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Month in Review • December 2024
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NOAA's 2024 Arctic Report Card says tundra is now a net source of carbon to the atmosphere

Holistic pan-Arctic carbon assessment reviews the climate drivers impacting carbon storage and emissions across the Arctic region, including thawing permafrost and wildfires

A chapter of the National Oceanic and Atmospheric Administration's (NOAA) 2024 Arctic Report Card, published today, presents a new, comprehensive pan-Arctic carbon assessment that, when accounting for wildfire emissions, finds that the Arctic tundra has shifted from storing carbon to being a source of carbon emissions to the atmosphere.

While the Arctic has been a carbon "sink" for thousands of years—storing more carbon than it releases—the Arctic Report Card chapter, Arctic Terrestrial Carbon Cycling, explores how rapid Arctic warming is prompting a range of ecosystem changes that are leading to increased emissions throughout the region. Among these are thawing permafrost (perennially frozen ground), wildfires, and plant and microbial changes.

In particular, the assessment, led by scientists at Woodwell Climate Research Center, finds that 2024 marked the second-warmest average yearly permafrost temperatures on record for Alaska, and the second-highest year for wildfire emissions north of the Arctic Circle.

"The Arctic is warming up to four times the global rate, and we need accurate, holistic, and comprehensive knowledge of how climate changes will affect the amount of carbon the Arctic is taking up and storing, and how much it's releasing back into the atmosphere, in order to effectively address this crisis," said Dr. Sue Natali, Woodwell Climate scientist, chapter lead and

lead of Woodwell Climate's Permafrost Pathways project. "This report represents a critical step toward quantifying these emissions at scale which is critical for understanding their impacts on global climate and informing equitable mitigation and adaptation strategies."

"In recent years, we've seen how increasing fire activity from climate change threatens both communities and the carbon stored in permafrost, but now we're beginning to be able to measure the cumulative impact to the atmosphere, and it's significant," said Dr. Brendan Rogers, Woodwell Climate scientist, chapter co-author, and co-lead of Woodwell Climate's Permafrost Pathways project.

"This year's report demonstrates the urgent need for adaptation as climate conditions quickly change," said Twila Moon, lead editor of the 2024 Arctic Report Card and deputy lead scientist at the National Snow and Ice Data Center. "Indigenous Knowledge and community-led research programs can inform successful responses to rapid Arctic changes."

Contributions to the chapter were also made by Woodwell Climate scientists, Dr. Kyle Arndt, Dr. Jacqueline Hung, Greg Fiske, Stefano Potter, and Dr. Anna Virkkala, as well as collaborators at University of Alaska-Fairbanks, Northern Arizona University, and Université de Montréal.

The Arctic Report Card combines the best available research from over 97 scientists from 11 countries, including seven from Woodwell Climate. Its chapters reveal record-setting observations of a rapidly warming Arctic, including rising air temperatures, declines of large inland caribou herds, and increasing precipitation. These climate impacts and others threaten the health, subsistence, and homes of many Indigenous communities living in the Arctic.

LEARN MORE

Read the full Arctic Report Card:
[arctic.noaa.gov/report-card/
report-card-2024/](https://arctic.noaa.gov/report-card/report-card-2024/)



New study links Arctic warming with severe cold spells across the Northern Hemisphere

Despite rapid Arctic warming, researchers find evidence for more severe and frequent winter in the future

A new study, published in *Environmental Research: Climate* and co-authored by Senior Scientist Dr. Jen Francis, finds that despite abnormal warmth globally, and especially in the Arctic, severe winter cold-air outbreaks will continue, and perhaps become more frequent across the Northern Hemisphere.

“Even though the globe is warming and cold records are falling less often, we are still seeing surprisingly severe cold spells that sometimes last for many days and invade regions unaccustomed to severe cold,” said Dr. Francis. “It seems really

During recent warm winters with a relatively warmer Arctic, however, this vortex has tended to weaken, which can disrupt the normal flow of the jet stream below it (a river of wind above northern midlatitudes) and lead to conditions called “blocking”, which in turn allow pockets of cold Arctic air to plunge much farther south than normal.

This review provides a new analysis of recent research that offers further clarity around these complicated interactions.

According to study co-author Dr. Muyin Wang, “An improved understanding of Arctic-midlatitude climate linkages is likely to benefit seasonal prediction and extreme weather preparedness, as well as the understanding of climate change.”

