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SCIENCE NEWS BY AGU

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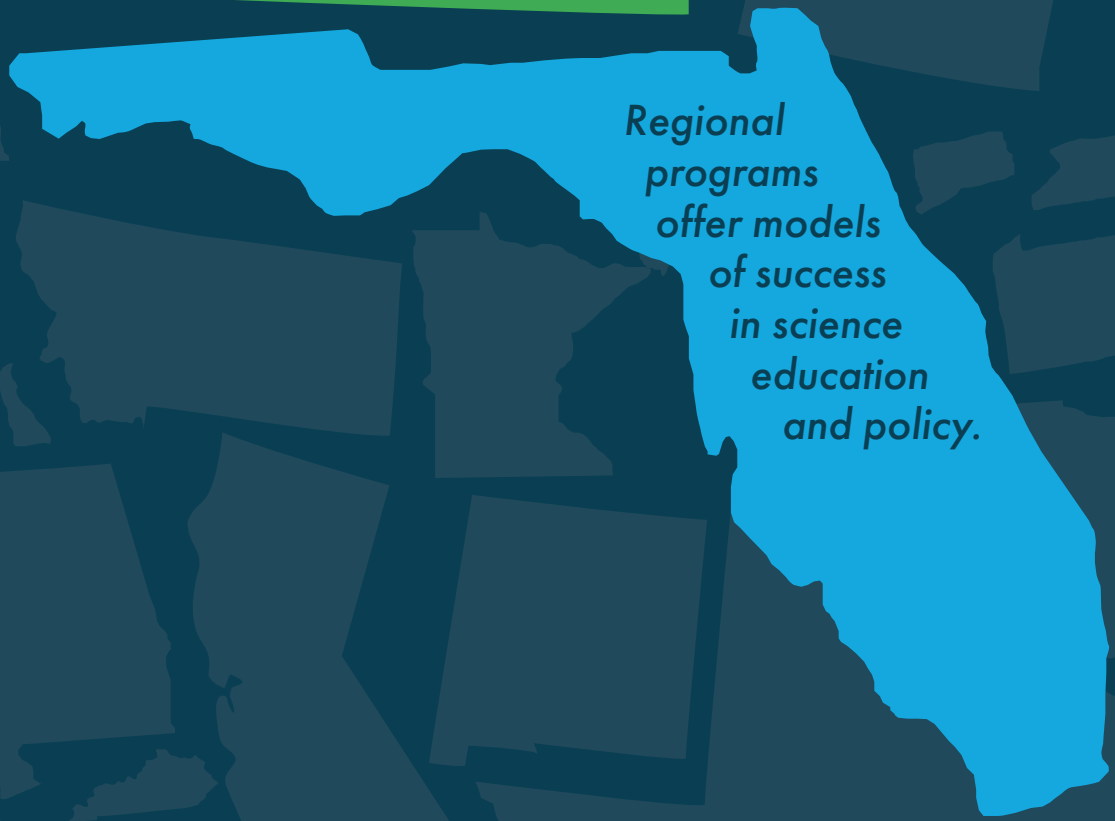
Microplastics Are the Not-So-Secret Ingredient in Marine Snow

States of Mind

Regional programs offer models of success in science education and policy.



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Eos AGU ADVANCING EARTH AND SPACE SCIENCES

From the Editor

In this issue, we explore how two diverse, state-focused approaches to science communication provide road maps for meaningful outreach to policymakers and students.

On the Cover

Warmworld/Depositphotos.com

In the January 2024 issue, Frederick Scarf was misidentified in "The 21st Century's 'Music of the Spheres.'" He was a principal investigator on Voyager's plasma wave research.

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Janice Lachance, Interim Executive Director/CEO

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Spring Heat Waves Pack a Punch for Snowpacks in the Pacific Northwest

Pictured here is the snow-covered peak of Mount Ranier in Washington state. A barrage of short-term, moderate temperature spikes can erode snowpacks. Credit: Peter Emery/Unsplash

Snowflake by snowflake, mountain snowpacks build an important water resource for communities and ecosystems. And though intense heat domes—such as the one that struck the Pacific Northwest in 2021—can trigger early melting, researchers have now shown that even short-term, moderate temperature spikes can prematurely melt significant amounts of snow.

Given that such springtime heat waves have been increasing in frequency since the early 1990s, many ecosystems will likely be affected by changes in the availability of water and snow in the future, the team concluded.

"We went in wanting to look at just what the heat dome did."

Deadly Heat

In late June 2021, a heat dome blanketed the Pacific Northwest in record-setting heat. Temperatures approached 50°C in some places, and hundreds of people died from heat-related illnesses.

That extreme event was a catalyst for many researchers. Luke Reyes, an Earth scientist at Washington State University in Vancouver, and his thesis adviser, Marc Kramer, were interested in understanding how the heat dome affected snowpack in parts of the Pacific Northwest. "We went in wanting to look at just what the heat dome did," Reyes said.

The researchers focused on roughly 51,000 square kilometers (20,000 square miles) of the states of Oregon and Washington at a mean elevation of about 1,600 meters (5,000 feet). That decision was borne partly out of necessity, Reyes said. "When the heat dome rolled around, there wasn't too much snowpack at low elevations."

Reyes and Kramer amassed daily snow measurements from a model—the Snow Data Assimilation System (SNODAS)—that had been validated using weather station observations. But rather than analyze snowpack depth, the researchers focused on so-called snow water equivalent. That metric refers to the depth of the pool of water that would persist if the snow that's present completely melted.

Snow water equivalent takes into account the density of snow, which can vary by up to an order of magnitude, Reyes said. It's therefore a more accurate reflection of the true amount of water stored in snowpack, he said.

Emptying Lake Shasta

The researchers compared their snow water equivalent data with daily measurements of air temperature taken from a climate model and found that the 2021 heat dome had a significant effect: Snow water equivalent after the event was roughly 2.5 times lower (74 millimeters; 3 inches) than it was before it (180 millimeters; 7 inches). Over just 5 days, more than 540 million cubic meters (19 billion cubic feet) of water flowed out of high-elevation snowpack—that's roughly equivalent to the volume of Lake Shasta in Northern California.

But the data reflected other discrete decreases in snow water equivalent as well, Reyes and Kramer found. "We looked at the snowmelt overall for that season and saw there were actually a couple of times that snowmelt rapidly accelerated," Reyes said. "What's going on with these other dips?" he remembered thinking.

Again and Again

Reyes and Kramer realized that those dips corresponded to other heat waves that had

happened earlier in the year. "They weren't as extreme as the heat dome, but they were still evidently enough to cause rapid snowmelt," Reyes said.

The researchers counted four such heat waves from April through June with temperature anomalies ranging from 3.8°C to 7.0°C (the heat dome had an average temperature anomaly of 13.4°C). Each springtime heat wave removed roughly 90 millimeters (3.5 inches) of snow water equivalent, the team found. Therefore, the cumulative impact of those heat waves far outweighed that of the heat dome, Reyes and Kramer concluded.

"That's a really important finding," said Rachel White, an atmospheric scientist at the University of British Columbia in Vancouver not involved in the research. Relatively little is known about the impact of early-season heat waves on snowpack, she said. "When we study heat waves, most of the research is about summertime heat waves."

The researchers also expanded their search for springtime heat waves beyond 2021. "We zoomed out from there to look at other years," Reyes said. The team found an increase in the frequency of 5.0°C+ temperature anomalies occurring in April, May, and June since 1993.

Even years that were expected to be characteristically cooler—so-called La Niña years—were exhibiting more heat waves, Reyes and Kramer noted. It's therefore likely that early-season snowpack loss will accelerate in the future, the team concluded. These results were published in *npj Climate and Atmospheric Science* (bit.ly/snowpack-loss).

Such a shift could have significant impacts, not only on local plants and animals that rely on persistent snow cover but also on lower-elevation ecosystems. That's because snowpack is somewhat like a battery, said White. "It stores the precipitation from winter and then releases it in summer so that we have streamflow and water within an ecosystem."

There's now good evidence that heat waves are increasing in frequency and intensity, she added, but getting at the root cause of this trend requires a better understanding of circulation patterns high in the atmosphere, which will require novel new data sets. "We've been measuring surface temperatures for over 100 years in some places. We haven't been measuring what's happening 10 kilometers above the Earth's surface," White said.

By **Katherine Kornei** (@KatherineKornei), Science Writer

Maps Strengthen Collaboration Between Tribes and Federal Agencies

In 2022, the administration of U.S. President Joe Biden finalized new federal guidance on elevating Indigenous Knowledges in federal policymaking. In 2023, the U.S. Forest Service released its own action plan geared toward strengthening tribal consultations and nation-to-nation relationships.

Maps could be key to the success of these efforts, according to research presented at AGU's Annual Meeting 2023 (bit.ly/AGU23-maps).

"What does it mean to take a presidential memo and then operationalize it? How does that translate to day-to-day decisions?" asked Kristin Green, a doctoral student at the University of New Hampshire and the lead researcher on the project. Maps, she said, are "ripe for engaging" with those questions.

Through research with the Nez Perce Tribe, Green is constructing a framework to inform federal agencies on how best to elevate tribal perspectives in maps used in policymaking.

Bending Boundaries

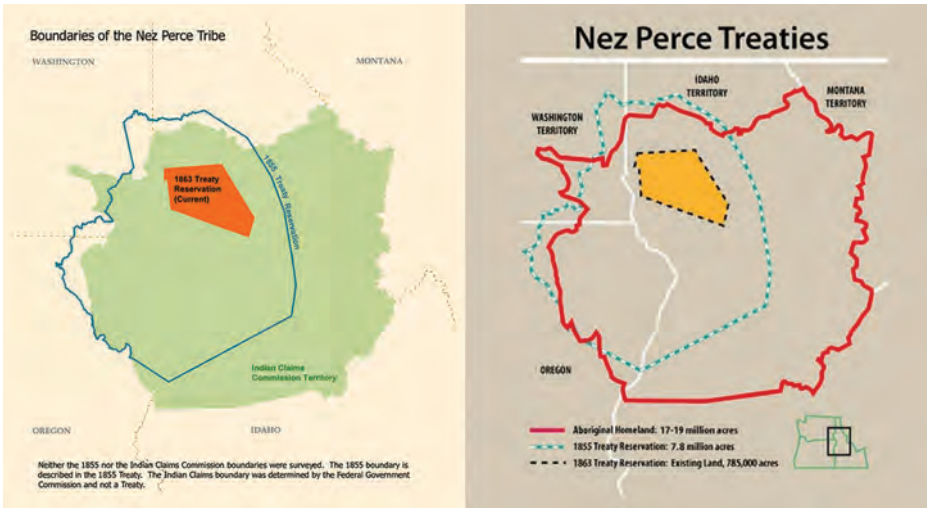
Efforts on behalf of U.S. agencies to consult with tribes can fail, Green said, in part because federal decisionmakers may not accept some Indigenous Knowledges as legitimate.

Information presented on maps is harder to discount, said Margaret Pearce, a cartographer and a Citizen Potawatomi Nation member who was not involved in the research. "What I see in maps is the potential for all our unspoken assumptions to be laid bare," she said.

For example, a 2016 map of the Nez Perce Reservation and surrounding area from a Forest Service planning document marks a large swath of land in Idaho, Oregon, and Washington as "Aboriginal Homeland," whereas a 2019 map made by the Nez Perce Tribe marks the same area as "Indian Claims Commission Territory."

> **"What I see in maps is the potential for all our unspoken assumptions to be laid bare."**

The Indian Claims Commission was an independent agency (decommissioned in the early 2000s) meant to compensate tribes for lands ceded to the United States. It relied on designating areas as exclusive to certain



A 2016 map (left) created by the U.S. Forest Service names a large, off-reservation area as "Aboriginal Homeland." A 2019 map (right) created by the Nez Perce Tribe and updated for this article, identifies the area as "Indian Claims Commission Territory." Credit: (left) USDA Forest Service, (right) Nez Perce Tribe GIS Program

Maps can legitimize certain realities, making them a valuable way to advance nation-to-nation collaboration. Credit: Binyamin Mellish/Pexels

tribes. If two tribes claimed the same land, neither would be paid for it.

The differences between the two maps are important: Labeling the area as "Indian Claims Commission Territory" rather than as a "homeland" indicates that areas outside that boundary are Nez Perce homelands, too. The tribe's homelands "absolutely extend beyond this area," Green said. Adding the Indian Claims Commission boundary also makes the source of the boundary explicit, she said.

The two maps serve as a "tangible example" of important ideas presented in Green's framework, specifically, that boundaries are not universal and context is critical for mapmaking, she wrote in an email. Getting information from all stakeholders onto a map is one way to start to understand all perspectives and strengthen nation-to-nation partnerships, said Pearce.

Tribes' inherent rights to a place often "go beyond the boundaries listed within the treaty," said Iva Moss, a Northern Arapaho Tribe member, cartographer, and STEM (science, technology, engineering, and mathematics) educator at Fort Washakie Middle School in Wyoming. "That's something that people forget when they're working with maps." Moss teaches her students to make their own maps of familiar places that incorporate Arapaho place-names as one way to enforce the boundaries of Arapaho homelands.

Tribal mapmaking may differ from typical Western mapping techniques in conceptions of borders, time, and perspective. Green's framework is informed by previous work that outlines these differences, including a study led by Sierra Higheagle, water quality program coordinator for the Nez Perce Tribe (bit.ly/Indigenous-space-time).

"Let them be who they are, as separate entities: Western science and Indigenous Knowledge."

Higheagle and her team asked community members to identify locations on Google Maps within and around the Nez Perce Reservation that were important for water quality.

Many responded expressing ideas of connection across boundaries and long time frames that could not be placed on a map. Some respondents said they couldn't pick just one place because all water and its quality are connected. "It's almost asking people to do something that goes against the grain culturally of what water is," said Teresa Cohn, a professor of natural resources at the University of New Hampshire who helped conduct the survey and is a coauthor of the new study. "Water is an entity. Dividing it doesn't make sense."

"How much space does an area need to protect it? What are the buffers?" Green said. "This is something that comes up a lot."

Higheagle's work illustrates Indigenous relationships to water and treaty rights that many maps, including those made by the Forest Service, do not reflect, Green said. The framework she's helping to create is designed to bring this idea—that certain mapping methods represent specific perspectives and leave out others—to light.

The starkest difference between Indigenous mapping methods and those used by state and federal agencies is how they conceive of natural resources, Moss said. Mapping for her is about identifying places of an abundance of animals and plants; the Forest Service's maps are much more about identifying resources for economic purposes, she said.

But collaborative maps can circumvent this in nation-to-nation partnerships because they include everything—and everyone's priorities: In a collaborative map, everyone's perspectives must relate to each other and to the land that the map depicts, Pearce said.

Cocreating Cartographies

The researchers used a concept called two-eyed seeing to illustrate how agencies could think about using Indigenous-made maps in policymaking (bit.ly/2-eyed-seeing). The basic principle of two-eyed seeing is that Indigenous Knowledge and conventional Western science don't have to validate each other to both be useful to policymaking. The goal is to gain the benefits of both rather than trying to integrate one into the other, Green said.

