in January 2022, and 63,000 to date (the populations of Louisville and Superior are ~19,300 and 13,000). Experts listed on the site continue to field emails and calls through the writing of this nomination.

Boulder County's Bill Hayes, Air Quality Program Coordinator, worked closely with this team and sent "thousands" of people to the website for guidance. "I cannot over-express the value of their work to answer questions from an understandably stressed public," Hayes wrote in a nomination of the work for a Boulder County Award (see question 11).

INDOOR AIR QUALITY RESEARCH

Simultaneously, the CIRES/CU Boulder-based team began to deploy instruments into homes damaged by the fires. They scrounged instrumentation from labs to set up sophisticated systems in homes that had been badly vs. barely smoke damaged, adding measurements to the experiment as they obtained funding. Graduate students were critical to this effort. Led by CIRES' Joost de Gouw, the team sought to understand: Was it safe for people to return home?

In most homes, measured pollutant concentrations were higher than in a typical home. But the team did find that airborne pollutants indoors had decreased to more normal levels after several weeks. They also found that simple and low-cost activities had immediate, significant impact on indoor air quality: Opening windows and running air purifiers, for example. Even low-cost fan-and-filter systems made with box fans, furnace air filters, and duct tape dropped pollutant levels dramatically and quickly. Importantly, the scientists shared these results in near real-time with regulatory agencies and with the general public.

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OUTDOOR AIR QUALITY

NOAA Chemical Sciences Laboratory supports a team of scientists with extensive experience with fire and smoke research and urban air quality. Within days of the Marshall Fire, a team led by Steve Brown began talking with experts from the Colorado Department of Public Health and the Environment, and Boulder County Public Health, about deploying CSL's mobile research lab, which might provide immediate, relevant information on outdoor air quality. After ensuring that air quality data would help, not hinder, recovery efforts, NOAA-based scientists began driving through Louisville and Superior, measuring air pollutants in the burned area and downwind. The readings clearly showed the chemical signature of smoke in the air—consistent with the lingering smell—but the levels at that point were much lower than would normally be associated with an active wildfire. Moreover, the levels of smoke-related compounds in the air were comparable to or lower than what might be called "ordinary urban air pollution," emissions from vehicle tailpipes, for example. On the basis of these readings, the team judged that there was likely not a continuing threat to local air quality in the burn area. January 5, Boulder County issued a press release with these findings. (https://bouldercounty.gov/news/outdoor-air-quality-indicators-in-marshall-fire-burn-areas-similar-to-unburned-urban-areas/)

HOW HAS THIS RESEARCH BEEN APPLIED, UTILIZED, COMMERCIALIZED OR OTHERWISE ADOPTED OUTSIDE YOUR LAB?

The most immediate high-impact application of this rapid-response science after the Marshall Fire was service to people and communities impacted by the fires themselves. By collecting data that only NOAA and CU Boulder experts could quickly collect, the scientists made an enormous difference in people's lives. Importantly, these experts worked closely with county and state officials before releasing public information. In general, scientists wait for peer review and publication before dispensing critical information. Given that data would be of most use immediately, this engagement with regulatory agencies provided an important review element.

The value of the research will increase with time, as well. First, the rapid-response science provided the research community with a protocol for future fires and other high-impact air quality events. When mobile laboratories are available or researchers have equipment that can be deployed for public service, it is now more likely that equipment will be put to immediate use. For example, in response to the Marshall Fire, CIRES established a rapid Innovative Research Program application and review process, so researchers can apply for grant funding within days of an event. Second, evidence is accumulating about the value (to indoor air quality) of various post-fire cleanup activities, from opening windows and running filter-fan systems to paying for professional remediation, ripping out carpets and repainting. Unfortunately, we cannot yet provide the initial data to the judging panel – papers are in preparation for publication and they may well prove somewhat controversial. But results will be out within months, and CIRES, CU Boulder and NOAA scientists will work with the county and state once more, to ensure people understand the implications of the research for cleanup from future fires. With apologies for the lack of detail: This work has the potential to significantly change cleanup processes post-fire.