Researchers also underscore the need for urgent action to address the climate crisis, and mitigate and adapt to the consequences of increasingly extreme weather. “The Arctic may seem irrelevant and far away to most folks, but our findings show that the profound changes there affect billions of people around the Northern Hemisphere,” said Dr. Francis. “To reverse these trends, and better protect our communities and our planet, we must take bold and rapid action now to reduce the burning of fossil fuels and the build-up of heat-trapping gases in the atmosphere.

The tools to achieve this exist if we can muster the will.”

The study resulted from an international workshop held in Lincoln, UK, in 2023, and was supported by the International Arctic Science Committee, the World Climate Research Programme’s Climate & Cryosphere project and the University of Lincoln.

counterintuitive, but there will be plenty of ice, snow, and frigid air in the Arctic winter for decades to come, and that cold can be displaced southward into heavily populated regions by Arctic heat waves.”

“In this comprehensive review of recent literature augmented with new analysis, we find the ongoing warming of the Arctic may provide an explanation,” added study lead author Dr. Edward Hanna.

The stratospheric polar vortex is a mass of cold whirling air that forms high above the Arctic surface in response to the large north/south temperature difference that develops during winter.



LEARN MORE

Read the full journal article:
doi.org/10.1088/2752-5295/ad93f3/



Arctic Indigenous mapmakers are reclaiming the past, shaping their future

Permafrost Pathways builds GIS capacity with Alaska Native communities, leverages co-produced maps for policy change

Jess Howard Arctic Communication Specialist



“What if you’re not on the map?”

Dr. Kelsey Leonard of the Shinnecock Indian Nation addressed this question to a room of Geographic Information System (GIS) professionals at Esri’s global mapping conference in 2023. Leonard, who uses maps to advance Indigenous water justice, asks this question to raise awareness about the absence of Indigenous land and languages in GIS tools. The removal of traditional place names in physical spaces, cartographic maps, and geospatial software often contributes to the erasure of Indigenous culture and history.

The Permafrost Pathways project, like Leonard, is working to change that.

Building Indigenous GIS Capacity in the Arctic

Due to dispossession and forced displacement caused by colonization, Indigenous People in the United States have lost nearly 99% of their land. While verbal and physical land acknowledgments aim to recognize this history of land theft and elevate the visibility of Indigenous Peoples as the land’s original and rightful inhabitants, another movement to decolonize place and space is gaining momentum: Indigenous mapmaking.

Permafrost Pathways has been working with Alaska Native partners to support this larger movement by building GIS capacity within communities. The project trains Tribal liaisons to use mapping tools and software through a long-standing partnership with GIS software provider, Esri.

“Tribal sovereignty is a huge priority for Permafrost Pathways,” said Darcy Peter, Woodwell Climate’s Arctic Adaptation Lead. “While providing GIS as a service to communities is meaningful and important work, we find a deeper value in building Tribal

GIS capacity and sovereignty. Tribes have relied on outside entities for a multitude of necessary things, but I think it’s time for that to change. People who live in the community know what’s best for their people, their land, their way of life.”

Earlier this year, Permafrost Pathways and Esri co-hosted a mapping workshop on Esri’s campus in Redlands, California with Alaska Native community partners from Akiak (Akiak), Kuigluk (Kwethluk), Nunapicuaq (Nunapitchuk), Kuigilnguq (Kwigillingok), Qipnek (Kipnuk), Cev’aq (Chevak), and Quinhagak (Kwinhagak).

The workshop included hands-on GIS training sessions and presentations about using geospatial data to map landscape change and support adaptation decision-making. Esri’s menu of specialized ArcGIS tools—including products like Survey 123 and ArcGIS StoryMaps—can also help community partners track storm impacts, collect environmental data, and share their own stories and observations of how climate change is unfolding in their villages.

“Learning mapping and GIS skills is important to me and my community of Kuigilnguq because it helps us plan more accurately regarding our relocation efforts,” said Lucy Martin, Tribal Resilience Planning Assistant for Kuigilnguq. Martin uses Esri’s ArcGIS StoryMaps application to document local observations of environmental change and raise awareness about climate impacts in her village.

Expanding on what they learned at the workshop, Martin and Ferdinand Cleveland, former Permafrost Pathways Tribal Liaison from Quinhagak, attended the annual Esri User Conference in San Diego this summer. At the conference, they participated in additional GIS technical sessions and workshops.