"Let them be who they are, as separate entities: Western science and Indigenous Knowledge," said James Rattling Leaf Sr., a tribal engagement specialist for the University of Colorado's North Central Climate Adaptation Science Center and a member of the Rosebud Sioux Tribe. "And then try to figure out a third space where they can communicate."

By **Grace van Deelen** (@GVD__), Staff Writer

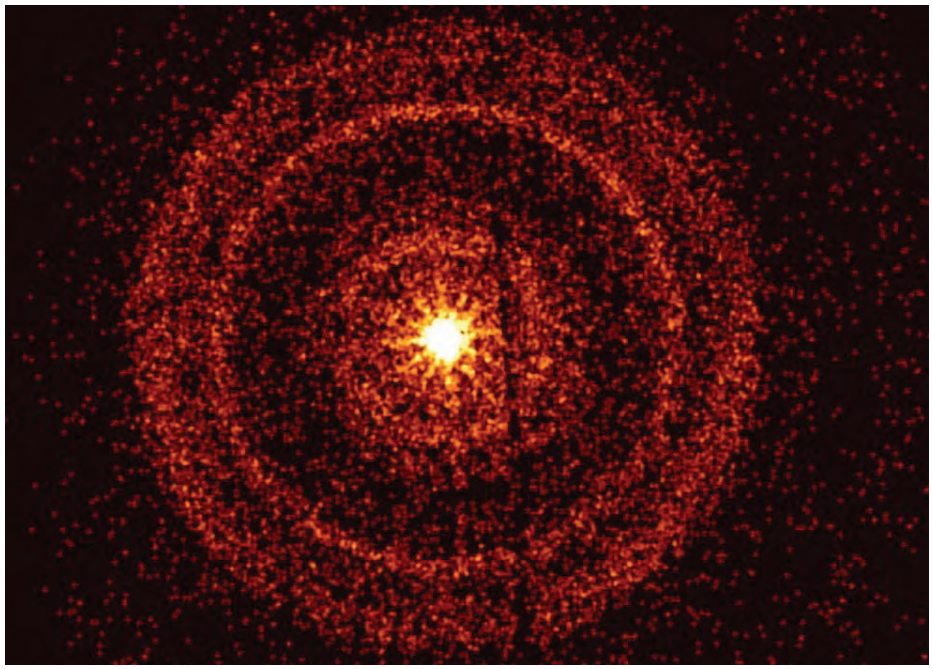
Did a Cosmic Explosion Make the Ionosphere Dance?

On 1 August 1983, Earth's atmosphere recoiled from a gamma ray burst (GRB) likely produced by the explosion of a nearby massive star. The high-energy photons disturbed the lower ionosphere—the partially ionized region of Earth's atmosphere—enough to affect low-frequency radio waves traveling around the planet.

In the 40 years since, astronomers have recorded an average of more than one GRB per day. However, none appeared to perturb the atmosphere in a noticeable way, until a group of researchers connected a bright GRB on 9 October 2022 with a disturbance in the uppermost ionosphere.

"It is, in general, a threshold problem," said space weather scientist Mirko Piersanti of the University of L'Aquila and the Italian National Institute of Astrophysics, who was the lead author of a study published in *Nature Communications* presenting the finding (bit.ly/ionosphere-GRB). He and his colleagues used data from the Chinese-Italian observatory China Seismo-Electromagnetic Satellite (CSES, also known as Zhangheng) to simulate how the ionosphere responds to gamma radiation from deep space.

The threshold problem, in Piersanti's view, is that only a very powerful GRB ionizes enough of the low-density upper atmosphere for long enough to be detectable. The difficulty, then, lies in detangling cosmic gamma rays from the many other phenomena that affect this region.



An X-ray image of the gamma ray burst detected on 9 October 2022 shows the explosion itself as the bright source at the center. The rings around it are where light bounced off dust in the Milky Way. Credit: NASA/Swift/A. Beardmore (University of Leicester)

Cosmic Satellite Killers

In addition to the value that understanding GRBs has to astrophysics, the human stakes are potentially high.

"More and more of our infrastructure and economy is parked in space and power systems, so more and more is at risk, globally," said Aaron Breneman, an atmospheric scientist at NASA's Goddard Space Flight Center who was not involved with the study.

Coronal mass ejections from the Sun disturb the atmosphere enough to disrupt communications and navigational satellites, as well as electrical power grids, and it would be good to know whether GRBs can do the same. (Some researchers have even speculated that a nearby powerful GRB could have contributed to a mass extinction about 450 million years ago (bit.ly/GRB-extinction, bit.ly/Ordovician-GRB)).

The best data for measuring the magnitude of the threat come from events like the 2022 GRB.

"It is, in general, a threshold problem."

Dance of the Ionosphere

In 1988, G. J. Fishman and U. S. Inan proposed using the ionosphere as a planetary-scale GRB detector (bit.ly/GRB-detector). Since then, astronomers have built many telescopes (including the space-based Swift and Fermi observatories) capable of characterizing GRBs, but none of those hundreds of events registered in ionospheric measurements.

Many factors could explain that dearth of data. Though GRBs are among the most luminous events in the cosmos, peak gamma ray emissions from so-called long GRBs last only a few minutes. Their short duration, combined with Earth's great distance from most of the stars whose explosions exist there—millions or billions of light-years—makes it likely that few GRBs produce enough photons to make the ionosphere dance.

When high-energy photons strike the atmosphere, they strip electrons from some atoms, forming the ionized gas known as plasma; this process is called photoionization. Over time, electrons rejoin nuclei (known as neutralization). CSES includes an electric field instrument that can measure these processes.

The density of gas in the upper atmosphere is low, so even dramatic events such as GRBs might not produce a lot of plasma. The researchers' simulation shows that the photoionization rate needs to be at least 5 times faster than neutralization for the GRB's effect to be detectable in the ionosphere.

Typically, Piersanti pointed out, only solar events—which last on the order of hours—affect the atmosphere that strongly.

In contrast, the atmospheric response is too slow for most GRBs to produce a similar effect. In one sense, that's reassuring: If GRBs are common in a cosmic sense but their ionospheric effects are rare, the danger to the planet is low for the foreseeable future.

If Piersanti and his collaborators are correct, the 1983 and 2022 bursts just happened to be powerful enough to flood the ionosphere with ionizing radiation faster than recombination could erase the evidence.

That's a big if.

Complications

"There are so many more things that weren't even considered here that could be affecting their results," said space weather researcher Alexa Halford, also at NASA's Goddard Space Flight Center, who was not involved in the study. The ionosphere itself is a big part of the problem, she said. "It's really hard to get in situ measurements globally all the time."

"There are so many more things that weren't even considered here that could be affecting their results."

To make matters worse, other things far closer to home can increase or decrease ionization. The Sun is by far the most significant source of gamma rays and electrically charged particles that affect the ionosphere. Depending on whether it's day or night and how much solar activity or how many terrestrial storms are in effect, the amount of ionized gas in the upper atmosphere can vary significantly.

"Even lightning can cause lots of really cool [ionospheric] effects," Halford said. "We don't fully understand that either."

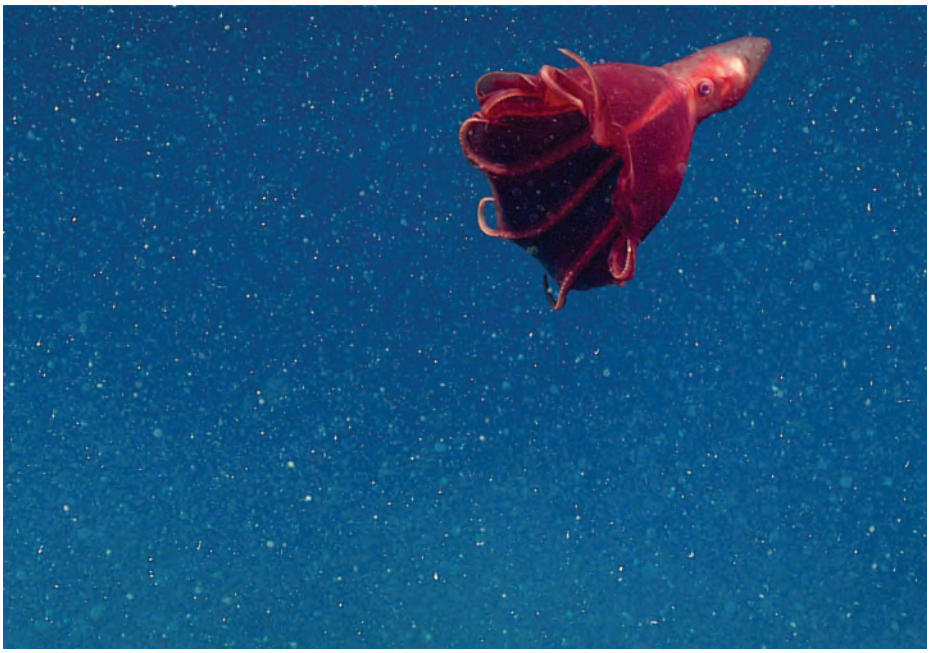
Part of the problem is that the ionosphere is difficult to reach. Much of the data comes from the transmission of long-wavelength radio waves, which interact with the ionized gas. Other experiments involve high-altitude sounding rockets that fly directly through the lower ionosphere. The CSES spacecraft used by Piersanti and his collaborators flies through the topmost layer of the atmosphere. None of these methods provide global 24-hour views of the ionosphere, though, leaving gaps in the data that need to be filled with statistical inference or theoretical models.

With these uncertainties and only two GRBs to work from, Halford and Breneman joined Piersanti in calling for wider collaborations among atmospheric, space weather, plasma physics, and astrophysics researchers.

"The ionosphere as a [GRB] detector is still something that is highly desirable and something that we definitely need to do more to understand," Halford said.

By **Matthew R. Francis** (@DrMRFrancis), Science Writer

Microplastics Are the Not-So-Secret Ingredient in Marine Snow



An octopus swims through marine snow. Credit: NOAA Office of Ocean Exploration and Research

In 2020, scientists discovered that plastics had infiltrated our planet's water cycle, hitching a ride through clouds and rain. Research has shown that the carbon cycle is chock-full of plastic as well: Microscopic particles are drifting to the seafloor with natural organic debris called marine snow.

In a study presented at AGU's Annual Meeting 2023, scientists showed how bacteria and phytoplankton colonize the surfaces of sunburned bits of microplastic and drift to the bottom of the ocean (bit.ly/marine-plastic-snow). This debris-driven flux potentially upsets the delicately balanced system that removes carbon from the atmosphere.

Ocean carbon goes through a cyclical process called the biological carbon pump. Plant-like organisms called phytoplankton float near the surface and use carbon from the air in photosynthesis. Zooplankton consume phytoplankton and excrete fecal matter into the water. Their poop combines with tiny bits of dead plants and animals and sinks to the seafloor in microscopic flakes called marine snow. Upwelling eventually cycles them back to the surface.

To understand how microplastics have affected this vital system, oceanography graduate student Astrid Zapata De Jesús of the University of New Hampshire and her colleagues studied biofouling—the process that envelops microplastics in marine snow.

"This study will form one of the building blocks of this emerging understanding of how microplastic pollution may be affecting natural carbon cycling."

Biofouling happens when anything floating in the ocean—from boats and buoys to microscopic plastics—gets colonized by bacteria and phytoplankton that collect on the surface of the foreign object. These cells combine to produce a sticky organic ooze called biofilm.

The researchers hypothesized that microplastic marine snow forms as microorgan-

isms create little snowballs of biofilm around cores of microplastic. These aggregates collect other organic hitchhikers in the water and sink to the seafloor. The team tested whether biofilm buildup on microplastics affects how fast they sink.

"The idea is, the plastic surface gets bumpy and rough, so there are more spaces and more holes for microorganisms to attach."

The researchers studied both pristine and degraded microplastics. To damage and "weather" the plastic fragments, they used ultraviolet light in the laboratory to mimic the natural effects of prolonged exposure to sunlight. "The idea is, the plastic surface gets bumpy and rough, so there are more spaces and more holes for microorganisms to attach," Zapata De Jesús said.

The researchers exposed both kinds of plastics to natural seawater and two mixtures of microorganisms for 15 days. They periodically used a purple dye to trace any attached living cells.

In a surprise, no relationship was found between biofilm buildup on the particles and their sinking speeds. Instead, the team believes, other physical factors such as changes in density and water resistance in the materials determined how quickly they settled to the ocean floor.

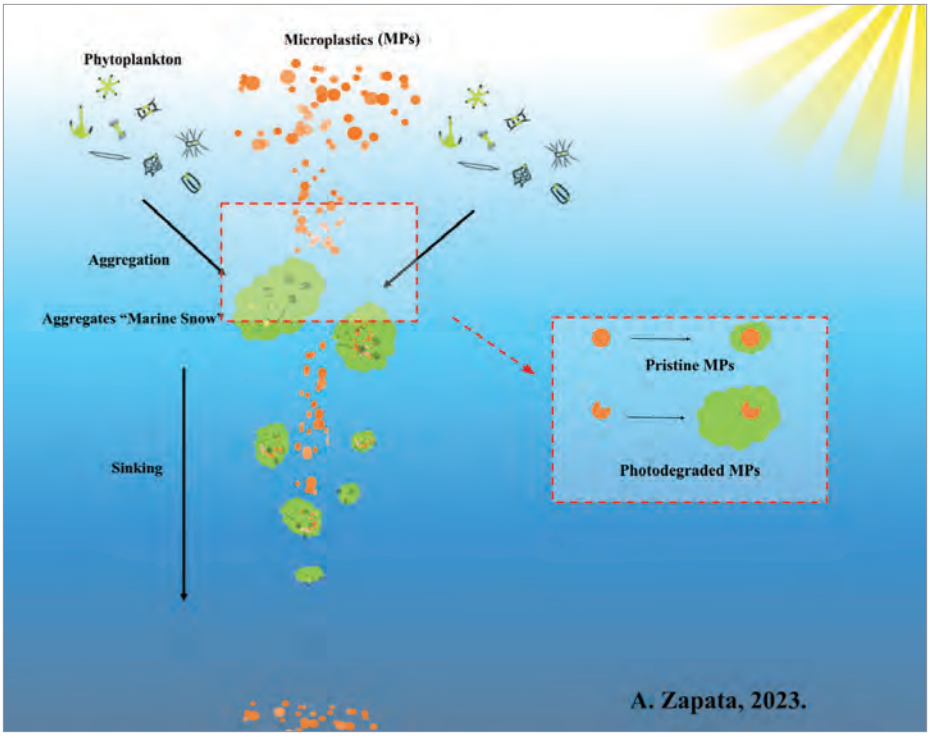
However, the results showed that the degraded plastics collected biofilms faster than the pristine plastics, suggesting that plastic pollution floating under the Sun develops a slimy coating of biofilm faster than previously thought.

More Plastics in the Sea

The ever growing storm of plastic-rich snow might trigger unforeseen ecological chain reactions, according to the researchers.

For instance, some microbial hitchhikers could encounter new organisms in deeper water and have to compete for food. The photosynthesis and respiration rates for these cells could change, affecting how much oxygen the ocean produces for the planet.

The added carbon in marine snow could also alter how much of it cycles back to the surface and into the atmosphere as carbon dioxide via long-term upwelling.



