WHAT'S IN THE HONEYCOMB?

RESEARCH HIGHLIGHTS

College of Earth, Ocean, and Atmospheric Sciences | 2019

Oregon State University

Contents

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About the College

The College of Earth, Ocean, and Atmospheric Sciences (CEOAS) is an internationally recognized leader in the study of the Earth as an integrated system. With more than 100 faculty, 200 graduate students and 600 undergraduate students, the college has an annual budget of more than $50 million. Most of the college's research support comes from the National Science Foundation, National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration and other federal agencies and philanthropic organizations.

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A message from the Dean

If you want to go fast, go alone; if you want to go far, go together.

This African proverb is particularly appropriate for solving the environmental challenges we face. The global connections that define the Earth system are vast and varied; addressing them requires a confluence of intellect, creativity and drive that generates essential insights into our past to help define our future. The College of Earth, Ocean, and Atmospheric Sciences embodies this spirit. Our transdisciplinary approach to studying the Earth sciences inspires creative answers to stubborn challenges and generates game-changing discoveries that benefit people and the planet.

You will find evidence of our transdisciplinary scholarship throughout the 2019 issue of Research Highlights. Read about an ancient community of undersea microbes that may resemble early life on Earth, and what the Snowball Earth hypothesis can tell us about the fascinating and extreme states of our planet. Learn more about the discovery of novel food webs in the deep ocean, and why nearby volcanoes may have radically different eruption histories. The cover story, featuring the work of Alyssa Shiel, highlights research in which biogeochemists are using honey collected at urban beehives to trace heavy metals in our environment.

At CEOAS, we are in it for the long haul. We hope you enjoy reading about some of our biggest research accomplishments this year.

Roberta Marinelli
Dean

CEOAS POINTS OF PRIDE: Counting up

1 **One** century of cutting-edge research in the Earth sciences at Oregon State has led to amazing discoveries, from the strange creatures that live around deep-sea hydrothermal vents to the inner workings of supervolcanoes.

2 **Two** new research vessels, the most advanced and capable in the U.S. research fleet, are under construction in Louisiana. CEOAS received the largest grant in Oregon State's history to design and construct them. The first, to be named R/V *Taani*, will be ours, home-ported in Newport. The second will be operated by the University of Rhode Island. A third ship, which will be under construction soon, will go to an institution on the Gulf Coast.

3 Our oceanography program is ranked **#3** in the world by the Center for World University Rankings.

4 **Four** CEOAS faculty members have served as authors for reports issued by the Intergovernmental Panel on Climate Change, considered the scientific gold standard for assessing the global risks of human-induced climate change.

The buzz about biomonitoring:
Looking for lead in honey from urban hives

Photos by Hannah O'Leary

Geochemist **Alyssa Shiel** and a team of Canadian colleagues have found a sweet way to test for the presence of heavy metal pollution in urban neighborhoods: They are measuring the levels of metals in honey from hives maintained by neighborhood beekeepers. This work represents a new application of a technique that uses isotope analysis to search for low levels of lead, zinc, copper and other elements.

The study is thought to be the first of its kind in North America using honey as a biomonitor.

"Urban geochemistry is an emerging field, but because it focuses on concentrated population centers, it can be very complicated," said Shiel, a researcher in the College of Earth, Ocean, and Atmospheric Sciences. With respect to potential sources, "You have to factor in the local infrastructure – including roads, industrial areas and residential areas – as well as historical land use.

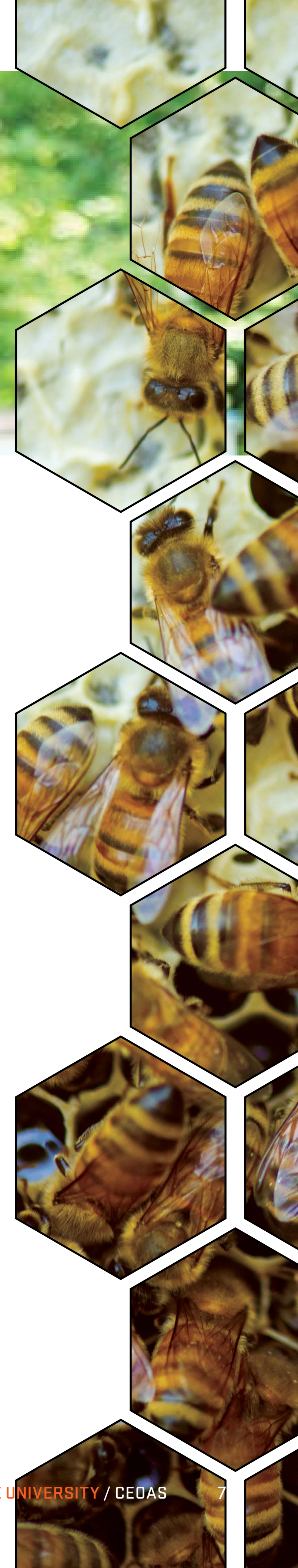
"But the positive thing is the study shows that we not only can identify low levels of heavy metals; we also can use 'isotopic fingerprints' to give us a strong idea as to where they came from."