They also learned about how other Indigenous GIS professionals across the world are using Esri's tools during the event's Native Nations Summit.

Many Alaska Native community partners, like Cev'aq Tribal Liaison Reggie Tuluk, are also using Esri's software to create Indigenous place name maps of their communities in their Native languages. Tuluk said the GIS workshop was an "amazing and educational experience." He is also hoping to engage the youth in Cev'aq to get more involved in GIS.

"I look forward to getting more in-depth education in learning mapping and GIS skills," said Tuluk.

Like Tuluk, Nunapicuaq Tribal Liaison Morris Alexie also plans to involve youth from his community, especially when it

comes to archiving cultural lifeways and learning Yugtun, the traditional Yup'ik language.

"There are place names in certain areas of our community that are not used anymore," Alexie said.

He hopes to use StoryMaps to inspire youth to combine modern technology with educational storytelling to keep Yugtun alive for future generations.

Woodwell Climate's Senior Geospatial Analyst Greg Fiske, who has been working with Esri and Alaska Native community partners for years, found it especially rewarding to see these collaborations come to fruition at the GIS workshop and Esri User Conference.

"The group was able to come together, and it was immediately clear that there are many ways shared GIS technology can support climate-related challenges in the Arctic," Fiske said.

Co-producing maps to track environmental change

Permafrost Pathways is also working with Alaska Native community partners to co-produce maps of the changing landscape in and around their communities. In villages like Cev'aq and Akiaq, rapid erosion caused by permafrost thaw and flooding is a major threat to community infrastructure and safety. Co-creating maps that illustrate these threats helps to inform community disaster planning and response, as well as supplement environmental assessment reports and grant applications.

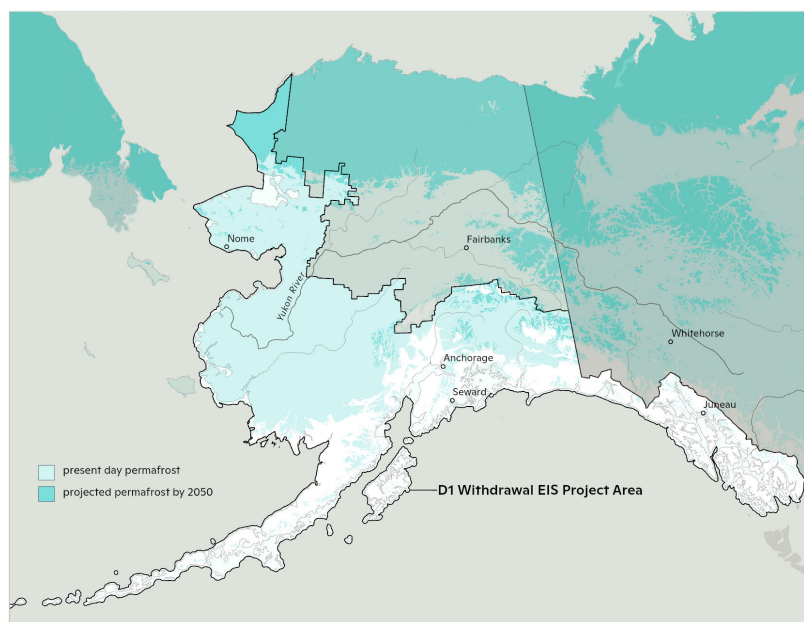
In April 2023, Fiske worked with Gary Evon, a former Permafrost Pathways Tribal Liaison, to correct a map from a community hazard assessment report conducted by an external engineering firm that had inaccurately captured the severe tidal flooding in Kuigilnguq. Evon used high-resolution satellite imagery to identify unflooded areas during high tide. He and Fiske then plotted those areas using GPS to co-produce a map that better reflected the extreme tidal inundation occurring regularly across the community.

Evon and Fiske's co-produced flood map illustrates the importance of including lived experiences and local observations from community experts in geospatial representations of environmental hazards. Maps created without community input lack important insight into the bigger picture and often underrepresent the true extent of environmental threats and community adaptation needs.

Maps inform Arctic policy responses

Co-produced maps also have the potential to influence policymakers. By combining Indigenous Knowledge and community observations with Western science, co-production communicates the needs of communities more accurately and powerfully than science alone.





“Maps are key for storytelling,” said Senior Scientist and Project Lead Dr. Sue Natali. “A good map helps you navigate your local space. They can also change people’s minds, they can shift policy.”