Marine plastics accumulate a biofilm as they sink into the ocean. Credit: Astrid Zapata De Jesús

This marine snow was formed in a lab so researchers could track how fast it sank. Credit: Astrid Zapata De Jesús

The natural movement of particles involved in the planet's biological carbon pump is already complex, even without adding microplastics to the mix, said biogeochemical modeler Karin Kvale of GNS Science in New Zealand, who was not involved in the work. "This study will form one of the building blocks of this emerging understanding of how microplastic pollution may be affecting natural carbon cycling," Kvale said.

Indeed, the team's study highlighted just one piece of a large, complex system, Zapata De Jesús said. She emphasized how important it is for the public to have a better grasp of basic processes in the ocean: "As we add more carbon to the atmosphere, we need to understand how microplastic pollution and other things affect these vital procedures, because if they get super disrupted, that will have consequences."

By **Molly Herring** (@mollymherring), Science Writer

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Flash Floods May Support One of the World's Rarest Fish

Devils Hole pupfish, living in a single pool on the Nevada side of Death Valley National Park, have clung to their existence under the watchful eyes of ecologists and public agencies. Numbers of the uniquely isolated and critically endangered species have ebbed and flowed with shifting conditions and nearby development. Now, researchers have identified a new factor that could cause fluctuations in the famously fragile population: flash floods.

Sudden pulses of rainfall, projected to grow more intense with climate change, stir the species' cavernous habitat, researchers reported at AGU's Annual Meeting 2023 (bit.ly/AGU23-pupfish). The fish have a tangled relationship with the sediment that floods add to their natural fishbowl. The finding offers state and federal agencies deeper insight into how the fish adapts to its harsh environment.

"Devils Hole is a really small ecosystem that responds very quickly to climate stresses," said the study's lead author, hydrologist Mark Hausner of the Desert Research Institute in Nevada. Floods disturb the ecosystem in the short term, he said, but could generate a greater food source for the pupfish in the long run.

"Devils Hole is a really small ecosystem that responds very quickly to climate stresses."

Fish on the Brink

Devils Hole is a watery window into a limestone cave network and aquifer beneath the parched desert, fenced off in a detached portion of Death Valley National Park. Geologists think that shaking from an earthquake collapsed the geothermal cavern at least 500,000 years ago and estimate that it reaches more than 137 meters (450 feet) deep. The rectangular hole, 22 meters (72 feet) long and 3.5 meters (11 feet) wide, features a rock ledge submerged in shallow water on one side. The pupfish depend on this shallow shelf to lay their eggs and forage for algae and insects.

Devils Hole pupfish (*Cyprinodon diabolis*) are shimmers of blue the length of a paper clip. Their numbers exceeded 400 before the 1990s, then plummeted to a low of 35 in 2013. For the past 10 years, however, the population has been on the rise. Today, 263 fish live in the wild.

Scuba divers have plunged 30 meters (100 feet) into the balmy 92°F water twice per year since 1972 to count the fish. But scientists did not consistently track benchmarks such as sunshine, air temperature, and food abundance until the population started crashing in the early 2000s. When that happened, the U.S. National Park Service, the U.S. Fish and Wildlife Service, and the Nevada Department of Wildlife initiated a long-term, rigorous ecosystem monitoring plan for Devils Hole in 2011.

Devils Hole pupfish live in this single rectangular pool in Death Valley National Park in Nevada. Credit: Stan Shebs/Wikimedia, CC BY-SA 3.0 (bit.ly/ccbysa3-0)

"I think they're definitely onto something."

A Rush of Sand and Stone

Hausner and his colleagues used the monitoring data to trace how 120 different environmental factors may have influenced the plight of the pupfish between 2010 and 2019. The team used a machine learning algorithm that works like a decision tree to point to potential relationships. This analysis identified which factors best predicted the population's ups and downs, unveiling a complex relationship between the fish census and overland floods.

Torrents that washed through the desert in 2015 and 2016 carried water laden with sediment and organic matter into Devils Hole, data revealed. First, the flow unloaded rocks and sand onto the shallow shelf, smothering fish eggs, algae, and small insects. That influx

A Devils Hole pupfish forages in a mat of algae. Credit: Olin Feuerbacher/USFWS

also decreased the shelf's water depth, making it warmer, and temporarily depleted oxygen.

But after several months, the pupfish rebounded when nutrients delivered by the pulse of water worked their way up the food chain. Algae flourished, feeding the pupfish population.

The monitoring data and analysis could help answer many questions that remain about the pupfish's resilience, said Christopher Martin, a biologist at the University of California, Berkeley who was not involved in the research. "This is long overdue," he said. "I think they're definitely onto something."

Scientists expect that major floods in the region will grow in magnitude and frequency in response to climate change. It's too early to say how that will affect population trends for the pupfish, Hausner said, because desert rainfall events are so erratic.

Fans of the pupfish are glad to have any additional information that might predict the species' fate. "When you don't have a clear picture of what's going on, dealing with a crisis is very difficult," said Kevin Brown, author of a book on Devils Hole pupfish and a past collaborator of Hausner's.

By **Alix Soliman** (@alixoutdoors), Science Writer

Satellites Map Environmental Vulnerabilities in U.S. Prisons

Incarcerated people in the United States face disproportionately more environmental hazards than the overall population, a pattern of environmental injustice referred to as prison ecology.

Although efforts to recognize environmental injustice have grown in recent years, prisons have been largely overlooked, said Ufuoma Ovienmhada, a graduate student in remote sensing science at the Massachusetts Institute of Technology in Cambridge. "Most people don't think about prison, period, and even those who think about prison have not always heard about the issue of environmental injustice," she said. "It's still underreported and underdocumented."

Now, researchers are using remote sensing data, supplemented by on-the-ground reports from currently and formerly incarcerated people, to uniformly define the scope of environmental vulnerability across the carceral landscape.

Multiple Axes of Marginalization

In the United States, more than 6,300 carceral facilities imprison almost 2 million people. For years, reports have trickled in from across the country about adverse environmental conditions experienced by incarcerated people, prison staff, and corrections officers. For example, excessive heat in Texas prisons is a recurring issue; air pollution in prisons near coal ash sites has been litigated; and carceral facilities built on landfills, such as Rikers Island in New York City, report abnormally poor health conditions for prisoners and staff alike.

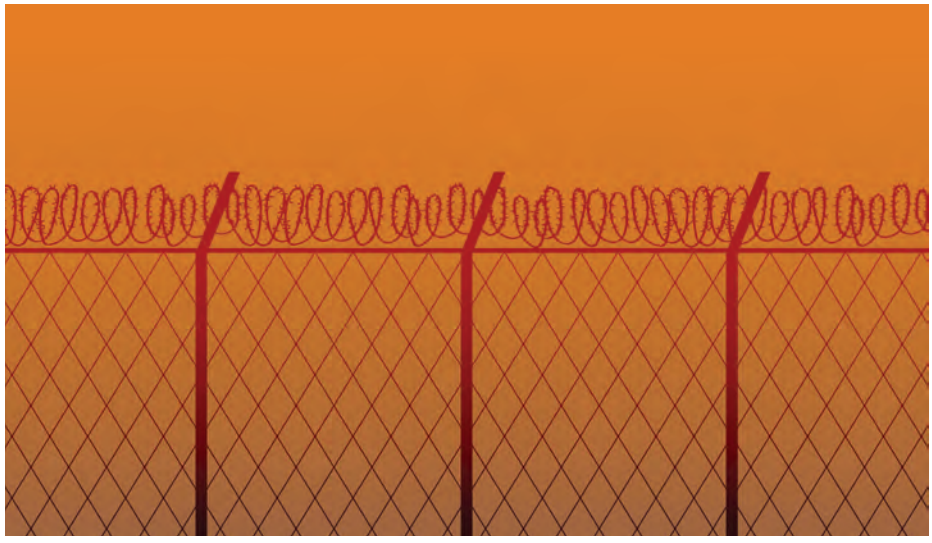
Prisons are environmental justice communities, said Caitlin Mothes, a geospatial data scientist at Colorado State University in Fort Collins. "They have an overrepresentation of both people of color and people of low income," she said, as well as few options to move away from unhealthy environmental conditions.

The U.S. EPA began including prisons in its Environmental Justice Screening and Mapping Tool (EJScreen) in 2017. Researchers and policymakers use this tool to identify areas and groups of people that may have a greater need for environmental conservation efforts or have been exposed to undue environmental burdens.

However, efforts to uniformly gather data on environmental conditions across the entire carceral system have been slow to gain speed.

"For a long time, prisons were marginalized even within environmental justice research," Ovienmhada said, "and environmental justice research has been marginalized within the traditional Earth sciences." This marginalization has led to a lack of data needed to understand the scope of environmental issues facing incarcerated populations.

Mothes said she became aware of this gap through colleagues who were studying forced



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prison labor in agriculture. Together they realized that they lacked geospatial data on the environmental conditions that forced laborers experience. The group sought to "examine it at all prisons across the U.S. to build a foundational dataset that we…can use and build off."

Ovienmhada said that her shift in research focus was prompted by the 2020 murder of George Floyd and the national reckoning with racial justice that followed. "I learned about this intersection of prisons and environmental injustice, and I felt like the remote sensing skills that I already had could support documenting these hazards," she said.

Redrawing Pollution Maps

Mothes, Ovienmhada, and their colleagues separately turned to satellite data to characterize the problem. They partnered with currently and formerly incarcerated people and their families, who shared their experiences and testimonies to help the researchers understand which environmental conditions were most prevalent or put people at the most risk.

Ovienmhada's team homed in on particulate matter ($PM_{2.5}$) exposure to describe the environmental vulnerability around prisons (bit.ly/prison-satellite-data).

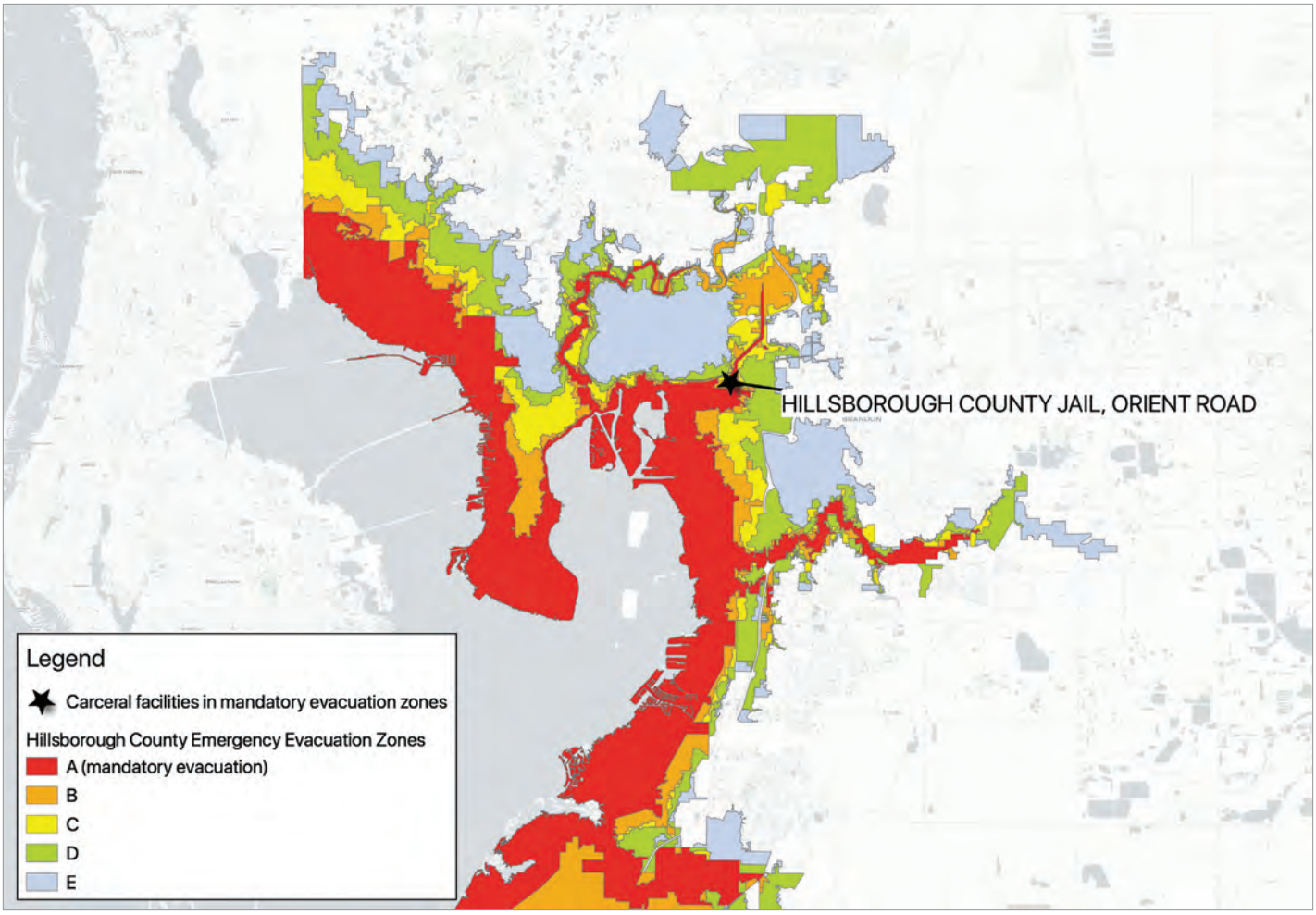
The researchers used a satellite-derived model to track $PM_{2.5}$ exposure around carceral sites at the 1-kilometer scale from 2000 to 2018 and determine which facilities exceeded EPA's National Ambient Air Quality Standards. For comparison, EJScreen uses data with a 12-kilometer resolution to evaluate air pollution exposure.

"We found dozens of facilities that would not have been recognized as experiencing that type of air pollution burden when using the more coarse federal data set," Ovienmhada said. In their analysis of data from 2017, the Baltimore City Correctional Facility, New Jersey State Prison, and FCI Morgantown in West Virginia scored in the 90th percentile for $PM_{2.5}$ exposure, but were below this threshold in EJScreen. That might affect which areas receive attention under recent environmental policies like the Justice40 Initiative, she said.

Ovienmhada and her colleagues are also currently working with land surface temperature information from several satellite data sets to show how many days per year different prisons experience extreme heat, which has been tied to severe health risks (bit.ly/prison-heat). Ovienmhada presented this research at AGU's Annual Meeting 2023 (bit.ly/AGU23-prison1).

Big Data for Environmental Justice

Mothes's group combined several indicators into a single environmental vulnerability



Hillsborough County's Orient Road Jail (star) in Tampa, Fla., was within the mandatory evacuation zone (red) ahead of Hurricane Ian in 2022. The jail evacuated 160 inmates to another jail outside the red zone ahead of the storm. Credit: Ovienmhada et al., 2023, bit.ly/prison-satellite-data, CC BY 4.0 (bit.ly/ccby4-0)

index that describes conditions at prisons across the country. "This kind of big data hasn't been around forever," she said. "We're in an era where we can now do large-scale analyses for not just scientific research but also social and environmental justice work."

They gathered publicly available data on 11 environmental metrics going back around 10 years from several satellites and government databases, focusing on the areas surrounding almost 1,900 state- and federally run prisons.