The study focused on beehives in six neighborhoods in Vancouver, British Columbia. The researchers say honey collected from local hives provides a good indication of nearby conditions because honeybees typically utilize pollen and nectar within a range of one to two miles. The researchers carried out their study using sophisticated instruments that measure the elements in parts per billion, said University of British Columbia's Dominique Weis, the lead scientist on the project. It is the "equivalent of one drop of water in an Olympic-size swimming pool."

The researchers found traces of lead in the honey, but those isotopic fingerprints did not match any local, naturally occurring lead sources, suggesting a fairly clean local environment. However, some of the honey – as well as trees they tested in Vancouver's Stanley Park – revealed isotopic fingerprints that were chemically similar to aerosols, ores and coal from large Asian cities. Evidence of long-distance transport demonstrates the inherent connectivity of Earth's systems – contaminants from industrial processes far across the globe can be detected in public parks thousands of miles away.

The good news is that the lead was in small enough amounts that it shouldn't be a human health concern, the researchers noted. It would take consumption of about two cups of honey per day to exceed tolerable levels.

"This is a great example of how citizen science can play a role in helping researchers address issues around the world," Shiel said. "Urban beekeeping is on the rise, and honey is an untapped resource that can be used as a biomonitor."



Iron man: Rene Boiteau wants to know how marine microorganisms get enough metal in their diets

Assistant Professor **Rene Boiteau**, with the College of Earth, Ocean, and Atmospheric Sciences, has many irons in the fire, many of them related to, well, iron.

Boiteau is interested in how organisms orchestrate the flow of nutrients and energy in the world around them. A perfect example is the amazing biochemistry that allows marine microbial organisms to grow and thrive in ecosystems where biologically usable iron, a necessary micronutrient, is scarce.

In many places in the ocean, nutrients such as nitrogen and phosphorous are abundant, but oddly, primary productivity is strikingly low. Most of these places, known as high nutrient, low chlorophyll systems, are limited by iron availability, which is as necessary for productivity as nitrogen and phosphorus. Even when iron enters the ocean, usually via atmospheric deposition of iron-rich dust from land, it is highly insoluble in seawater and unavailable for biological use. In order to be successfully utilized, iron needs to be bound to another molecule, called a ligand, which keeps the metal in solution.

Where can primary producers find these all-important ligands? Some bacteria have taken matters into their own hands and evolved to make their own iron-binding ligands, called siderophores. "We've known about siderophores from biomedical research for a long time," Boiteau explained. "Pathogens need iron for respiration, so they often produce siderophores to scavenge iron from the host's blood." It turns out that siderophores are present in the marine environment as well.

Boiteau has conducted research from the South Pacific to the California Current ecosystem, examining the distribution of iron and siderophores in the marine environment. He also uses cutting-edge imaging technologies, like high-resolution mass spectrometry coupled with chromatography, to determine ligand structure, which can reveal more about how these molecules work and where they come from.

One question that fascinates him is what happens to the siderophores once they are released into the ocean. How can the bacterial cells that produce these compounds use them efficiently if they are excreted into a dilute liquid environment? Do the cells release the siderophores, only to have the molecules "wash away" before they are used? Boiteau and colleagues have determined that bacteria in iron-starved regions of the ocean produce siderophores with long fatty acid tails that remain associated with the microbial cell wall so that the molecules are not excreted and set free to drift. "The microbes seem to be sort of using them as fishing rods to acquire dissolved iron," Boiteau said.

In some areas of the ocean, such as the North Atlantic, iron is plentiful, thanks to iron-laden dust that is blown from as far away as the Sahara Desert and deposited on the ocean's surface. However, this iron may not be available for primary productivity. Boiteau and a colleague at University of South Florida recently received a grant to study how iron associated with dust is transformed into a usable nutrient in that region of the Atlantic. They will ask a number of important questions: How much iron comes from dust drifting and settling on the ocean? Is iron dissolved via the action of siderophores? How fast do the siderophores work to solubilize the iron?

In order to answer these questions, Boiteau and his colleagues will conduct some unique experiments. They will collect atmospheric dust from a land-based observatory in Bermuda, and then introduce the dust to filtered seawater samples while on research cruises in the Sargasso Sea and the Gulf of Mexico. Then they'll look at which, if any, siderophores are being churned out by the microbes in the seawater samples. "We'll ask what the composition of those ligands is and determine their binding strength," which will tell them about the rates and efficiencies of the ligands, Boiteau explained. They can't simply collect the seawater samples and look for ligands, because "it's not only the ligands that are there when you conduct the cruise that matters; it's the ligands that are produced by the microbes once the dust is added that are important," he said.