Maps have the power to transcend language, cultural, and disciplinary boundaries that often present communication barriers. For policymakers from the contiguous United States who aren’t regular witnesses to rapid environmental change in the north, maps are paramount to understanding the impacts of Arctic permafrost thaw and realizing the urgent need for more federal support for climate adaptation and mitigation. Additionally, maps can also help these policymakers understand the potential impact of their legislation and decision-making.

For example, in 2023, the U.S. Bureau of Land Management (BLM) proposed to open nearly 28 million acres of protected lands (known as D1 lands) across Alaska to industrial leasing—a move that would threaten the health of the surrounding environment and the many communities that rely on it. Permafrost Pathways and other opposed groups used maps to highlight how D1 lands overlapped with culturally significant subsistence hunting and fishing grounds, animal migration routes, and permafrost, all of which would be threatened. Alaska Native communities also cited concern for the unprecedented risks to traditional lifeways in the greater Yukon-Kuskokwim region, an area already under immense pressure due to climate-fueled disturbances like permafrost thaw and flooding.

Following public input on the environmental impacts of this decision, BLM issued a final environmental impact statement. With the help of maps and overwhelming public opposition to the proposed withdrawal, BLM ultimately left protections for D1 lands intact, marking a victory for both the environment and surrounding communities.

Reclaiming the past for a more equitable Arctic future

Permafrost Pathways’ GIS capacity-building work contributes to a larger, global effort to decolonize place and space by empowering Indigenous mapmakers.

For Alaska Native communities, Indigenizing the map is a way to reclaim ancestral homelands, one traditional name at a time. It’s also a way for future generations to maintain their cultural heritage and connection to place through their Native languages.

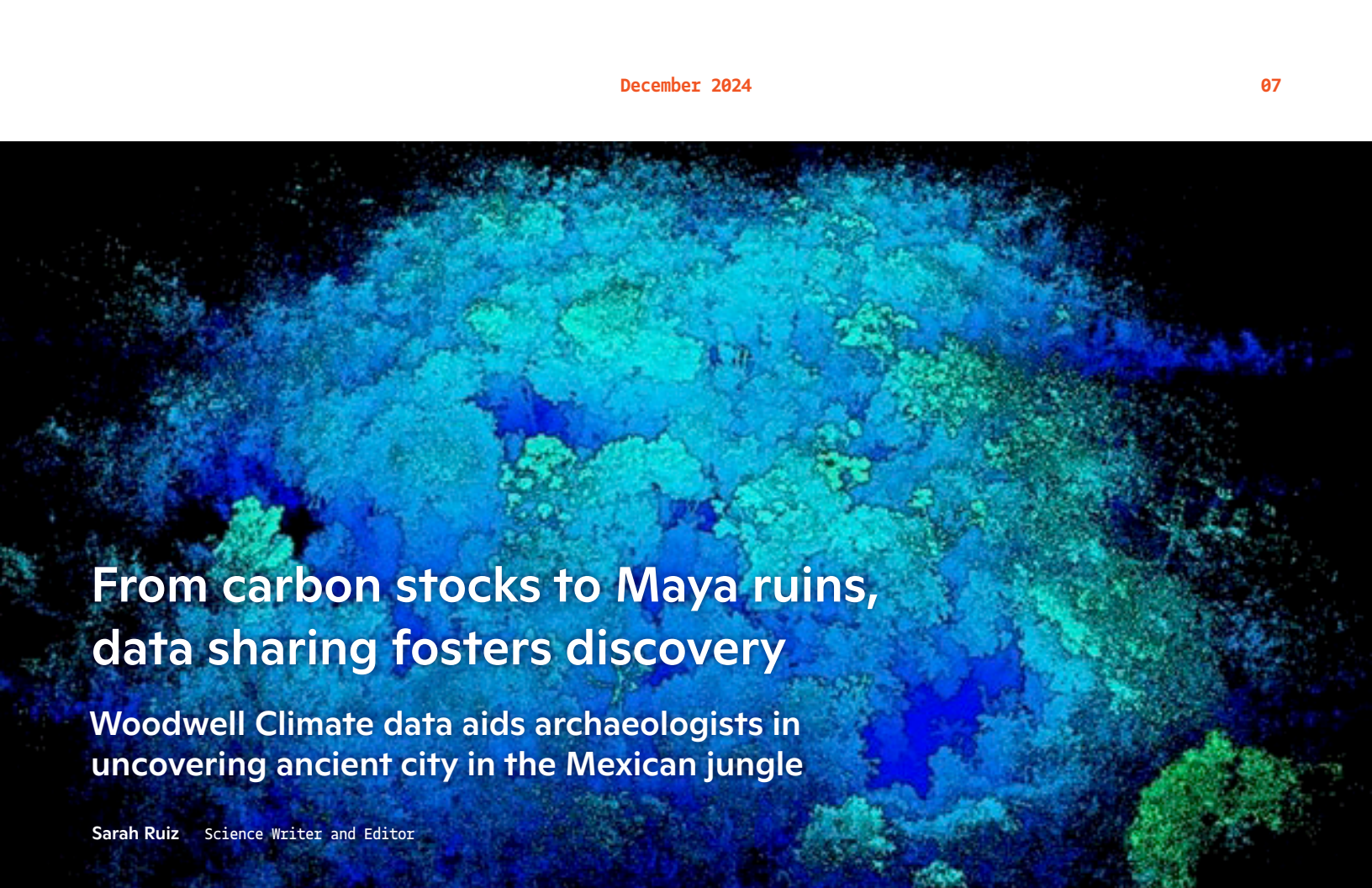
“I personally would love to see more of our Tribes speaking their traditional languages. Reclaiming language is one of the most powerful things we can do as Native peoples. There is so much that’s been lost, and language plays a huge part in that. There is so much traditional knowledge that doesn’t directly translate to English. Traditional place names, traditional hunting grounds, subsistence trails, I mean the list goes on,” Peter said.