The study focused on three categories: climate, environmental exposure, and proximity to sites previously identified as environmentally hazardous.

The climate metric considered heat exposure, canopy cover, wildfire risk, and flood risk. Facilities in California, Texas, and along the Pacific and Atlantic coasts scored poorly because of worsening wildfires, heat, and hurricanes.

Environmental exposure included ozone and $PM_{2.5}$ levels, traffic volume, and pesticide risk. Prisons in New York City and along the Mississippi River scored poorly in this category—the former because of poor air quality and the latter because of agricultural pesticide use.

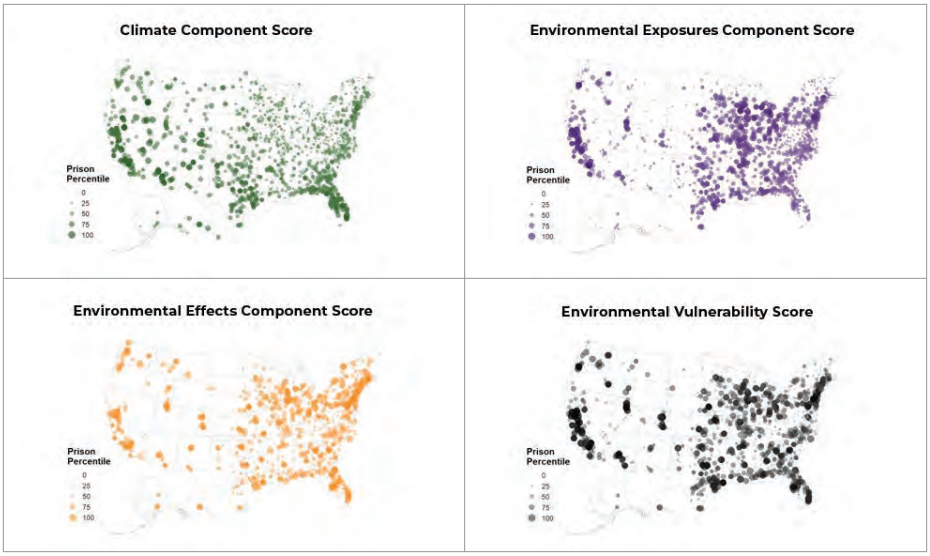
The third category included proximity to Superfund sites, hazardous waste sites, and nuclear and chemical plants. Facilities across the country scored poorly on this metric because carceral facilities are often built on or near these undesirable sites, for example, Rikers Island and the now closed Northwest Detention Center in Tacoma, Wash.

Mothes's team combined these three categories into a single environmental vulnerability index to better compare prisons across the country. Thirty of the 50 facilities with the worst overall scores were in California, she said.

"We hope this will be useful to other researchers or activists to highlight which prison we should focus on, write stories on, investigate further," Mothes said.

"But it's also important to look at individual environmental burdens, too. Some prisons could be high-risk because they're located close to so many different toxic facilities, whereas others might be high-risk for heat and climate risks," she said.

For example, the facilities that scored poorly in California did so because of climate risk and poor air quality. When the team examined the 50 facilities with the worst environmental effects because of their proximity to toxic sites, only two were in California, whereas 14 were in Maryland and seven were in Florida. Mothes presented this research at AGU's Annual Meeting 2023 (bit.ly/AGU23-prison2).



The environmental vulnerability of U.S. state and federal prisons was evaluated on the basis of climate, environmental exposures, and environmental effects. Scores within higher percentiles (larger circles) indicate that institutions scored worse in that metric compared with other prisons. These factors were combined into an overall environmental vulnerability index. Credit: Caitlin Mothes

"The reason why these projects have the potential to create real social change is precisely because of the collaborative nature of this work between scientists and laypersons."

Creating a Nontoxic Carceral Landscape

"I am delighted to see scientists developing and applying these tools to advance our knowledge of the range of environmental threats facing incarcerated populations," said David Pellow, an environmental scientist at the University of California, Santa Barbara and head of the Global Environmental Justice Project.

"These studies provide powerful visualization tools that can facilitate a deeper understanding of the challenges of environmental injustices facing incarcerated persons, corrections officers, and others working and living in and around carceral institutions," said Pellow, who was not involved with these projects.

Mothes and her team have made these data sets public and have also released the code they used to calculate their environmental vulnerability index. Researchers can generate new maps of environmental vulnerability as they gather updated environmental data or data covering other carceral facilities like county jails, Mothes said.

Ovienmhada's team is working to codesign a geographic information system (GIS) that integrates environmental and socioeconomic data to aid prison ecology researchers, policymakers, and activist organizations.

Pellow said he was particularly encouraged by the scientists' partnerships with groups such as Campaign to Fight Toxic Prisons, which works with and advocates for incarcerated people and their families. "The reason why these projects have the potential to create real social change is precisely because of the collaborative nature of this work between scientists and laypersons," Pellow said.

By **Kimberly M. S. Cartier** (@AstroKimCartier), Staff Writer

Sandy Fingerprints Trace Supply Sources

Sand is the most extracted solid material on Earth, but it's not an infinite resource. Sand mining can damage delicate ecosystems when removal operations trigger erosion and habitat loss, and lax oversight often allows for illegal operations. Without eyes following the raw material from sand mine to hardware store, there's no way for consumers to verify sustainable sources.

Now, as documented in a new study published in *Communications Earth and Environment,* scientists have figured out how to trace sand from source to sold (bit.ly/sand-fingerprints).

"Sand mining is the biggest sustainability issue you've never heard about," said Zachary Sickmann, a geoscientist at the University of Texas at Dallas. "Our entire world is built of sand."

Sickmann was studying how rivers carry sand from mountains to the sea when he realized that the tools he uses to identify specific mountain ranges and rivers that supply sand—tools that measure appearance, texture, and geological makeup—might also work for commercially sold sand.

To test the theory, Sickmann and his colleagues needed to know whether commodity sand retains its "fingerprint" throughout the industrial process. The researchers collected 41 samples from seven sand sourcing areas in Texas. They sampled sand directly from mine pits, sand stockpiles at concrete plants, and ready-mix concrete—a mixture of powdered Portland cement, sand, and gravel—from Home Depot.

"Sand mining is the biggest sustainability issue you've never heard about. Our entire world is built of sand."

They collected both raw and processed sand at each site and measured each sample's composition and particle sizes to show that sand from each source remained identifiable at its final stage. "We could see very distinctive pieces with just our eyes. Even as a trained sedimentologist, I wasn't expecting it to be that obvious," Sickmann said.

The group realized that if scientists could see the differences, they could train a simple image analysis algorithm to recognize unique sand fingerprints as well. They built sandID, an algorithm that's 90% effective at determining the original mining source of surveyed construction site samples. Sickmann said he hopes to develop a phone app to make the tool available for public use.

Traceability and source assurance have been missing from the sand industry, said Chris Hackney, a fluvial geomorphologist at Newcastle University who was not involved in the study. "I think there's an appetite for this," he said.

Meeting Global Sand Demand

Sustainable sand mining often involves digging a deep pit in the ground and cleaning out the soil in a series of complex and costly steps. It's much cheaper and easier to drive a dump truck onto a beach or riverbank and collect sand to use in concrete and other infrastructure. But that sand is important for keeping waterside environments in equilibrium.

The Texas sand supply chain is relatively simple and transparent, but Sickmann and his colleagues don't plan to stop there. With the success of this model, the practice of sand

Zachary Sickmann washes the gravel and cement from ready-mix concrete to sample sand for source matching. Credit: Zachary Sickmann

Shown here is a construction site from which researchers collected sand to trace the grains to their source. Credit: Zachary Sickmann

sourcing could be expanded to other regional markets. For example, Southeast Asia has a complex network of sand mining regulations, high demand for sand, and diverse geology, so it offers the perfect combination of factors for the new tool to have an impact.

The team plans to help build a database of sand fingerprints so commercial sand can be compared to nearby sources (sand supply networks are relatively simple and are not profitable beyond a certain distance).

"These materials are consumed in huge amounts, and they're also very heavy, very cheap, and very costly to transport. The moment that you increase the transportation distance, the price increases," said coauthor and sustainability scientist Aurora Torres of the University of Alicante in Spain.

The sandID tool has applications beyond modern compliance tracking. "You could test historical buildings to get an idea of where the materials that were used to build those structures came from and which areas were mined and targeted for producing materials," Torres said.

As urban centers rapidly expand and sand demand skyrockets, it is important to keep in mind all the potential impacts of unsustainable sourcing. "When we think about sand sustainability, it's all about scarcity," Torres said. "But we shouldn't also forget that the human and the environmental dimensions are equally important."

By **Molly Herring** (@mollymherring), Science Writer

Costa Rican Faults Quiver in Response to Distant Earthquakes

Nestled between two oceans and several tectonic plates, Costa Rica is known not only for its natural beauty and biodiversity but also for its hazardous geology. Active volcanoes and steady seismic activity are part of residents' daily lives, along with the occasional devastating earthquake.

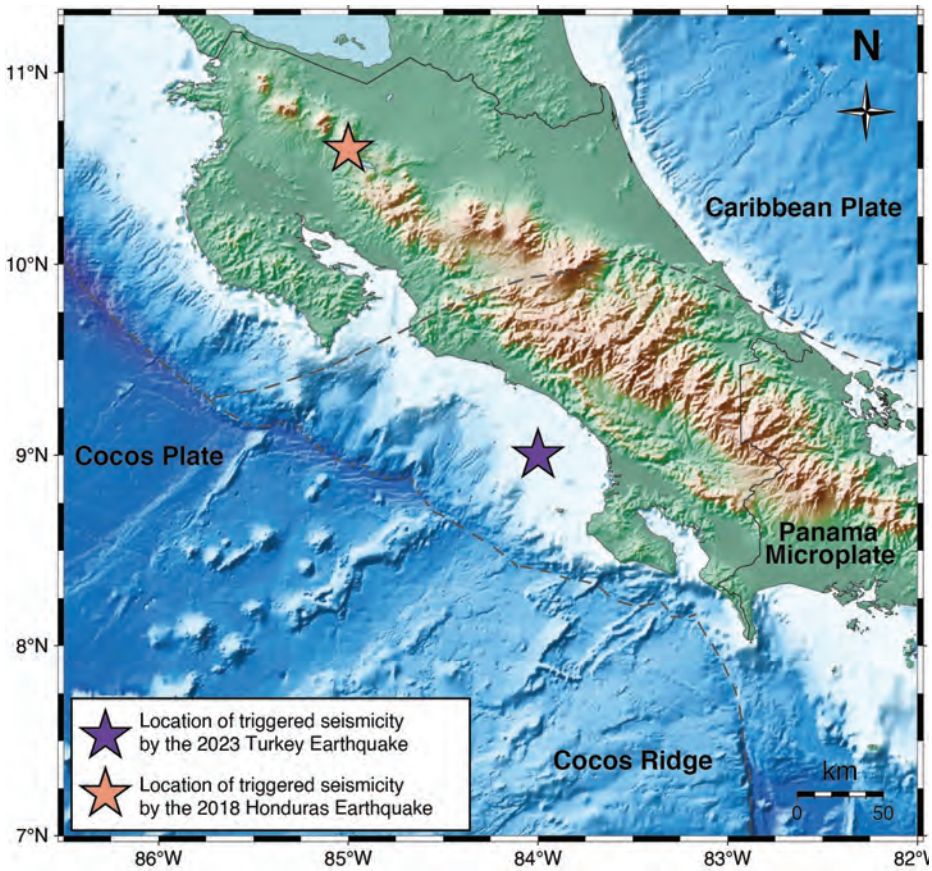
New research has suggested that Costa Rica's complex web of seismic faults has weak, potentially unstable zones that can respond to shaking from major earthquakes far away. This process, called dynamic triggering, often arises at geothermal and volcanic sites, but it is less common along continental faults. In the past decade, two major earthquakes have unsettled faults in Costa Rica by way of dynamic triggering, seismologists reported at AGU's Annual Meeting 2023 (bit.ly/AGU23-dynamic-triggering).

Stresses Far Underground

Seismologists have debated whether seismic waves from the world's biggest earthquakes can set off distant faults where stress has been accumulating. Signs of dynamic triggering have surfaced along Southern California's San Jacinto Fault Zone and Salton Sea Geothermal Field, among other sites, but hadn't been detected in Costa Rica.

Seismologist Esteban Chaves of the Volcanological and Seismological Observatory of Costa Rica and undergraduate student Sonia Hajaji of the University of Costa Rica set out to look for that evidence.

They combed through data from a network of seismic stations throughout Costa Rica that were recording before, during, and after the 25 largest earthquakes in the Americas since 2010. They also included the magnitude 7.8 earthquake that struck the Türkiye-Syria bor-



Costa Rica sits within active tectonic boundaries (dashed lines). Distant earthquakes have triggered microseismicity near these boundaries. Credit: Sonia Hajaji

Researchers install a sensor in a dense forest in Costa Rica. A network of such seismometers recorded microseismicity throughout the country following two large, distant earthquakes. Credit: Esteban Chaves

der on 6 February 2023 because it was the most recent major event at the time of the analysis.

The researchers looked for a sign that local seismic activity increased following the distant large earthquakes. "We first have to see the waves of the distant earthquake here in Costa Rica," Hajaji said. To confirm dynamic triggering, "we need to see that the rate of the seismicity here increases after the arrival of these waves." Hajaji and Chaves searched for upticks in high-frequency local seismic activity just after the arrival of low-frequency waves from the distant events.

They saw this on two occasions: after a magnitude 7.6 earthquake in 2018 in the Caribbean Sea off the coast of Honduras and after the Türkiye-Syria magnitude 7.8 earthquake.

"Maybe [dynamic triggering] is more common than we think."

The spike after the Honduras earthquake was concentrated in Costa Rica's northern volcanic regions. After the Türkiye-Syria quake, seismicity peaked along Costa Rica's Pacific coastal subduction zone—where the 2012 earthquake hit—and at shallow faults in the center of the country.

The team's dissection of local seismic data to reveal high-frequency waves was novel, said seismologist Joan Gomberg of the U.S. Geological Survey. Gomberg studies dynamic triggering but was not affiliated with the study.

"Maybe [dynamic triggering] is more common than we think," Gomberg said. "If faults are really sensitive, and they're really sensitive right before they go, it might provide some clue that some areas are ripe for an earthquake."

Which Waves Are at Fault?

The results left Chaves and Hajaji with a burning question: Why had the Türkiye earthquake triggered seismicity in Costa Rica, when other large earthquakes much closer had not?

The 2018 and 2023 events had something in common, the team realized. Both were supershear earthquakes—during which a fault rupture propagates faster than the earthquake's *S* wave (shear wave). These notable events are similar to a sonic boom and produce particularly strong shaking. Gomberg agreed that the correlation merits further exploration of the underlying mechanism behind triggering.

"No one has looked at the effects of supershear ruptures at a distance," Chaves said. "Do they have more potential to trigger more earthquakes than other events? We don't know yet."