Why care about whether bacteria are getting enough iron? For one thing, bacteria provide a foundation for extensive food webs that ultimately produce the kinds of marine organisms that humans like to put on our dinner plates. In addition, primary production at the base of the food web affects processing of carbon in the ocean, with implications for large-scale climate dynamics.

The littlest of microbes can, in fact, affect the planet, but only if they pump enough iron.

Solving the mystery of the rise in atmospheric CO_2 during deglaciation

Most people are familiar with the fact that carbon dioxide in the atmosphere plays an important role in climate change. However, long before humans began emitting CO_2 by burning fossil fuels, the level of atmospheric CO_2 rose significantly as the Earth came out of its last ice age.

Many scientists have long suspected that the source of that carbon was the deep sea. But they haven't been able to document how the carbon made it out of the ocean and into the atmosphere. It has remained one of the most important mysteries in the field of Earth system science.

Alan Mix and **Jianghui Du**, with the College of Earth, Ocean, and Atmospheric Sciences, and **Brian Haley**, formerly with the college, are part of a research team that appears to have found some of the most compelling evidence to date for how it happened. They believe it was the result of a "flushing" of the deep Pacific Ocean caused by the acceleration of water circulation patterns that begin around Antarctica.

"The Pacific Ocean is big, and you can store a lot of stuff down there. It's kind of like Grandma's root cellar – stuff accumulates there and sometimes doesn't get cleaned out," Mix said. "We've known that CO_2 in the atmosphere went up and down in the past, we know that it was part of big climate changes, and we thought it came out of the deep ocean.

"But it has not been clear how the carbon actually got out of the ocean to cause the CO_2 rise."

Du, a doctoral student, said there is a circulation pattern in the Pacific that begins with water around Antarctica sinking and moving northward a few miles below the surface. It continues all the way to Alaska, where it rises, turns back southward, and flows back to Antarctica where it mixes back up to the sea surface.

It takes a long time for the water's round-trip journey in the abyss – almost 1,000 years, Du said. Along with the rest of the CEOAS team, Du found that flow slowed down during glacial maximums but sped up during deglaciation, as the Earth warmed. This faster flow flushed the carbon from the deep Pacific Ocean – "cleaning out Grandma's root cellar" – and brought the CO_2 to the surface near Antarctica. There it was released into the atmosphere.

"It happened roughly in two steps during the last deglaciation – an initial phase from 18,000 to 15,000 years ago, when CO_2 rose by about 50 parts per million, and a second pulse later added another 30 parts per million," Du said. That total is just a bit less than the amount CO_2 has risen since the industrial revolution. So, the ocean can be a powerful source of carbon.

"This finding that the deep circulation sped up is the smoking gun in this mystery story about how CO_2 got out of the deep sea," Mix said. "We now know how it happened, and the deep Pacific is the culprit – a partner in crime with Antarctica."

The concern, researchers say, is that it could happen again, potentially magnifying and accelerating human-caused climate change.

"We don't know that the circulation will speed up and bring that carbon to the surface, but it seems like a reasonable thing to think about," Du said. "Our evidence that this actually happened in the past will help the people who run climate models figure out whether it is a real risk for the future."

Scientists spend the winter in Antarctica to study juvenile krill diet and health

Oceanographer **Kim Bernard** and two of her students headed south for the winter. So far south that they packed anoraks and heavy boots, rather than shorts and snorkel gear.

Bernard and the students – **Kirsten Steinke**, a Ph.D. candidate; and **Julia Fontana**, an undergraduate senior who graduated in spring 2019 – spent the austral winter of 2019 in Antarctica, investigating how the winter diet of juvenile krill affects the health of this key species.

The biomass of Antarctic krill is estimated to exceed that of any multi-cellular animal species on Earth, including humans. But as Bernard and others are learning, climate change – in addition to rapidly increasing human harvest of krill for human nutrition, aquaculture feed and pet food – may change the equation.

With funding from the National Science Foundation (NSF), Bernard and the students, all with the College of Earth, Ocean, and Atmospheric Sciences, spent six months at Palmer Station – one of the U.S. Antarctic Program's three research stations. They were the only science team overwintering. The other 18 people at the station were all contracted support staff who maintain winter operations on behalf of the NSF.

Palmer Station is extremely remote – it takes at least four days to reach the station by ship, when it is accessible at all. Sometimes the station is completely inaccessible in the middle of winter because of sea ice. This is why Bernard and her all-women team had to pass a series of rigorous medical exams before being approved to go. And it's also why, once they arrived in mid-April, they were not able to leave until mid-October. "I think this is the closest I'll ever get to going into space," Bernard said.