Supporting this global movement means removing access barriers to GIS education and tools for Indigenous communities. For Permafrost Pathways, Peter says the overall priority of GIS capacity-building is “to uplift Tribal capacity and Tribal sovereignty.” With the help of powerful allies like Esri, the project is moving that needle.

“For each respective Tribe to have a mapmaker in their community that speaks their traditional language, and for communities to be their own GIS experts, their own scientists, their own advocates, their own storytellers, their own decision-makers—that would be one of the biggest successes of the project, and quite frankly of my life.”

above left: A map representing the overlap of D1 lands and permafrost in Alaska. / map by Greg Fiske

above right: Permafrost Pathways Research Assistant Jackie Dean and Cev’aq Tribal Liaison Reggie Tuluk using GPS to co-create maps that illustrate the extreme erosion impacting community infrastructure in Cev’aq. / photo by Sue Natali



From carbon stocks to Maya ruins, data sharing fosters discovery

Woodwell Climate data aids archaeologists in uncovering ancient city in the Mexican jungle

Sarah Ruiz Science Writer and Editor

Under the thick forest of Mexico's Yucatán Peninsula, the ancient ruins of a Maya City have been uncovered with the use of remote sensing.

Of course, that wasn't the outcome that Woodwell Climate's Chief Scientific Officer, Dr. Wayne Walker, anticipated when he and his team collected and processed the remote sensing dataset for an unrelated project nearly a decade ago.

Walker's team was mapping the region as part of the Mexico REDD+ project, a collaborative, international effort to explore strategies for reducing emissions from deforestation and degradation in the country. Using a remote sensing technology called LiDAR, which scans terrain from a low-flying plane using pulses of laser light, Walker and project collaborators created a comprehensive map of forests—and the carbon they contain—across Mexico.

Walker and team coordinated the flights and processed the raw data for use in the project, uploading it afterwards to a website for public use. But, once the project ended, he all but forgot about the effort, apart from responding occasionally to researchers interested in downloading the dataset for their own work.

One of those researchers was Luke Auld-Thomas, a Ph.D. candidate at Tulane University researching the Classic Maya

civilization, which thrived in the Yucatan until the 9th century when much of the region was abandoned, though their culture and languages persist to this day. Because of its unique ability to provide a detailed three-dimensional picture of whatever features are present on the ground, LiDAR imagery is an incredibly powerful tool for a multitude of purposes, from climate science to archaeology. And while the Mexico REDD+ project was interested in documenting the forests, Auld-Thomas was interested in what might be hidden beneath them.