By **Gillian Dohrn** (@dohrn_gillian), Science Writer

Finding Common Ground in the Field to Inform Science Policy

The pathways through which science informs policy in the United States are often underdeveloped, especially at the state level. Federal agencies, national scientific advisory bodies, and professional societies provide opportunities for scientists to interact with federal legislators, but historically, scientists have had fewer chances to collaborate with state policymakers. Considering that laws influencing natural resources, environmental health, and other concerns to which science is highly relevant aren't crafted at just the federal level, the shortage of opportunities for state-level science-policy collaboration may result in rules and regulations not guided by the best available information.

Some organizations and states are working to address this need. In Kansas, the state geological survey organizes an annual field conference that brings together scientists, legislators, and public officials to network, learn, and collaborate in a relaxed, neutral environment. The format offers an opportunity for these parties to communicate with one another and, ultimately, to share the benefits of their collaborations with the public. In this way, legislators are better equipped to make policy decisions that sustainably support their communities.

As we relay below, direct feedback from participants during and after the June 2023 Field Conference sheds light on the event's value, not only in Kansas but also as a model that could be adapted elsewhere.

Kansas Geological Survey (KGS) staff and Field Conference participants gather around an index well in southwestern Kansas on 8 June 2023 to learn about groundwater resource management. Credit: Andy Connolly

A Firsthand Tour, with In-Person Expertise

Scientists Bob Sawin and Rex Buchanan of the Kansas Geological Survey (KGS) initiated the annual Kansas Field Conference in 1995. During these conferences, state legislators, public officials, and industry leaders are invited on a 3-day field trip to sites where natural resources are extracted, refined, or used. At each stop, scientists and local operators discuss the site's significance related to local resources and geologic history. The overall goal of the conference is to present participants with nonpartisan, firsthand information about natural resources in Kansas.

Blair Schneider, an associate researcher and scientific outreach manager at KGS, has been the organizational architect of the Field Conference since 2019. She explained that her developmental process starts with a vision board; she designs the conference by determining where in Kansas it should occur, what resource issues are most pressing in that region, what KGS's role is with respect to those issues, and whom in the area state legislators and agencies would benefit the most from meeting and networking with. "From there, I do my research and create a theme," Schneider said. "This theme works to 'connect the dots' from stop to stop each year and tell a more complete story about all natural resources like water, energy, and more."

Participants agreed that their top takeaway was the value of the conversations the conference enabled.

The 2023 conference centered around the theme of adaptation with respect to water resources in southwestern Kansas. Nearly 50 participants, along with KGS staff, visited a prairie preserve, a dried bank of the Arkansas River, local playas (shallow depressions that intermittently fill with water), a cattle yard, a water treatment facility, and a research index well. At each location, scientists and industry professionals spoke about relevant water-related concerns such as availability, quality, and usage.

Another focus of the recent conference was the economic impact of local industries that consume the state's limited water resources. Conference participants visited a soon-to-open cheese factory where operators are seeking to implement sustainable solutions to achieve carbon neutrality but are likely to face challenges with water conservation. Presenters at the stop included several members of the factory's management, who talked about the construction of the facility, the products it will manufacture, and community effects.

After the presentations at each stop, participants had an opportunity to converse with

the speakers and one another. Often, they asked unprompted questions, wanting to know how new economic developments could affect water issues in the region. For example, at the new cheese factory, an attendee asked a representative from the Kansas Water Office how water would be sustainably managed in the factory given that the local dairy cow population would increase significantly (one cow consumes 110–190 liters of water every day).

This sort of dialogue, which brings both science and policy practitioners into conversation on common ground, is the core function of the conference.

Participants are also given a guidebook with a detailed itinerary, attendee contacts, and supplementary information to help contextualize their understanding of the region and its resources. The guidebook includes concise articles that offer geological and anthropological background specific to each stop—without straying into jargon or overly technical detail—as well as its connection to the conference theme. As guidebook editor Julie Tollefson pointed out, the book is meant to be a resource not only during the trip but also long after it ends.

The hope is that participants will return to it when they need to make informed decisions about related issues in the context of their legislative or policy work.

Conversational Opportunities and Enhanced Learning

The success of the communication afforded by the Field Conference is clear to KGS, but we were interested in gathering firsthand feedback from participants to determine whether their perceptions echoed our own. So we asked them what, in their view, the conference accomplishes.

To our delight, interviewed participants agreed that their top takeaway was the value of the conversations the conference enabled. In postconference surveys, a vast majority responded that they were highly satisfied with the opportunities they had to network with other attendees.

Brad Loveless, secretary of the Kansas Department of Wildlife and Parks, remarked that the conference offers much more than a chance to listen to presentations and ask questions. "The other things that happen on the bus, between stops, and the sidebar conversations are very valuable too, because they promote that understanding, that relationship, and hopefully set the stage for future conversations," he said. When these future conversations happen, "people know who you are and that you're approachable, and so hopefully it fosters better collaboration between agencies, and between agencies and legislature."

KGS Assistant Scientist Sam Zipper (left) and Earl Lewis, chief engineer of the Kansas Department of Agriculture (right), describe the history of the Arkansas River at a site near Dodge City where the riverbed is dry. Credit: Andy Connolly

Many participants noted that the casual atmosphere of the conference created a relaxed learning environment and encouraged an ease of interaction among individuals that is harder to come by in more formal meeting spaces.

"Humans are often tactile and visual and audio learners, and they learn best [about a subject] when they're seeing it, they're touching it, they're hearing it, and they're smelling it."

"We tend to shed our political differences when we're out here together. I've seen a lot more collegiality on this trip than I think you see when you're in Topeka during a [legislative] session," said Nick Levendofsky, executive director of the Kansas Farmers Union. He expressed an appreciation of the diversity in professional backgrounds represented among conference attendees.

"With every bus stop, you see people moving seats," Levendofsky observed. "You see an urban legislator sitting next to a rural legislator…and a Republican sitting next to a Democrat."

Meeting and networking in the field have other upsides as well. "All these people that are here bring resources and ideas, and we're able to take those and put them together, which you can't do on a Zoom call or over email. You have to get together in person," said Shannon Kenyon, district manager of Groundwater Management District (GMD) 4, one of five such districts in the state. "I am recharged," she said of the experience, grinning, and adding that she was looking forward to sharing her excitement with colleagues at an upcoming meeting.

Not only does the atmosphere promote conversation and cross-pollination of ideas, but being physically present at the locations discussed may also have educative benefits for participants.

"Humans are often tactile and visual and audio learners, and they learn best [about a subject] when they're seeing it, they're touching it, they're hearing it, and they're smelling it," said KGS director Jay Kalbas.

"The impressions you get from being on-site are far different and far better than what you're going to get from seeing a PowerPoint presentation."

This perspective aligns with reports from many conference participants, who expressed that it was often eye-opening to visit field sites in person.

During a stop at a dried-up portion of the Arkansas River near Dodge City, where participants heard about the river's history, Kansas State Senator Chase Blasi remarked that he was "shocked to see that it's not flowing this far west and to hear that it hasn't had a true flow for over 20 years." Blasi, whose district lies northwest of Wichita and is segmented by a flowing portion of the Arkansas, added, "It's a reminder to me that the state has got to take conservation seriously."

Pros for the People

We also asked participants how they felt their attendance at the conference benefited the public.

Katie Durham, district manager of GMD 1, said, "It's about knowing what resources are available, specifically for my producers, and making sure that I can get those resources on field and in their hands."

In her leadership role, Durham is responsible for helping GMD 1 develop programs and policies that support the community economy and prioritize the conservation of groundwater. KGS has a lot of technical abilities, such as its well-monitoring resources, and it is important to make sure that farmers, factories, and other producers know what tools and assistance they can access, Durham said. "A lot of state agencies are really apt to work with producers and come up with solutions that are viable and economically sound."

Aside from benefiting from the economic management of resources, participants said their experiences at the conference would help them inform the broader community about natural resource issues in the state. The Nature Conservancy's Kansas state director, Ben Postlethwait, and the organization's government relations manager, Justin Cobb, said that collaborations and partnerships formed through the conference will help all parties find common ground on issues such as water conservation.

"In the world of conservation, there's a lot of misunderstanding, oftentimes, on how we solve problems," said Postlethwait, who emphasized that misinformation can hurt the conservation efforts of state agencies and independent organizations.

Kansas State Representative Lindsay Vaughn tries her hand at lowering a measuring tape down an index well. Credit: Andy Connolly

"Conferences like this one help us educate the public efficiently" by getting different state-level officials on the same page and helping them share consistent, accurate messages about conservation, Postlethwait said.

They also help these officials "make better policy decisions," added Cobb.

Conference participants reported that they felt better prepared to converse with peers about resource management issues, thanks to insights they gained from the Field Conference, a distinct benefit when it comes to implementing tangible science policy.

State Senator Carolyn McGinn noted that demonstrations, such as on the function and status of the index well, provide helpful agricultural and hydrological context for those who have not had direct field experience.

"I think their understanding is really going to help when they go back to either committees or their communities," said McGinn. "They'll be able to explain [the context] to other people and why it's important."

Further, information gathered from conference presentations and conversations empowers public officials to ask about and evaluate existing natural resource practices in their respective districts and to consider whether local practices can be adapted or improved. They can also gauge the effectiveness of management strategies used around the state and start conversations about how those strategies might be implemented elsewhere.

A Model for Successful Science-Policy Communication

KGS's Field Conference format offers several clear benefits.

It fosters an open, collaborative learning environment to encourage science conversation among a variety of participants from different sectors.

It presents an opportunity for scientists and state leaders to get in touch with the Earth science that influences their everyday life, an experience they can share to spark inspiration in the next generation of researchers and policymakers.

It equips public officials with knowledge to make more informed science policy decisions to help their communities. In addition, the accessibly written conference guidebook serves as a lasting reference to inform people about regional geology and natural resources.

In these ways, the conference offers a template for a practical approach to science communication—one that other regions, states, or municipalities could adapt to support science-informed policy and education in their own communities.

Environmental change does not occur in a vacuum; no one is exempt from its effects. In our rapidly evolving world, it is more important than ever to manage natural resources and solve ecological problems as a unified front of scientific, political, and industrial thinkers. As KGS continues to offer and update its annual Field Conference in response to participant feedback and new research, we are confident that the event will continue to provide insight into how science-policy communication pathways can be improved in Kansas, and in the greater global community as well.

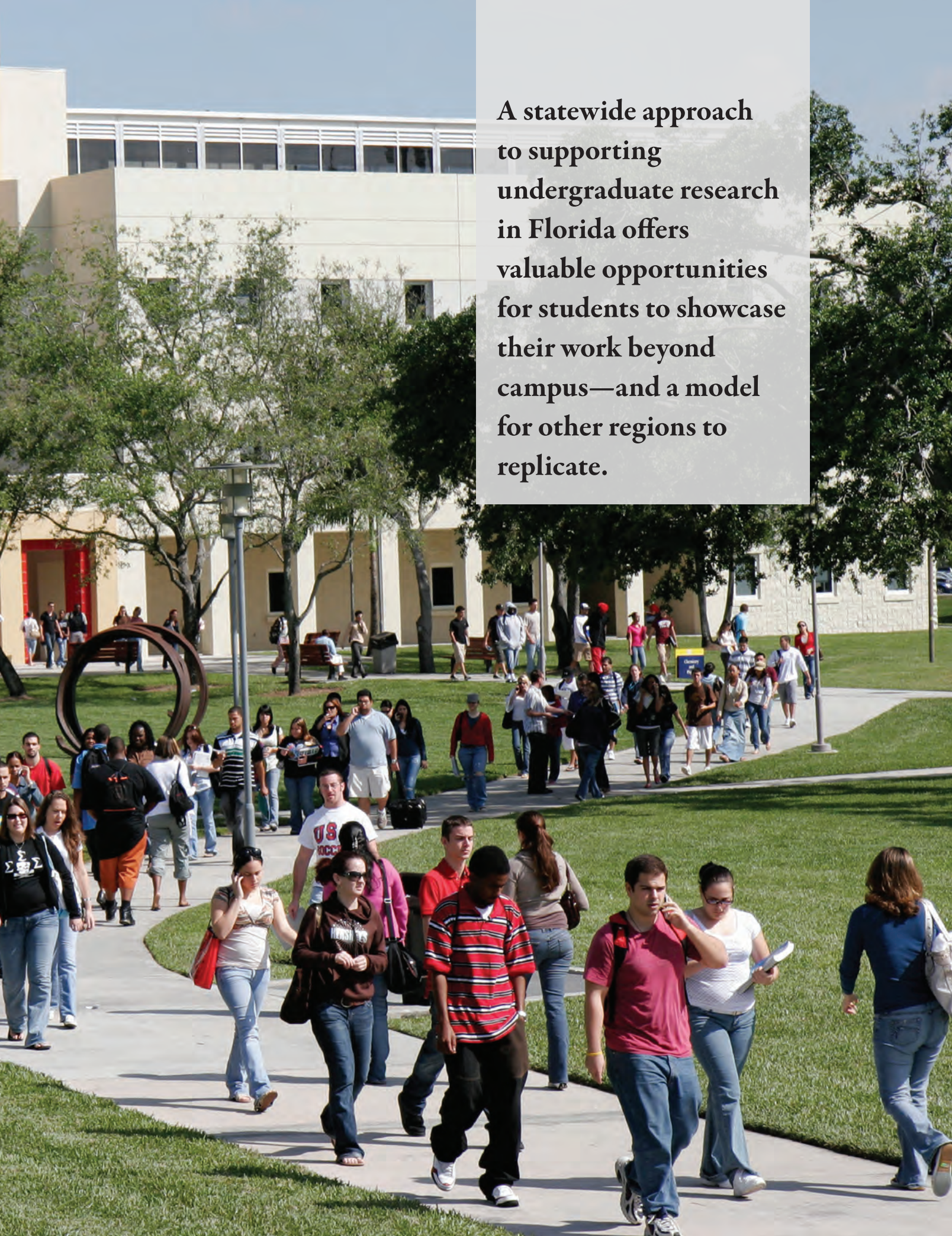
By **Sunday Siomades** (ssiomades@ku.edu), **Blair Schneider,** and **Andy Connolly,** Kansas Geological Survey, Lawrence

Read the article at Eos.org

A Regional Ecosystem That Helps Undergraduate Research Flourish

By Alanna L. Lecher, Melodie Eichbauer, Kimberly Schneider, and Latika Young

Florida International University, pictured here, is an institutional member of the Florida Undergraduate Research Association (FURA). Credit: Jeff Greenberg/Universal Images Group via Getty Images



A statewide approach to supporting undergraduate research in Florida offers valuable opportunities for students to showcase their work beyond campus—and a model for other regions to replicate.

A regional undergraduate research ecosystem can help overcome barriers by providing low-cost and inclusive opportunities for students to share their research beyond their campus.

Any graduate student or postdoc in the sciences can tell you that conducting and presenting original research require training and experience. Undergraduate research experiences give students a head start on this learning process, increasing their interest in science, encouraging them to remain in science majors, and building their confidence and ability to conduct research [*Russell et al.*, 2007].

Presenting and explaining one's research to fellow scientists, policymakers, or public audiences can require as much or more learning and practice as conducting the research itself. However, undergraduates—whether in STEM (science, technology, engineering, and mathematics) fields like the geosciences or in any other discipline—generally have few opportunities for this type of learning.