NOAA's Chemical Sciences Laboratory scientists said they learned lessons that will surely be adopted in the future: We "learned how to put together a scientific package in a short period of time for rapid response to a community need," Steve Brown said. "That ability will serve us well in the event of similar requests in the future. Our normal spin-up time would have been on the order of weeks or months. Here, we had the van package operational in less than 24 hours."

The NOAA group already has a substantial database on the emissions and chemical fingerprints of wildfire smoke in ambient air. However, fires like this one that also burn into communities and consume homes are increasingly frequent events. Combustion of homes likely has a different impact on air quality, and scientists don't understand these emissions or its key fingerprint well, yet. Combustion of things like PVC pipe and other synthetic materials in homes has the potential to release air toxics that are not yet characterized. Analysis of the data from the air chemistry instruments used both indoors and outdoors may ultimately show trace levels of these sorts of pollutants, but it will take time for this analysis. The outcome may inform safety protocols for first responders in the future.

And finally, the event helped bring together and cement some pathfinding partnerships among air quality chemists and other scientists from several NOAA labs and CU Boulder departments. CU Boulder engineering faculty coordinated with NOAA scientists and CIRES scientists in new ways. Graduate students from several departments will have chapters in their Ph.D. theses with "Marshall Fire" in the title.

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Related awards, recognitions and media about this research.

Two Boulder County Healthy Community Awards, September 30, 2022:
- "National Oceanic and Atmospheric Administration is being recognized for supporting communities impacted by the Marshall Fire. NOAA provided outdoor air monitoring immediately after the fire throughout the burn areas. Measuring gaseous air pollutants caused by the fire was essential in ensuring residents in and around the burn areas were safe." Please note that the NOAA team included scientists from the Chemical Sciences Laboratory and CIRES.
- "Home SOS Program at the University of Colorado is being recognized for its work in supporting our communities impacted by the Marshall Fire. The SOS Home Team provides clean up guidance and indoor air monitoring in fire-impacted homes to determine levels of pollutants, characterize risks and provide mitigation measures. Their work was essential in assisting residents in cleaning up and returning to damaged homes more safely." Please note that this team involved scientists from CIRES and several other departments around CU Boulder campus.

Research and Service by NOAA employees and affiliates (including CIRES and CIRA) were highlighted in an excellent StoryMap published by NOAA just one month after the fire; the storymap has been viewed more than 23,000 times since publication January 28.

The indoor air quality team received a Rapid Innovative Research Program grant of $43,000 from CIRES, which helped fund initial deployment of instrumentation in impacted houses.

With immediate results already coming in, the CU Boulder-based team applied to NSF for a more substantial funding to study "Sustained Air Quality Impacts of the Marshall Fire in Boulder County." They were successful: NSF Award Number 2218009; Principal Investigator: Joost de Gouw; Organization: University of Colorado at Boulder; Start Date: 04/01/2022; Award Amount: $200,000.00.

Regarding the Pathfinding Partnerships Award, University of Colorado Boulder Acting Vice Chancellor for Research and Dean of the Institutes Massimo Ruzzene said "These two award-winning teams exemplify the best of the CU Boulder and NOAA collaboration. This high-impact work could not have happened without all contributors: federal, university, and other key experts."

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About CO-LABS:

Started in 2007, CO-LABS is a non-profit consortium of federal laboratories, research institutions, businesses and economic development organizations that provide financial and in-kind support for programs that promote the retention and expansion of Colorado's federally-funded scientific resources. Through events, economic analyses, strategic communications and networking activities we work to:

- PROMOTE Colorado as a global leader in research and technology
- EDUCATE the public about federal research labs' and institutions' impact, and importance of sustained funding for research
- CONNECT the labs, universities, economic development organizations and businesses to facilitate partnerships and technology transfer

To learn more, visit www.CO-LABS.org.