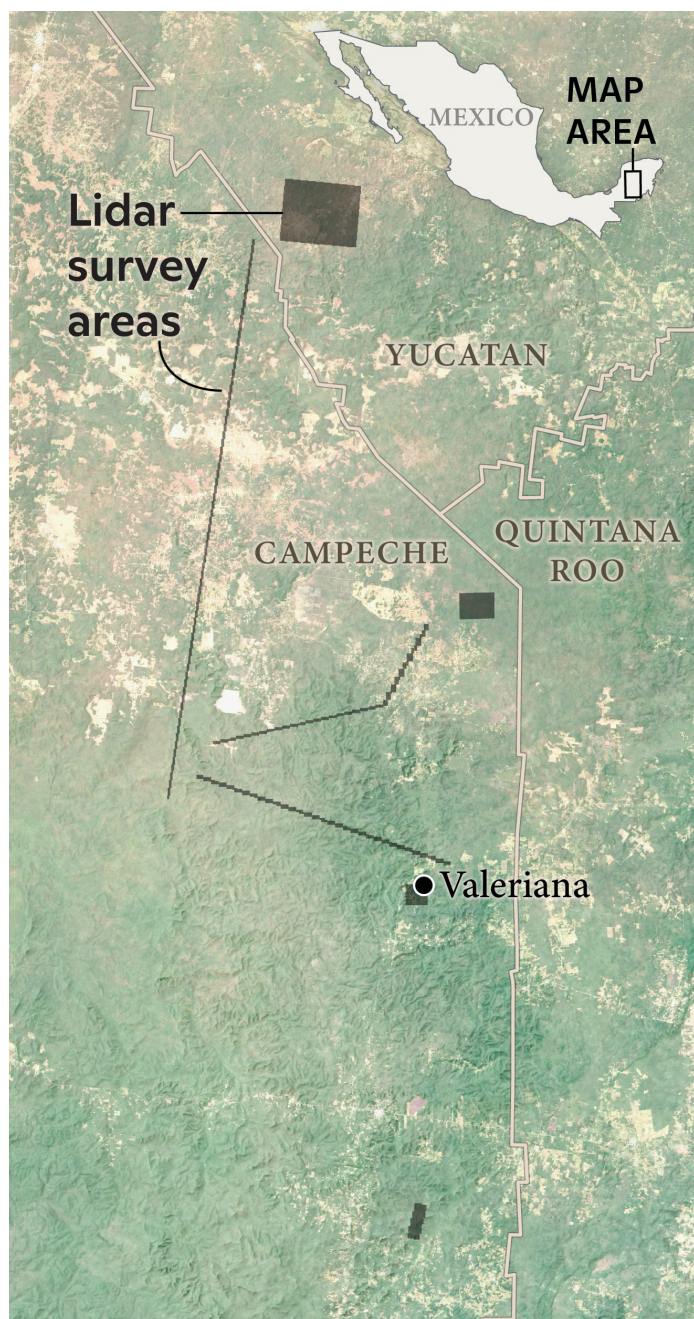
"One scientist's noise is another's entire field of study," says Walker. "In our other projects, like Climate Smart Martha's Vineyard, we see historical structures like stone walls that aren't necessarily meaningful to our work but could be of interest to archaeologists."

In Mexico, the large areas surveyed by Woodwell Climate revealed not just individual human-built structures, but the plazas, reservoirs, and ball courts of an entire, previously undocumented city. The discovery, published in the journal *Antiquity*, supported the theory that the region was, in fact, densely settled during the height of Classic Maya civilization.

"We knew that it was close to a lot of interesting sites and settlements—areas of large-scale landscape modification

that had been mapped and studied—but none of the survey areas themselves were actually places that archeologists ever worked, making it a really exciting sample to work with,” said Auld-Thomas.

Auld-Thomas had specifically been on the hunt for a pre-existing LiDAR dataset like the one Walker helped create—a survey conducted for completely non-archaeological purposes and therefore free of any biases. Essentially a “random sample” of the region. That randomness, and the subsequent discovery of an entire city, allowed Auld-Thomas and his colleagues to more strongly argue their point about intense urbanization in the Yucatán.



“If you’re only going to places where you know there’s going to be something, then of course, you’re going to find something significant, right? These random samples, not collected for archeological purposes, are gold in some respects,” said Dr. Marcello Canuto, who co-authored the paper. Canuto directs the Middle American Research Institute at Tulane, where the research for this study was conducted.

The unexpected outcome of the LiDAR survey offers a textbook example of the value of open data access. Sharing data and resources both within and between fields of science can jumpstart discovery and distribute the costs of an otherwise expensive data collection effort.