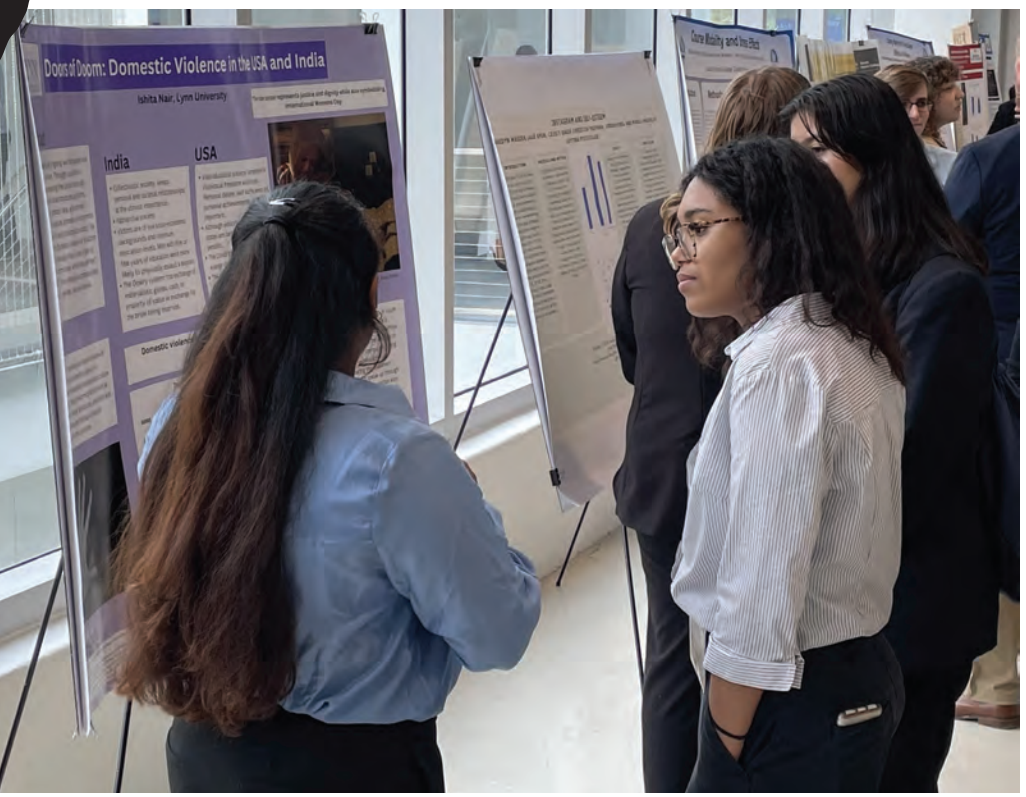
On-campus symposia where undergraduates share their research projects have become common. But far fewer undergraduates take the next step to present at conferences or publish their work beyond campus. Entrenched barriers to this valuable form of science communication include costs associated with conference attendance and publication, as well as the quality of research, which, despite being valid, may simply not meet the rigors of professional journals.

A regional undergraduate research ecosystem can help overcome these barriers by providing low-cost and inclusive opportunities for students to share their research beyond their campus. The nonprofit Florida Undergraduate Research Association (FURA)—of which we are all current or past board members—has developed such an ecosystem, offering transitional opportunities for undergraduates through various initiatives.

At the annual Florida Undergraduate Research Conference (FURC), for example, undergraduates present research posters, network with fellow students and graduate school recruiters, and attend skill-building workshops. And every other year, students from FURA member institutions present their research to state legislators at an event called Posters at the Capitol in Tallahassee.

Student researchers have opportunities to submit manuscripts about their work for publication in FURA's peer-reviewed *Florida Undergraduate Research Journal* (*FURJ*). FURA also organizes the annual Florida Statewide Symposium: Best Practices in Undergraduate Research to prepare university faculty and staff to mentor and support undergraduate research experiences.

These initiatives work together cohesively to support undergraduate research experiences in Florida and to bridge the gap from students presenting their studies in on-campus journals and symposia to students presenting at broader conferences and in peer-reviewed publications. This model, which we detail below, can be replicated and applied elsewhere to further foster undergraduate professional development and benefit the disciplines—from STEM fields to the arts and humanities—these students are entering.



Undergraduate students present their research during a poster session at the Florida Undergraduate Research Conference (FURC) in 2023. Credit: Alanna Lecher

What Is FURA?

FURA is a 501(c)(3) organization registered with the state of Florida and run by a board of nominated volunteer faculty and staff from Florida colleges and universities. The board organizes different aspects of FURA by way of committees, such as the Membership Committee and the Events Committee, which assist schools hosting the annual research conference and statewide symposium.

Funding for FURA comes largely from institutional memberships. Currently, 21 Florida colleges and universities—ranging from public research universities to private, predominantly undergraduate institutions—pay $300 annually for membership, which provides discounts for their students, faculty, and staff to attend FURC and the state symposium, as well as opportunities for participation in Posters at the Capitol and for faculty and staff to sit on FURA committees. (Only board members can chair committees.)

Inclusivity is a driving principle for FURA, so the association works to keep institutional membership fees low enough that smaller schools and community colleges—which may not budget for such memberships—are not hindered by cost from joining. Larger schools often earn back the cost of membership in just the savings from reduced registration fees for the students they send to FURC.

Conference and symposium registration fees—$60 for nonmembers and $55 for members for FURC 2023, for example—are also kept low and rarely increase. And FURA provides a limited number of registration fee waivers for students whose schools cannot send them to attend FURC.

Meeting locations move around the state so that students from the same schools aren't forced to travel longer distances or absorb the associated costs year after year. Furthermore, conferences are limited to 2 days so that only one night in a hotel is typically needed.

Another example of FURA's work toward inclusivity is evident in revisions made in 2022 to the nomination process for the organization's Mentor of the Year Award. Previously, students were asked to write a two-page essay explaining how their mentor had influenced them. We found, however, that this approach favored mentors of students who were more experienced writers and who, typically, were enrolled at larger universities. To counteract this bias in the process, we removed the essay and instead now ask students to respond to more pointed prompts, such as "Describe the impact that your mentor has had on your professional and personal growth with specific examples."

A Signature Experience for Student Researchers

FURC was first held in 2011 and is FURA's signature event. It occurs in late February, with a different school playing host each year (Figure 1). Schools apply to host FURC 2 years in advance and are solely responsible for the organization, budget, and other workings of the conference, with support from the FURA Events Committee.

Students from all academic disciplines present posters at FURC, although the conference typically has robust representation from STEM fields (including the Earth and environmental sciences) and psychology programs. To participate, students submit an abstract in December, which may be accepted, sent back for revisions, or, in rare cases, rejected. The timings of abstract submission and of the conference itself are set to give mentors and mentees enough time to finalize a research project and to avoid conflicts with students' winter and spring breaks and with on-campus research symposia.

The weekend conference includes a keynote speaker and Friday night reception for participants to socialize and network, followed by poster sessions and workshops on Saturday. Workshops are hosted by faculty or student clubs and typically focus on topics related to research (such as ethical behavior for researchers) or career development (such as résumé building). A graduate school recruitment fair runs throughout the conference as well.

In postconference surveys, 92% of student attendees have reported feeling more confident about presenting a research poster after they participated in FURC. More than half said they'd received helpful feedback on their posters and learned more about their research topic at the conference.

Undergraduates enrolled in a 2- or 4-year public or private institution of higher education in Florida can submit their research for publication in the Florida Undergraduate Research Journal. *Credit: Florida Undergraduate Research Association*

In postconference surveys, 92% of student attendees have reported feeling more confident about presenting a research poster after they participated in the Florida Undergraduate Research Conference.

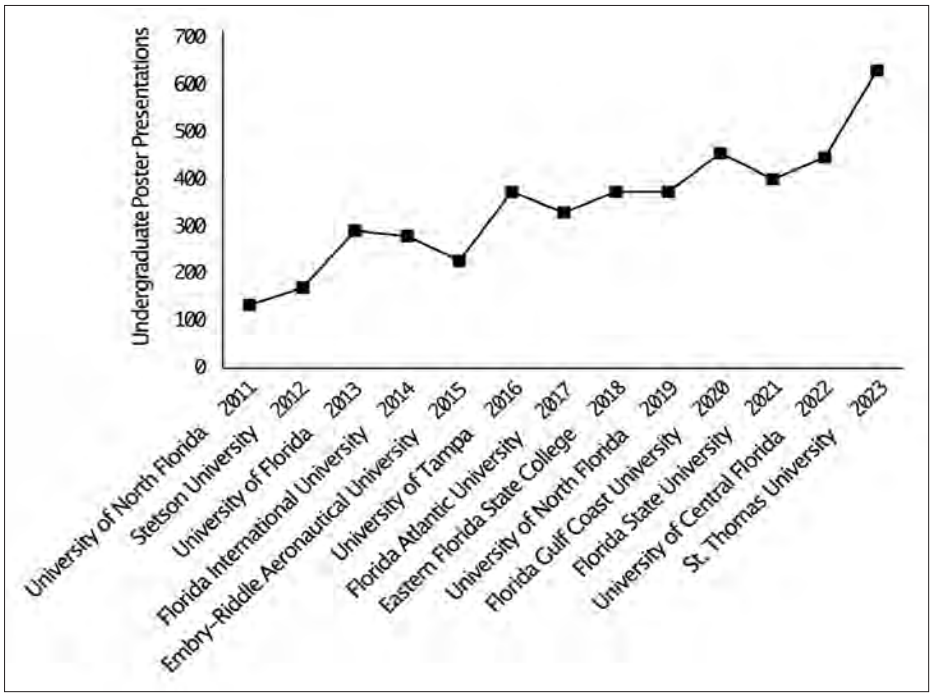


Fig. 1. The number of poster presentations at FURC has trended steadily upward since the conference's inception in 2011. Host institutions are indicated below each year.

For many students, FURA has smoothed the transition from undergraduate to graduate research.

And the majority of participants have reported that the structure of the conference works well and that session lengths are appropriate [*Freundt and Schneider,* 2019]. The growth of participation in the conference since 2011 is further testament to the value that students find in attending it (Figure 1).

Presenting for Policymakers

Through the biennial 2-day Florida Undergraduate Research Posters at the Capitol event, four students from each FURA member institution are invited to Tallahassee. There, they share their research with Florida legislators and the public. They also learn about the political process and how to advocate for undergraduate research at local and state levels, an important element of FURA's mission.

After being selected, the students, with support from the FURA board and their home institutions, contact their representatives to invite them to their presentations and arrange individual meetings. Students meet in the evening of the first day to have dinner, network, and learn more about advocacy work. The following day, they present their posters in the Florida Capitol before meeting with legislators and staff. They sometimes also take time to visit the Florida Historic Capitol Museum or take in views of Tallahassee from the Capitol's 22nd-floor observation deck.

During the event, FURA hosts an information table in the building's rotunda, allowing board members to amplify messages about the value of undergraduate research in the state and how FURA's activities further that research. In addition to publishing an event program, FURA also shares a one-page advocacy sheet detailing the benefits of undergraduate research in Florida, such as the fact that students who participate in undergraduate research are more likely to graduate.

An Avenue to Publishing

Accessibility is critical to undergraduates' ability to publish their research. Unfortunately, students do not always have access to submit their work to disciplinary journals beyond their own campus.

FURJ, which published its first volume in 2022, gives students an avenue for publication that is a step beyond their campus journal.

The journal is open access and accepts submissions from students enrolled in a 2- or 4-year public or private institution of higher education in Florida. These submissions are peer reviewed according to disciplinary standards, and the feedback provided to student authors resembles what they would receive from disciplinary journals. *FURJ* uses a three-tiered rubric in the review process that is designed to provide all students with consistent, professional feedback in different formats. The tiers include (1) an initial round of comments from the executive editor, (2) a second round of comments from a student editorial board, and (3) a disciplinary review from an anonymous faculty reviewer at an institution different from that of the student author or authors.

Students from any institution in the state can apply to be on the editorial board. Under the guidance of the journal's executive editor, editorial board members promote the journal on their respective campuses and provide feedback to authors that helps strengthen manuscripts and ensure that they are accessible to a broad audience. The board members also hone National Association of Colleges and Employers career readiness competencies with respect to career and self-development, communication, critical thinking, equity and inclu-

sion, leadership, professionalism, teamwork, and technology.

Sharing Best Practices in Undergraduate Research

The annual Florida Statewide Symposium began in 2008 at the University of Central Florida (UCF), where it ran for 10 years. The location now rotates around the state, returning to UCF every other year. This event gathers faculty, administrators, and professional staff from institutions across the state to network and share best practices to promote, grow, and strengthen undergraduate research experiences in Florida.

The weekend symposium typically hosts 80–100 participants, and, as with FURC, FURA keeps registration fees low, asking only enough to cover the cost of organizing the conference. Presentations, panels, and posters at the conference cover a range of topics, including university-wide programs (such as running a university undergraduate research journal), classroom-level initiatives (such as integrating research experiences into individual courses), and even initiatives seeking to build research skills within the context of single assignments or modules within a course.

From the start, the symposium was welcomed by participants. In the first year, 100% of attendees who filled out evaluations "strongly agreed" that the symposium was useful. Evaluations since have continued to recognize its value for education and undergraduate research across the state.

The symposium's success led to the creation of FURC, the idea for which emerged from discussions among undergraduate research mentors over the event's first few years. Indeed, the symposium is the foundation of FURA's other activities, as it trains faculty and staff to prepare their students to present research at FURC and Posters at the Capitol and to publish in *FURJ*.

A Model for Supporting Students

FURA's overarching purpose is to support students through its initiatives. Since the association's inception, more than 4,000 students have participated in its events or have published in *FURJ*. It's difficult to measure quantitatively the full impact of these programs, but student and mentor feedback tells much of the story.

Taryn Lagor, a student at Lynn University in Boca Raton who published her undergraduate archaeology research in *FURJ*, explained how the experience changed her perspective of criticism and peer review: "A lasting lesson I learned from publishing was not to take criticism or revision suggestions too harshly and how much those suggestions will improve your work. They're absolutely not setbacks, and the patience and work that I put in to revise the work made my paper exceedingly better."

Lagor is now pursuing a master's degree in bioscience studying how wildlife preserve characteristics influence gopher tortoise populations—and she is applying what she learned through the *FURJ* peer-review process to her master's thesis. For many other students, FURA has similarly smoothed the transition from undergraduate to graduate research.

FURA's successful regional ecosystem approach could readily be translated to other states and regions across the United States—particularly where there is a relatively high density of students in higher education institutions—or perhaps could even be adapted to education systems elsewhere. We hope it will be—to the benefit of even more students who want to develop their careers and gain valuable research experience.

Here in Florida, FURA will continue looking to expand the number of students served, to improve our existing initiatives, and to innovate in creating new and valuable opportunities for undergraduates.

Students present their research to visitors in the rotunda of Florida's Capitol during a Posters at the Capitol event. Credit: Latika Young

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Ocean Warming Sets the Stage for Dangerous but Predictable East Africa Droughts

In summer 2022, East Africa experienced massive levels of food insecurity due to the impacts of sequential droughts. Long-lead forecasts helped guide and motivate timely human relief efforts. Credit: USAID U.S. Agency for International Development/Flickr, CC BY-NC 2.0 (bit.ly/ccbync2-0)

Frequent droughts—interspersed with floods—have become the new norm in eastern East Africa over the past few years, driving a massive food security crisis. In 2020, the Horn of Africa entered its longest and most severe dry spell in more than 70 years, and 2022 marked the driest springtime drought on record. More than 20 million people experienced extreme hunger because of failed harvests, and there were more than 9 million livestock deaths.