"Our work focused specifically on juvenile krill, which have largely been neglected in the research," she said. "We know that adult krill can survive the winter on very little food and may feed on things other than algae in winter; they tend to be more carnivorous. They also tend to be less associated with sea ice."

But a recently published study of Bernard's found that "the presence of sea ice and the timing of its formation is related to the amount of algae found in the diet of juvenile krill, suggesting that ice algae is a key food source for juvenile krill during the winter."

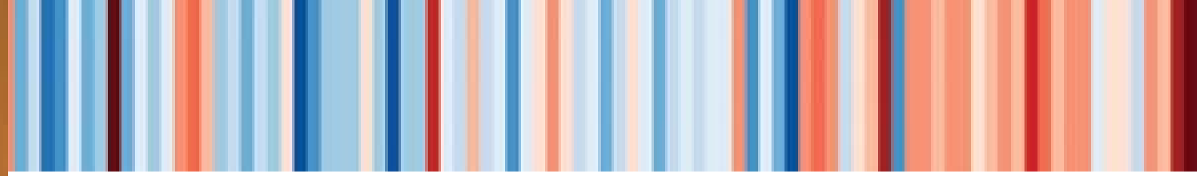
Warming occurring in this part of Antarctica is causing sea ice to form later in the winter, thus providing less ice algae for overwintering juvenile krill. Bernard said young krill may be forced to find alternative food in the winter, which may not be as nutritious as the ice algae.

This change may spell trouble for the rich Antarctic food webs that depend on krill. To learn more, follow Kim Bernard on Twitter and Instagram; her handle for both is @psycho_kriller.

Climate report:

Warming taking its toll on Oregon

Forest fire in the Rogue-Siskiyou NF, Oregon, 2018. Forest Service photo by Kari Greer



The Oregon Climate Change Research Institute (OCCRI) issued a 2019 report that indicates that the changing climate is having a significant impact on Oregon. The state is growing progressively warmer, experiencing more severe wildfires, and undergoing a shift of seasons resulting in less snowpack and lower summer stream flows. And the outlook for the future is not much better.

The year 2018 was much drier than normal, resulting in emergency drought declarations for 11 Oregon counties. A plethora of wildfires in the western United States in August of 2018 caused Portland and the Willamette Valley to experience some of the worst air quality on the planet. Ranchers in southern and eastern Oregon reported significant economic losses from the lack of water.

These results likely are the new norm and not anomalies, said authors of the Fourth Oregon Climate Assessment Report, a synthesis of peer-reviewed scientific studies published over the past two years.

Kathie Dello, former associate director of OCCRI, now director of the North Carolina State Climate Office and North Carolina State Climatologist at NC State, said the impacts from warming will affect Oregon in a variety of ways, with some regions experiencing greater effects than others.

“One of the most obvious impacts of climate change has been the surge in fires – even in normally wet forests, like the Eagle Creek fire in 2017,” Dello said. “The disruptions to local economic activity from fires have become almost routine, and regional air quality has suffered, leading to respiratory ailments.”

Above: Oregon’s “warming stripes” graphic depicts the average annual temperature for the state for 1895-2018 using data from the National Oceanic and Atmospheric Administration. Blue tones indicate cooler temperatures, and red tones indicate warmer temperatures. Explore more sets of warming stripes at showyourstripes.info.

The report includes several dire predictions about Oregon’s future climate outlook:

- Oregon is projected to warm by 4-9 degrees (F) by 2100, with the exact rise depending in part on whether global emissions follow the current path or can be curtailed.
- Annual precipitation is not projected to change significantly, but more will fall as rain instead of snow. Extreme precipitation events are likely to increase by 20% in eastern Oregon, with heavy rainfall potentially resulting in slope instability, landslides and transportation closures.
- The number of days with temperatures higher than 86 degrees in many Oregon locations – excluding the cooler mountains and the coast – is expected to increase by 30 days a year by mid-century.

“Efforts made now to proactively adapt to these changes could reduce further damages. But we need to get started now,” Dello said. “Proactive management can take many forms, such as creating resilient agro-ecosystems, building more robust water markets and managing forests while considering natural resources and wildfire prevention.”

Dello said reducing vulnerability for socio-economic groups most affected by climate change can include implementing policies meant to limit the public’s exposure to the impacts of fire and increasing temperatures.

“Building community capacity and leadership in frontline communities to participate in the processes where climate-related decisions are made is paramount,” she said. “And modernizing crucial infrastructure – including bridges, roads, buildings and culverts – may mitigate climate risk and build resilience into Oregon systems.”