“Just look at what came out of the moonshot,” says Canuto. Thousands of technologies, developed in humanity’s pursuit of the moon landing, have found unforeseen applications in today’s world—including LiDAR.

“Certainly, many of us have produced datasets that have led to incremental advances in closely related fields,” says Walker. “But here is a special case of open source data advancing discovery in an entirely unrelated field of study.”

Advancements across fields continue to better our understanding of the world around us. And the lessons learned from a civilization like the Maya have very real parallels to today’s climate crisis.

As Auld-Thomas and Canuto show, the Maya densely settled the Yucatán Peninsula, maxing out the capacity of the surrounding environment to support their population. And then the regional climate shifted. A long-term drought settled in, resources became scarcer, governments became unstable, people started leaving the cities, and the infrastructure of the larger civilization collapsed.

“The reason environmental scientists collect LiDAR data of the forest, is that they are trying to understand environmental processes in order to help human societies conserve the landscape,” says Auld-Thomas. “As archaeologists, we try to understand how people in these exact environmental contexts have confronted deforestation and climate change and all of these other things before.”

For Canuto, the lesson to be learned lies not just in the environmental perils, but in the societal ones. Because what complex societies hate—be they the Classic Maya or today’s modern culture—is a lack of predictability. If a system cannot adapt, it will fail.

“The collapse was more than just climate change,” says Canuto. “It was a failure of a political system to respond to climate change.”

New municipal risk assessments focus on flooding

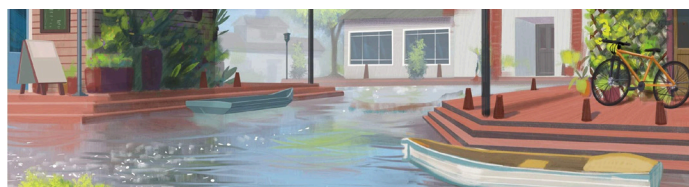
Partnerships with two disparate Massachusetts towns point to shared challenges.



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In the news: highlights



Dr. Max Holmes was featured in an episode of the podcast *Conservation Connection*, discussing carbon credits, natural climate solutions, and Arctic permafrost. bit.ly/podcast-holmes

Dr. Heather Goldstone was interviewed for an episode of WCAL's *The Point*, which focused on science communication and strategies for repairing the relationship between science and the public.

NOAA's 2024 Arctic Report Card got major media attention, especially a Woodwell-led chapter on Arctic land carbon cycling which presented that the tundra is now a net source of carbon to the atmosphere. Many media outlets covered this significant finding and quoted Drs. Sue Natali and Brendan Rogers, and other chapter contributors, including Drs. Jackie Hung and Anna Virkkala. Those outlets include: *NBC News*, *NPR*, *Vox*, *Grist*, *Axios*, *The Independent*, *Inside Climate News*, and *Alaska Beacon*.

The *New York Times'* *Climate Forward* newsletter quoted Dr. Brendan Rogers about the many changes in the Arctic linked to climate change, especially increasing wildfires. The newsletter also linked to the *NYT* article about NOAA's Arctic Report Card, which quoted Rogers as well.

Grist quoted Dr. Zach Zobel in a story about how extreme heat is shifting some work from day to night, including farming and fishing.

Dr. Christopher Schwalm was quoted in an article from *Grist* that examines the contradictory phenomenon of how air pollution can actually slow warming in cities, which was also published in *Fast Company* and *Popular Science*.

ABC News quoted Dr. Jen Francis in an article debunking the idea that solar activity is driving rapid warming. She was also quoted in a widely-syndicated *AP News* article about how this November was the second-warmest on record. *CNN* also quoted Francis on her doubts about the scalability of a controversial pilot project attempting to combat climate change by drilling holes in sea ice and pumping water to the surface to freeze. She also spoke about the links between weather and marine heat waves in an article by *BNN Bloomberg*.

The Guardian quoted Dr. Chris Neill in an article about \$6 million of grant funding recently announced to help convert cranberry bogs back to wetlands. *The Washington Post* also interviewed Neill for a story on converting retired commercial cranberry bogs into wetlands.

An article from NOAA about press conferences at the American Geophysical Union conference mentioned Dr. Brendan Rogers' participation in a panel about the 2024 Arctic Report Card.

Segre published an article covering the forest stability index, recently developed by Woodwell Climate and collaborators (Catalan).

Donations play an important role in securing the future of Woodwell Climate Research Center's work—and help safeguard the health of our planet for generations to come.

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