In what's been described as the East African climate paradox, climate change models did not anticipate these droughts, projecting instead increased springtime rains. However, researchers with the Famine Early Warning Systems Network (FEWS NET) were able to predict the droughts using tailored forecasts based on sea surface temperatures.

Identifying the link to Pacific Ocean temperatures has improved predictions, giving humanitarian relief agencies the chance to reduce the loss of lives and livelihoods. But scientists haven't fully understood why this connection existed. In a recent study, *Funk et al.* examined what's causing this link.

La Niña events have become more strongly linked to droughts since the western Pacific Ocean warmed dramatically in 1998. The researchers dug further into data about sea surface temperatures and rainfall observations and noted that rising temperatures in the western Pacific are causing the ocean's east-to-west sea surface temperature gradient to become more extreme. In spring, when East Africa usually experiences a rainy season, climate change–enhanced La Niñas further amplify this gradient phenomenon. This more extreme gradient intensifies an airflow pattern known as the Walker circulation, which tends to drive high heat and moisture near Indonesia but reduce moisture over East Africa.

The researchers showed that climate models predict that the east-to-west Pacific sea surface temperature gradient will continue to strengthen in the coming decades, so frequent droughts will likely continue in East Africa. But identifying the link between sea surface temperature and precipitation has already allowed FEWS NET scientists to predict many of the worst dry spells, as well as to anticipate the extreme rains and flooding that occurred in 2023.

This study further improves scientists' understanding of how climate change is bringing more extreme, but predictable, fluctuations in the Walker circulation, according to the scientists. (*Earth's Future*, https://doi.org/10.1029/2022EF003454, 2023) **—Saima May Sidik,** *Science Writer*

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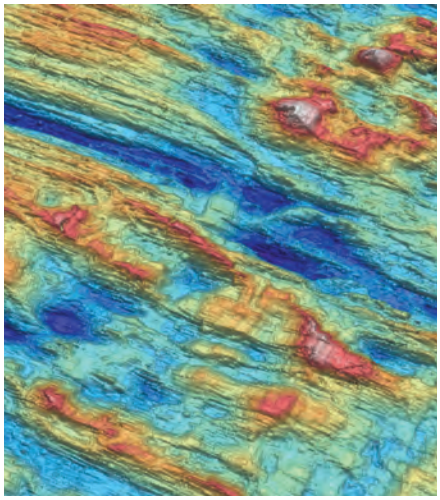
Seafloor Shapes on Mid-Ocean Ridge Flanks Are Linked to Magma Supply

Extending nearly 65,000 kilometers, the mid-ocean ridge system is the longest mountain range in the world. Mid-ocean ridges form at divergent plate boundaries, where tectonic plates move apart and magma rises to create new crust in a process called seafloor spreading.

Rifts along the axis of the mid-ocean ridge system are among the most seismically active locations on Earth.

Researchers have cataloged a wide range of geologic formations on the flanks of mid-ocean ridges, including volcanic cones, seamounts, and abyssal hills. Previous research suggested that the rate of seafloor spreading could be the cause of this varied bathymetry.

Tucholke et al. studied the flanks of mid-ocean ridges using multibeam bathymetric data to better understand how magma supply may have contributed to this variety of geologic formations. Their findings indicate that changes in magma supply influence seafloor shapes on the flanks of mid-ocean ridges more strongly than spreading rate does.



Multibeam bathymetry shows the morphology of a section of the Southeast Indian Ridge, south of Australia. New research finds that highly variable seafloor morphology is controlled by changes in magma supply along the axes of mid-ocean ridges. Credit: Ross Parnell-Turner

The researchers examined the differences in gravity among 122 mid-ocean ridge sites around the globe, as well as the rates at which the ridges were spreading apart at these sites, to infer magma supplies below the ocean floor. They noted that some patterns in seafloor morphology, including underwater abyssal hills that are longer, straighter, and connected, are correlated with greater magma supply. Steeper, rougher, more irregular abyssal hills are formed when magma supply is reduced. In parts of the Southwest Indian Ridge, exposed mantle is likely altered and weakened by interaction with seawater, which can prevent steep underwater hills from forming despite limited supplies of magma.

The methods used in this study, including a comparison of visual and quantitative findings using bathymetric data, can help other researchers investigate seafloor features further, the reasearchers said. (*Journal of Geophysical Research: Solid Earth*, https://doi.org/10.1029/2023JB027367, 2023) **—Rebecca Owen,** *Science Writer*

Protecting Power Grids from Space Weather

Activity from the Sun, such as solar flares, can cause fluctuations in Earth's geomagnetic field that send electrical currents flowing through power grids. These geomagnetically induced currents (GICs) can cause problems ranging from temporary voltage instabilities to widespread blackouts to reduced life spans for transformers. It is therefore important to develop effective mitigation strategies that protect against power disruptions caused by GICs while maintaining power to consumers.

Suggested solutions have included installing equipment such as capacitors to block GICs and changing to network configurations. *Mac Manus et al.* worked with the energy company Transpower New Zealand Ltd. to test four mitigation strategies that could be used throughout the country's North and South Islands. The team did this by running simulations of nine extreme space weather event scenarios—based on some of the country's worst recorded storms—and modeling potential mitigation responses.

Extreme space weather events can cause problems for power grids without proper mitigation. Credit: Benchill/Wikimedia Commons, CC-BY 3.0 (bit.ly/ccby3-0)

Transpower's former mitigation model was shown to be solid, but it was optimized for the South Island and was less effective elsewhere. Another tested option significantly reduced the risk of GIC-caused damage, but it involved disconnecting 121 (~30%) of the country's high-voltage transmission lines, increasing the overall risk of network failure.

Working with Transpower, the researchers found that the mitigation strategy that best balanced effectiveness and practicality reduced the effects of GICs by 16% with a targeted disconnection of just 24 lines. Transpower has adopted this as its new operational procedure to manage space weather events.

In addition, the group determined that installing capacitor blocking devices on 14 specific transformers could reduce GICs by another 16%. Transpower is considering implementing this as well.

The paper's findings demonstrate the benefits that can result when researchers work with industry partners to mitigate space weather impacts. The paper also provides techniques that could be applied in other regions of the world. (*Space Weather*, https://doi.org/10.1029/2023SW003533, 2023) **—Rachel Fritts,** *Science Writer*

Adding Oxygen to a Lake to Explore Methane Emissions

Lakes around the world emit methane to the atmosphere, accounting for up to 19% of total global emissions of this potent greenhouse gas. Most of the methane in lakes comes from microbes in the lake bed that consume dissolved organic matter for sustenance and release methane as a waste product. This process typically occurs in low-oxygen conditions; in environments with more oxygen, microbial metabolic processes that do not produce methane tend to dominate.

The dynamics of methane emission from lakes are still being worked out, and scientists typically rely on small-scale experiments conducted in bottles or enclosures that merely mimic lakes.

However, in a new study, *Pajala et al.* report the results of a rare ecosystem-scale experiment conducted in a small boreal lake in northern Sweden.

The researchers selected the lake because it has two connected basins. In summer 2019, they injected oxygen into the deeper waters of one basin. The other basin was left alone, resulting in naturally low oxygen levels in deep waters. They measured methane emissions from both basins to better understand how dissolved oxygen affects emissions.

In line with the researchers' expectations, only a small amount of methane accumulated in the basin with added oxygen, whereas more methane accumulated in the low-oxygen waters of the control basin. However, little of this accumulated methane was released to the atmosphere during summer months, contrary to expectations from prior research.

In addition, the lakes only partially underwent the autumnal and springtime mixing of shallower and deeper waters that typically results in significant methane emission. Further calculations suggested that a maximum of 24% and as little as 0% of the methane in the lake was released during seasonal mixing. The rest was consumed by a special group of microbes that use it for energy, providing an important ecosystem service called microbial methane oxidation.

To learn more about methane emissions from lakes, researchers equipped Lake Ljusvattentjärn, in Sweden, with temperature and oxygen loggers, floating chambers, and an aeration system installed above the deepest point of the lake. Credit: David Seekell

These findings suggest that in some cases, low-oxygen conditions may have a smaller impact on methane emissions from lakes than previously thought and that from year to year, emissions may vary widely because of different degrees of seasonal mixing. Further research is needed to better understand this variability and its implications for climate change. (*Journal of Geophysical Research: Biogeosciences*, https://doi.org/10.1029/2022JG007185, 2023) **—Sarah Stanley,** *Science Writer*

Just How Extreme Might Future Storms Get?

Storms that drop exceptionally high volumes of precipitation often cause flooding and otherwise imperil human safety, infrastructure, and ecosystems. As climate change progresses, such extreme events are likely to become even more intense and more frequent in many regions around the world.

Efforts to prepare for future extreme events benefit from accurate estimates of just how intense the events might be. However, because the most extreme events are rare, historical records are often too short to contribute to reliable estimates.

Gessner et al. demonstrate a novel way to combine storm simulations with statistical approaches to better estimate how extreme future precipitation events could become.

Focusing on central Europe in the colder months of October–April, the researchers first applied a statistical approach to evaluate the plausibility of future extreme events predicted from real-world historical data and from simulations generated using the Community Earth System Model Version 2. The resulting analysis suggested that precipitation events much more intense than previously recorded will be possible in the near future in the region.

However, those statistical estimates came with a high degree of uncertainty and did not address the physical mechanisms behind future extreme events. So the researchers next applied a strategy known as ensemble boosting, which involves generating many alternative simulations of how a past real-world extreme precipitation event may have unfolded over time, depending on very small perturbations in humidity several days prior to the event.

The approach produced estimates indicating that near-future extreme events might result in precipitation volumes that are 30%–40% higher than those seen in past events. The researchers note that even higher precipitation magnitudes cannot be ruled out. Further, their analysis suggested that some of the most extreme winter precipitation events in Europe can be linked to patterns of atmospheric pressure at sea level typically associated with atmospheric rivers—bands of concentrated moisture that stream through the atmosphere.

The researchers say the findings suggest that the ensemble boosting and statistical approaches can complement each other well in efforts to estimate the intensity of future extreme events, providing a way to "stress test" the resilience of infrastructure and ecosystems in the face of such events. (*Earth's Future*, https://doi.org/10.1029/2023EF003628, 2023) **—Sarah Stanley,** *Science Writer*

Some High-Threat Volcanoes Are Severely Understudied

The Cascade Volcanic Arc stretches from Northern California to southern British Columbia and contains more than a dozen volcanoes. The U.S. Geological Survey classifies 11 of them, including Mount Baker and Mount Hood, as "very high threat," meaning that they pose significant hazards to people and infrastructure.

Despite the potential for danger, scientists have only scant data regarding where magma is stored beneath the Cascades, knowledge that could help scientists better understand and predict future eruptions, *Wieser et al.* report in a recent review.

Seismic data, tiltmeter readings, and information from satellites can reveal ground deformations that indicate that magma is moving beneath the surface. However, most research focuses on a few Cascade volcanoes that have already been well characterized.

Practical limitations can also hamper scientists' understanding of volcanoes: Sometimes magma doesn't move enough to be detected, and at other times, noise from different geological processes (including background seismicity from faults) dwarfs the signal from the magma. Rugged terrain and difficulties acquiring permits to install monitoring equipment in protected areas can also make volcanoes hard to study.

For all these reasons, there is a stark lack of data on some of the most dangerous volcanoes in the United States and Canada, the researchers conclude. For example, very little is known about Mount Adams in southern Washington, which, the authors say, is "very concerning," considering that the volcano is classified as "high threat." The same could be said of Glacier Peak, a little north of Adams, they note.

More information is needed to understand the hazards volcanoes in the Cascade Volcanic Arc pose to nearby cities. Mount Hood, a Cascade volcano that last erupted in 1866, forms a backdrop for the city of Portland, Ore., shown here. Credit: Truflip99, Wikimedia Commons, CC BY-SA 4.0 (bit.ly/ccbysa4-0)

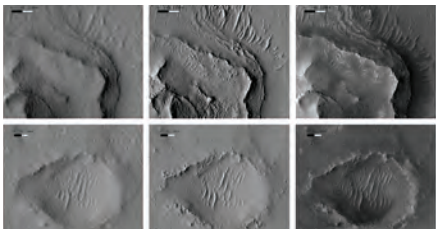
A few high-profile volcanoes, such as Mount St. Helens, are relatively well characterized. In other cases, more data should be forthcoming. For instance, researchers recently installed additional monitoring stations around Mount Hood to help scientists understand the amount and distribution of magma beneath it.

The researchers say they hope their work will help scientists prioritize where to focus their efforts on the basis of which volcanoes pose the biggest risk and are the least understood. (*Geochemistry, Geophysics, Geosystems*, https://doi.org/10.1029/2023GC011025, 2023) **—Saima May Sidik,** *Science Writer*

Deep Learning May Help Map Mars Landing Sites

Preparations for a safe landing on Earth, such as finding the most even terrain and equipping the appropriate landing gear, are also crucial for Mars missions.

Thus, landing a rover on the Red Planet requires careful mapping and planning well before a rover's descent begins. Scientists are working to create accurate 3D surface maps, known as digital terrain models, of the planet by compiling mosaics of images from past missions.



With deep learning methods, scientists generated the 50-centimeter-per-pixel HiRISE MADNet digital terrain model mosaic shaded relief (center). The fine-scale surface features of Mars stand out more clearly compared with prior digital terrain models (left). Their similarity to the features presented in the original HiRISE image (right) indicates that a pixel-to-pixel 3D retrieval was achieved. Credit: Yu Tao

Progress in image processing technologies over the past 2 decades has advanced map resolutions from hundreds-of-meter to submeter scales.

Although this is an extraordinary improvement, even resolutions of 1 meter per pixel cannot fully capture fine-scale features like dune textures, small craters, and large rocks.