To read the full report, go to www.occri.net/publications-and-reports/fourth-oregon-climate-assessment-report-2019/.

David Wrathall examines the illegal drug trade using satellites and computer models

Crews from the U.S. Coast Guard Cutter *Waesche* offload nearly 660 kilograms of narcotics, Feb. 2, 2015. U.S. Coast Guard photo by Chief Petty Officer Luke Pinneo

Since the Nixon Administration launched the war on drugs in 1971 and declared drug abuse to be "public enemy No. 1," the United States has spent an estimated $1 trillion on drug prevention and enforcement efforts.

That includes roughly $5 billion annually on cocaine interdiction, but that massive expenditure has had little effect on the drug's supply or its price, according to research conducted by geographer David Wrathall, of the College of Earth, Ocean, and Atmospheric Sciences, and his colleagues. Wrathall has been involved in a series of studies that use innovative geospatial tools and modeling to outline how efforts to curtail the flow of cocaine into the United States from South America have made drug trafficking operations more widespread and harder to eradicate.

Some of that work reveals that since the early 2000s, drug-trafficking organizations have been establishing drug transit hubs and money laundering operations in remote forested areas under the guise of land-intensive business ventures including cattle ranching. This is a new and significant driver of deforestation in Central America.

Drug trafficking affects conservation in other ways as well, Wrathall said. Environment ministries and park rangers have become the new front-line for drug enforcement, even at a time when they are understaffed, underfunded and ill-equipped. In this way, "The war on drugs is working directly at odds against the billions of dollars invested in conservation by donor countries, international conservation NGOs, advocacy groups and local communities," Wrathall said.

Another recent paper described the results of a computer model that successfully reproduced the "cat-and-mouse" dynamic between narco-traffickers and drug interdiction efforts. When interdiction efforts are focused in one location, drug traffickers simply relocate.

The findings from this research are important because after five decades, the United States' war on drugs has yet to prove itself effective or cost-efficient for dealing with cocaine trafficking, the researchers noted. These studies come at a time of increased attention on Central American migrants fleeing drug-related violence in their home countries.

"Between 1996 and 2017, the Western Hemisphere transit zone grew from 2 million to 7 million square miles, making it more difficult and costly for law enforcement to track and disrupt trafficking networks," Wrathall said. "But as trafficking spread, it triggered a host of smuggling-related collateral damages: violence, corruption, proliferation of weapons and extensive and rapid environmental destruction.

"Wholesale cocaine prices in the United States have actually dropped significantly since 1980, deaths from cocaine overdose are rising, and counterdrug forces intercept cocaine shipments at a low rate. More cocaine entered the United States in 2015 than in any other year," Wrathall said. "And one thing people who support interdiction and those who don't can agree on is that change is needed."

Wrathall's new ways of looking at the problem may help contribute to that change.

Snowball Earth: Massive ice sheets, meltwater and...mattresses?

For the past 2.6 million years (the Quaternary period), the Earth has bounced between two main climate states – glacial periods, commonly known as ice ages, when frigid temperatures trigger the spread of continental ice sheets; and interglacials, when the ice sheets retreat and give way to a milder climate, like what we enjoy today.

But what if there was a third state? One theory asserts that such a state evolved more than half a billion years ago, a frigid state lasting tens of millions of years and prompting a biological collapse more prolonged than when a meteorite wiped out the dinosaurs. Geologist **Jessica "JC" Creveling** at the College of Earth, Ocean, and Atmospheric Sciences has been studying the Snowball Earth hypothesis, which posits that our planet was once completely encased in ice. This cryogenic catastrophe would have killed off most early microscopic organisms and halted key biogeochemical cycles.

While our planet is currently cruising in the opposite direction of a Snowball Earth, Creveling said understanding the spectrum of Earth's climate state gives us a fuller picture of our history and the surprising tenacity of life.

"We are in no way concerned that we're heading towards a Snowball Earth event," Creveling said. "But this is an opportunity to ask: What is the most extreme glacial state that the Earth is capable of? From a geological perspective, it makes you realize the Earth is really good at recovering from all kinds of things."

Scientists first suspected the existence of a Snowball Earth when they discovered glacial debris at sea level in the tropics, meaning ice once happily existed at the planet's warm midriff. At that time, roughly 720-635 million years ago, continents clustered at the equator. The Snowball Earth hypothesis postulates that a complex series of global feedback mechanisms caused the planet to cool, and a runaway freeze eventually encased the planet in ice.

Of course, Earth did not stay a snowball forever. Volcanoes eventually spewed enough CO_2 into the atmosphere to warm the planet again. Rapidly melting ice sheets drove significant sea-level rise. Scientists can see evidence of this sea-level rise in deposits of marine carbonate rocks – typically found in warm, shallow seas – that formed immediately after the Snowball glacial succession.

But Creveling was puzzled by something. If water covered the world following Snowball ice melt, why aren't continents that were recently glaciated underwater today? Arctic Canada, for instance, was glaciated as recently as ~10,000-6,000 years ago, and yet is not submerged. In fact, GPS data reveal that Arctic Canada is actually rising, in essence rebounding after sloughing off the weight of an ice sheet that melted thousands of years ago.

"I always describe it as a mattress. You're sitting on a bed, you stand up, it comes right back up. The time scale is much bigger with continents. In this instance it's thousands of years, but the idea is the same," Creveling said.

Creveling began to wonder, what was different about the post-glacial rebound following Snowball Earth? "How do we reconcile getting sea-level rise everywhere during Snowball Earth with what we see today?" she wondered.

Because there is no GPS data to measure continental rebound from 635 million years ago, Creveling put together a numerical model to simulate the aftermath of Snowball Earth melt. The model revealed that the sheer volume of ice melting on every continent overwhelmed the rebound, in essence overcoming the "mattress bounce" of the continents.

"Let's think about North America with a Snowball ice sheet on it. North America's ice sheet would melt and contribute to sea-level rise. Even though it would want to rebound, every other continent was also melting. So, that global melt would totally overwhelm North America's rebound, and sea level would rise."

Creveling said the most revealing part of her model was further confirmation of the Snowball Earth hypothesis. The physics of rebounding continents couldn't have changed – just the conditions. She hopes to continue her research by visiting a site with geologic evidence of our former ice world and obtaining valuable observational data.

"One takeaway of this project is that the world is capable of wondrous and wacky things," said Creveling. "We've only observed a subset of those things."

Image credit: Kevin Gill under cc-by-2.0, via https://www.flickr.com/photos/kevinmgill/14326057397

Erin Pettit tracks glaciers on the move

There is a reason that we refer to slow events as moving at a "glacial" pace: glaciers usually change so gradually that their movement is not readily observable without repeat visits or cutting-edge imaging technologies.

While glacial change is slow, occurring over seasonal and longer time scales, it has a large effect on landscapes, ecosystems and people. "Glaciers provide water for human communities in many places," said glacier geophysicist **Erin Pettit** with the College of Earth, Ocean, and Atmospheric Sciences. She added that the cold streamflow provided by glacial melt in the Pacific Northwest is critical for many salmon populations. In addition to meltwater, another product of glacial breakup is icebergs, which can present hazards to ship navigation. Finally, on longer time scales, glaciers create landscapes, both by carving out valleys and simply by melting (Oregon's Willamette Valley, for example, is filled largely with sediment related to floods of glacial meltwater). When glaciers melt and disappear, areas of continental crust rebound – that is, they rise when the great weight of the glacier is lifted. Significant melt of glaciers, ice shelves and ice sheets can cause sea level to rise dramatically.

Given glaciers' impact on climate, ecosystems and human infrastructure, measuring their movement is paramount, albeit difficult. Pettit and her team use both high-tech and low-tech approaches. "We use time-lapse photography – we've been doing that forever. We sometimes do something as simple as sticking a stake in the glacier, recording its position with GPS, and then coming back the next year to see if the stake has moved. There's no reason to go with more complex technology if you can take a measurement with a simple approach," she explained.

Satellite technologies have been useful in her work as well. One of her students is examining changes in southeast Alaskan glaciers using data collected by the NASA satellite GRACE, which measures small changes in gravity. The more mass a mountain or glacier has, the larger force of gravity it exerts, and so monitoring gravity over time can reveal if a glacier has lost mass.

To look inside the glacier, Pettit is often opportunistic: She uses holes bored deep into the ice by other scientists who take ice cores for paleoclimate studies. The holes they leave behind offer Pettit a window into the heart of the glacier. For example, she and her students can look at physical deformation of the hole to see if all parts and layers of the glacier are moving at the same rate.

Pettit will take her glacial movement toolbox to a new setting in the coming year. The U.S. National Science Foundation and U.K. Natural Environment Research Council have partnered to undertake an intense study of Thwaites Glacier in western Antarctica. Like a cork in a bottle, this glacier holds back an immense ice sheet behind it, but the cork is disappearing. The International Thwaites Glacier Collaboration has funded nine projects there, and Pettit will serve as lead scientist for one. In 2020, she'll spend three months on the glacier examining how the ocean and atmosphere are affecting glacial thinning.