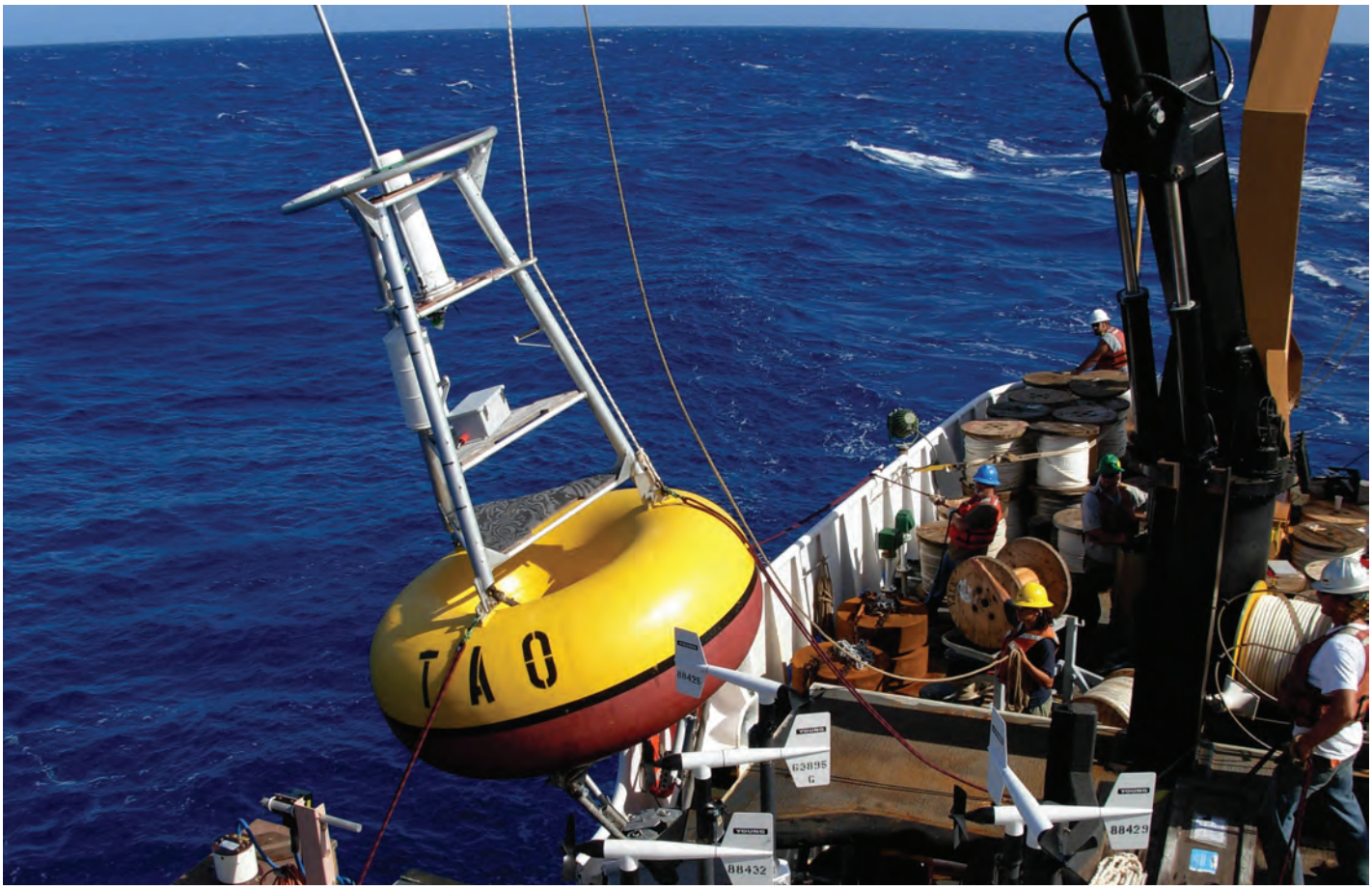
To better map the geologic features around the 2020 Perseverance landing site at Jezero crater, *Tao et al.* used a deep learning model called Multi-scale Generative Adversarial U-Net (MADNet), which they designed in previous work.

MADNet, trained using a blend of existing, postprocessed digital terrain models with resolutions ranging from 4 to 36 meters per pixel, refined the publicly available Mars 2020 Terrain Relative Navigation High Resolution Imaging Science Experiment (HiRISE) digital terrain model mosaic. The researchers also checked and refined multiple iterations to eliminate artifacts and gaps in the outputs.

The result is the 50-centimeter-per-pixel MADNet HiRISE Jezero digital terrain model mosaic. Compared with the original mosaics, the MADNet maps have an average height difference of just 0.009 meter, with a 0.63-meter standard deviation, which indicates that the results of the deep learning approach align with the traditional photogrammetric approach.

The researchers note that their product shows significant improvements over existing maps, including (1) increased effective resolutions that show fine-scale surface features like dunes, craters, and rocks; (2) reduced striping artifacts; (3) the elimination of regions with low matching qualities; and (4) the elimination of interpolation artifacts. (*Earth and Space Science*, https://doi.org/10.1029/2023EA003045, 2023) **—Sarah Derouin,** *Science Writer*

Bolstered by Buoys: Predicting El Niño



A Tropical Atmosphere Ocean buoy, part of a system collecting temperature, salinity, velocity, and surface meteorological data that inform climate predictions of ENSO, is lowered into the Pacific Ocean near the equator. Credit: Lt. Cdr. Matthew Wingate, NOAA Corps, CC BY 2.0 (bit.ly/ccby2-0)

The El Niño–Southern Oscillation (ENSO)—the climate phenomenon comprising the warm El Niño, cool La Niña, and neutral climate phases—occurs on a cycle that lasts 2–7 years. When it forms, ENSO drives irregular weather that can spark wildfires, cause drought or flooding, and disrupt agricultural production. Because of its global impacts, accurately forecasting ENSO's extremes is vital for human health and economies.

The Tropical Atmosphere Ocean (TAO) and Triangle Trans-Ocean Buoy Network (TRITON) mooring array straddles the equator across the tropical Pacific Ocean and has been a critical component of the multinational Tropical Pacific Observing System (TPOS) for decades. The TAO/TRITON system collects temperature, salinity, velocity, and surface meteorological data that inform climate predictions.

In response to a loss of monitoring resources, the international Synergistic Observing Network for Ocean Prediction (SynObs) project was begun to determine the best system to monitor and predict ENSO, and a TPOS initiative steering team made plans to reconfigure the array. As part of the effort, *Hackert et al.* investigated the role of TAO/TRITON data in these forecasts. The authors ran two simulations of the 2015 El Niño event, one that incorporated TAO/TRITON data and one that did not.

The results showed that the model assimilating the TAO/TRITON data provided more accurate estimates of temperature and salinity compared with the model without those data. The data notably improved reconstructions in the eastern tropical Pacific—off the coast of South America—where the upwelling of cold water shapes the ENSO climate response. In the same region, the TAO/TRITON model better forecast the increase in sea surface temperature that defines El Niño. Furthermore, data from the mooring array help to reveal the amplitude and timing of Kelvin and Rossby waves—specific kinds of ocean waves that are essential for ENSO cycling.

The results highlight the value of near-equatorial moorings and demonstrate the TAO/TRITON data's impact on ENSO forecasting. The authors note that the results can help inform future network designs as management agencies update observation systems. (*Journal of Geophysical Research: Oceans*, https://doi.org/10.1029/2023JC020039, 2023) **—Aaron Sidder,** *Science Writer*

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DESCRIPTION:
Leidos supporting the National Energy Technology Laboratory (NETL) is seeking a **Geospatial Data Scientist** to join our team. This is an opportunity to execute fundamental and applied research with world-class scientists and engineers using state of the art equipment to perform research aligned with the goals of the U.S. Department of Energy, including carbon management, critical minerals, and energy infrastructure analytics.

This position is required to work on site 3 days a week at the lab in Albany, OR (preferred) or Morgantown, WV. The other 2 days may be worked from their local home office. This is not a fully remote position. Applicants not in the Albany, OR or Morgantown, WV area or willing to relocate to the Albany, OR or Morgantown, WV area will not be considered.

REQUIRED EDUCATION & EXPERIENCE:
- Bachelor's degree in Geology, Geography, Geospatial Information Sciences, Environmental Sciences, or related field with 2+ years of research experience, or a Master's degree in Geology, Geography, Geospatial Information Sciences, Environmental Sciences, or related field with 1+ years of research experience.
- Competent in non-spatial and spatial data acquisition, management, handling, and analytics using GIS software.
- Familiar with Esri products (i.e., ArcPro, ArcEnterprise, ArcGIS Online) and other open-source GIS software (i.e., QGIS).
- Experience developing Esri web applications, including Experience Builder, Dashboards, Survey123, and Story Maps.
- Experience working with vector and raster subsurface data, including wellbore attributes, geologic maps, geochemical samples, geophysical, and other critical energy infrastructure datasets.

To see more details and apply for this position visit: **https://findajob.agu.org/job/8023396/geospatial-data-scientist/**

Brookhaven National Laboratory

ENVIRONMENTAL AND CLIMATE SCIENCES DEPARTMENT CHAIR

Lead the continued development of internationally competitive programs in climate and environmental sciences.

Work with the staff to recruit, mentor, and develop staff members, and maintain a diverse, inclusive, and respectful workplace supportive of creative scientific research.

Develop a scientific vision and decadal-scale strategic business plan for the Department appropriate for a leading National Laboratory, leveraging the unique capabilities and facilities at BNL and within DOE. Lead efforts to secure funding to bring the vision to light and execute the strategic plan, with the overarching goal to develop premier atmospheric, environmental, and terrestrial ecosystem science research programs consistent with the missions of the Department of Energy (DOE) and position the Department to take on new challenges.

Manage BNL's relationship with Earth and Environmental Systems Science Division within the DOE-Biological and Environmental Research (BER) program, which has three primary research activities: atmospheric research, environmental system science, and earth and environmental system modeling. Furthermore, oversee BNL's role in DOE-BER's Atmospheric Radiation Measurement user facility.

Build strategic partnerships inside and outside BNL that significantly enhance the responsiveness, competitiveness, productivity, and impact of the department R&D efforts, resulting in a sustainable growth in both the level and scope of department funding by DOE and other funding agencies.

Manage the Environmental and Climate Sciences Department to ensure safe and secure operations.

Contribute to ongoing departmental scientific research by being an active and independent scientist.

Position Requirements:
- Ph D. in atmospheric science, environmental science, ecology, or closely related field
- A minimum of 15 years progressive experience to include leadership and management of scientific, technical, and support professionals and programmatic funding stewardship.
- Demonstrated commitment to the development of staff within the framework of diversity, equity, and inclusion as the path to excellence.
- Demonstrated interpersonal skills and superior oral and written communication skills.
- A record of scientific accomplishment demonstrated by a record of publications in premier peer-reviewed journals.
- Experience working with federal and non-federal agencies that support climate and environmental science.

Preferred Knowledge, Skills and Abilities:
- Experience with DOE science programs and funding structure, with the mission and programs within BER's Earth and Environmental Systems Science Division.
- Active research program relevant to BER's programs in atmospheric, environmental, or terrestrial ecosystem science.
- Ability to obtain and maintain a security clearance.

To apply visit: **https://findajob.agu.org/job/8023416/environmental-and-climate-sciences-department-chair/**

Earth Sciences
UNIVERSITY OF TORONTO

ASSISTANT PROFESSOR - CONTRACTUALLY LIMITED TERM APPOINTMENT (2-YEAR TERM) – BIOGEOSCIENCES

The Department of Earth Sciences in the Faculty of Arts and Science at the University of Toronto invites applications for a **2-year Contractually Limited Term Appointment (CLTA) in the area of biogeosciences**. The appointment will be at the rank of **Assistant Professor**, with an anticipated start date of **July 1, 2024**.

Applicants must have earned a PhD in earth or environmental sciences, or a closely related discipline by the time of appointment, or shortly thereafter, with a demonstrated record of excellence in research and teaching. We seek candidates whose research and teaching interests complement and enhance our existing departmental strengths. The successful candidate would be expected to pursue innovative and independent research in biogeosciences, combining field-based, lab-based and/or modelling approaches to topics such as biogeochemical cycling, interactions between Earth systems (including biosphere, hydrosphere, lithosphere, atmosphere), or hydrobiogeochemical processes in the critical zone (surface water, groundwater, soils and vegetation). The successful candidate will be expected to teach a field course in hydrogeochemistry (which takes place annually in August in Renfrew County, Ontario), and additional courses in topic areas related to the successful candidate's area of research expertise, such as biogeochemical cycles, Earth system interactions, hydrosphere/groundwater or critical zone processes. The teaching load will be assigned following the Department's workload policy.

Candidates must provide evidence of research excellence, which can be demonstrated by a record of publications in top-ranked and field relevant journals, the submitted research statement, presentations at significant conferences, a track record of obtaining independent research funding, awards and accolades and strong endorsements from referees of high standing.

Evidence of excellence in teaching will be demonstrated by teaching accomplishments, and the teaching dossier, including a teaching statement, sample course materials, and teaching evaluations or other evidence of superior performance in teaching-related activities submitted as part of the application, as well as strong letters of reference. Other teaching-related activities can include performance as a teaching assistant or course instructor, experience leading successful workshops or seminars, student mentorship, or excellent conference presentations or posters. The successful candidate will be expected to contribute substantively to undergraduate teaching and graduate supervision in the Department.

Candidates are also expected to show evidence of a commitment to equity, diversity, inclusion, and the promotion of a respectful and collegial learning and working environment demonstrated through the application materials. Demonstration of how the candidate would bring new perspectives to the Department, experiences and meaningful plans for connecting to groups that have been historically marginalized in the geosciences are criteria that will be considered in our evaluation of excellence.

Salary will be commensurate with qualifications and experience.

For more information and to apply visit:
https://findajob.agu.org/job/8023467/assistant-professor-contractually-limited-term-appointment-2-year-term-biogeosciences/

Dear *Eos*:

In March 2023, as part of the European Research Council Starting Grant awarded to Donato Giovannelli, a team of 11 scientists from six institutions and diverse disciplines traveled across the Puna plateau in northern Argentina to sample gases, fluids, and sediments from geothermal systems to better understand the interactions between the geosphere and biosphere.

At 8:00 in the morning, our team of scientists is already busy sampling the hydrothermal springs at the top of a large travertine mound at an elevation of 4,130 meters near the Granada complex.

—Donato Giovannelli, University of Naples, Naples, Italy

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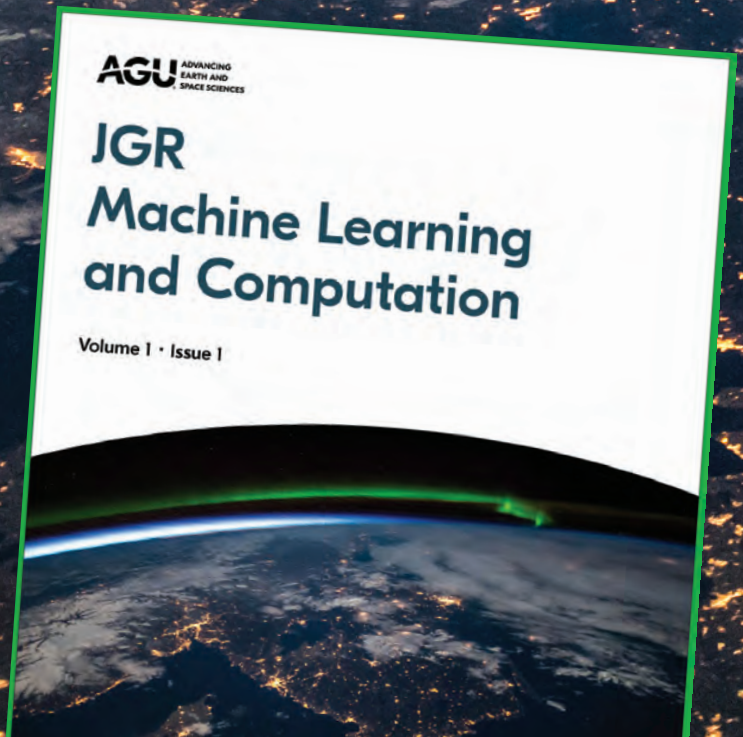

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