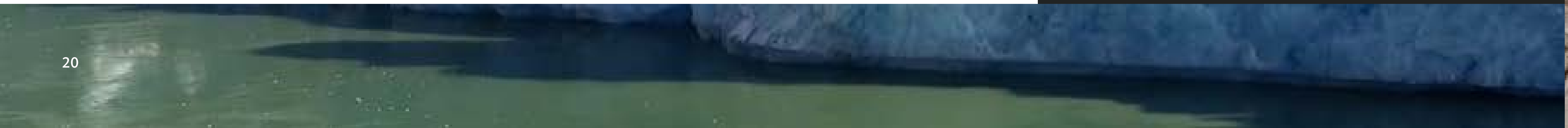
Pettit inspires the next generation with Inspiring Girls Expeditions

Erin Pettit didn't climb a glacier until college, but growing up in the Pacific Northwest, she did have a family that played in the great outdoors, providing her an introduction to camping, backpacking and hiking. These formative experiences gave her the skills and confidence she needed to become a field scientist who now organizes and conducts expeditions in some of the most challenging conditions on Earth.

But as a graduate student she knew that not every girl had access to these experiences, which might mean they would never consider a career in something like glaciology. To help fill that gap, she founded Girls on Ice, a summer program that takes high school girls on expeditions to scale glaciers and learn outdoor skills and field science in the Cascades, Alaska, Canada and Switzerland. Girls on Ice is now part of the more expansive Inspiring Girls Expeditions, which offers a range of other rugged wilderness experiences: Girls on Rock in Colorado's Rocky Mountains, Girls on Water in Kachemak Bay, Alaska, and more.

Pettit is interested in exploring new programs appropriate to Oregon: Girls in the Forest and Girls on Rivers might fit well, she thinks.

"This program can be life-changing for the students, and also for the instructors," who are all women, Pettit said. The program is free to participants. More information about the program can be found on the website, www.inspiringgirls.org.



Getting to know Cascades volcanoes can shed light on eruption risk

Photo courtesy of Dudley Chelton. Sunset view from Middle Sister. The mountains in the distance are (from left to right) Mt. Washington, Three-Fingered Jack, Mt. Jefferson, Mt. Hood and Mt. Adams. The big mountain in the foreground is North Sister.

Globally about 800 million people live within 100 kilometers of a threatening volcano. Those living in the U.S. Pacific Northwest are particularly cozy with their potentially eruptive neighbors. Of the 18 U.S. volcanoes rated by the U.S. Geological Survey as a "very high threat," the highest threat level the agency issues, 10 are in the Cascade Range. Knowing more about these volcanoes – Mount St. Helens, Mount Rainier, Mount Hood and their siblings – can only be a good thing.

The string of volcanoes in the Cascades Arc, ranging from California's Mount Lassen in the south to Washington's Mount Baker in the north, have been studied by geologists and volcanologists for over a century. Spurred by spectacular events such as the eruption of Mount St. Helens in 1980, scientists have studied most of the Cascade volcanoes in detail, seeking to work out where the magma that erupts comes from and what future eruptions might look like.

However, mysteries still remain about why nearby volcanoes often have radically different histories of eruption or erupt different types of magma. Now scientists would like to find out why – both for the Cascades and for other volcanic ranges.

In an essay published in the journal Nature Communications, geologist **Adam Kent**, with the College of Earth, Ocean, and Atmospheric Sciences, and others argued for more "synthesis" research looking at volcanology's big picture to complement myriad research efforts looking at single volcanoes. There are significant differences among volcanoes, Kent noted, even in the north and south of the Cascade Range.

"The volcanoes in the north stand out because they stand alone," Kent said. "In the south, you also have recognizable peaks like the Three Sisters and Mount Jefferson, but you also have many thousands of smaller volcanoes like Lava Butte and those in the McKenzie Pass area in between. Our work suggests that, together with the larger volcanoes, these small centers require almost twice the amount of magma being input into the crust in the southern part of the Cascade Range."

Why is that important? Kent explained that the past is the best informer of the future.

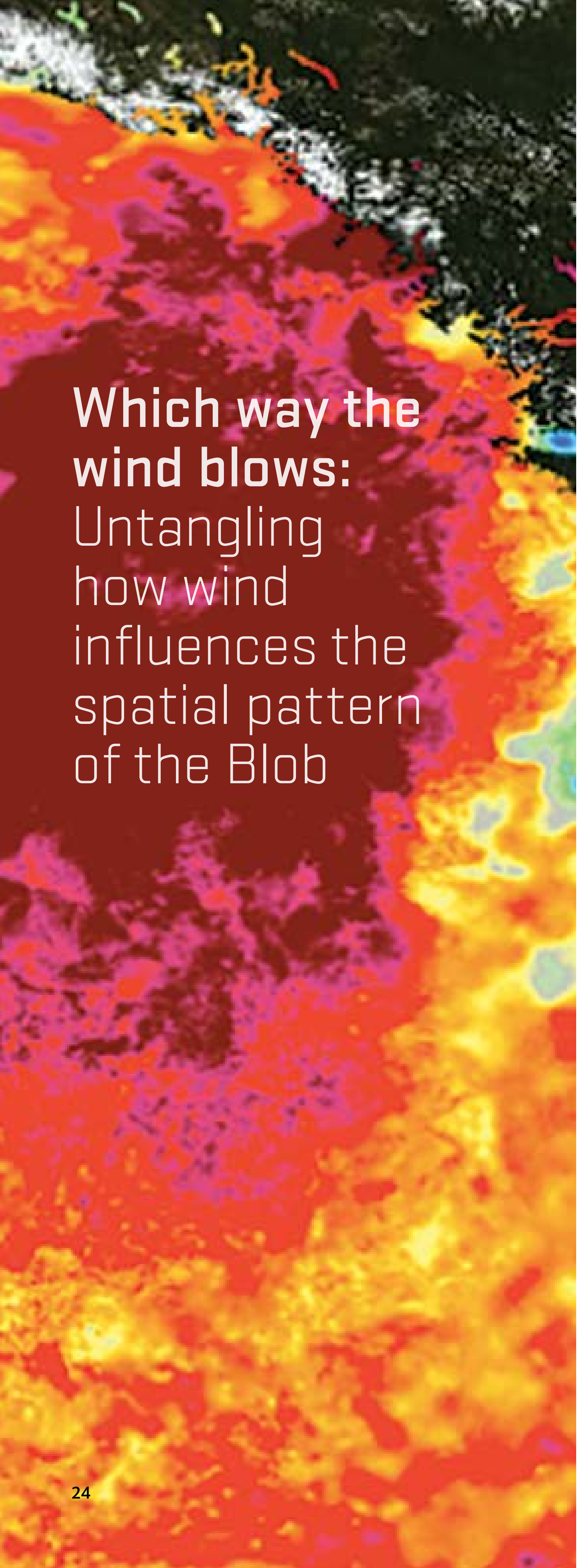
"If you look at the geology of a volcano, you can tell what kind of eruption is most likely to happen," Kent said. "Mount Hood, for example, is known to have had quite small eruptions in the past, and the impact of these is mostly quite local. Crater Lake, on the other hand, spread ash across much of the contiguous United States.

"What we would like to know is why one volcano turns out to be a Mount Hood while another develops into a Crater Lake, with a very different history of eruptions. This requires us to think about the data that we have in new ways."

The 1980 eruption of Mount St. Helens was a wake-up call to the threat of volcanoes in the continental United States, and though noteworthy, its eruption was relatively minor. The amount of magma involved in the eruption was estimated to be 1 km cubed (enough to fill about 400,000 Olympic swimming pools), whereas the eruption of Mount Mazama 6,000 years ago that created Crater Lake was 50 km cubed, or 50 times as great.

Which of the Cascades is most likely to erupt? The smart money is on Mount St. Helens, because of its recent activity, but many of the volcanoes are still considered active. "I can tell you unequivocally that Mount Hood will erupt in the future," Kent said. "I just can't tell you when."

For the record, Kent said the odds of Mount Hood erupting in the next 30 to 50 years are less than 5%.



Which way the wind blows: Untangling how wind influences the spatial pattern of the Blob

In 2014, something strange occurred in the north Pacific Ocean. A tropical species of tuna was spotted in Alaskan waters. Central American birds arrived unexpectedly in California. Starving sea lion pups washed ashore on California's beaches. Scientists suspected these incidents were linked to the unusually warm water that had appeared in the northeastern Pacific. This marine heat wave, informally known as the Blob, lingered until 2016, disrupting coastal upwelling that normally brings nutrients to the surface and fuels ocean life. Similar warm water episodes also occurred in 2018.

When this marine heat wave may recur is unclear. But scientists are closer to understanding where it will appear. Associate Professor **Melanie Fewings**, with the College of Earth, Ocean, and Atmospheric Sciences, has been examining whether and how wind has influenced the spatial pattern of the Blob. She suspected a relationship when she noticed that the pattern of the winds and marine heat wave shared some similarities.

First, both exhibited a split structure. California's coastline shape, specifically its signature eastward bend at Cape Mendocino, causes what Fewings calls a wind dipole that splits the winds into two parts. When winds along the northern part of the coastline weaken, the southern half often experiences stronger winds, and vice versa. These alternating wind intensifications and relaxations typically last between two and five days. Interestingly, about mid-way through 2015, the marine heat wave also split into two parts, one in the Gulf of Alaska and one south of the Oregon-California border.

The marine heat wave and the wind pattern shared another peculiar parallel. The abnormal heat off central California was shaped like a triangle, which was very similar to the shape of the southern half of the wind dipole.

Could the wind pattern have influenced the pattern of the marine heat wave?

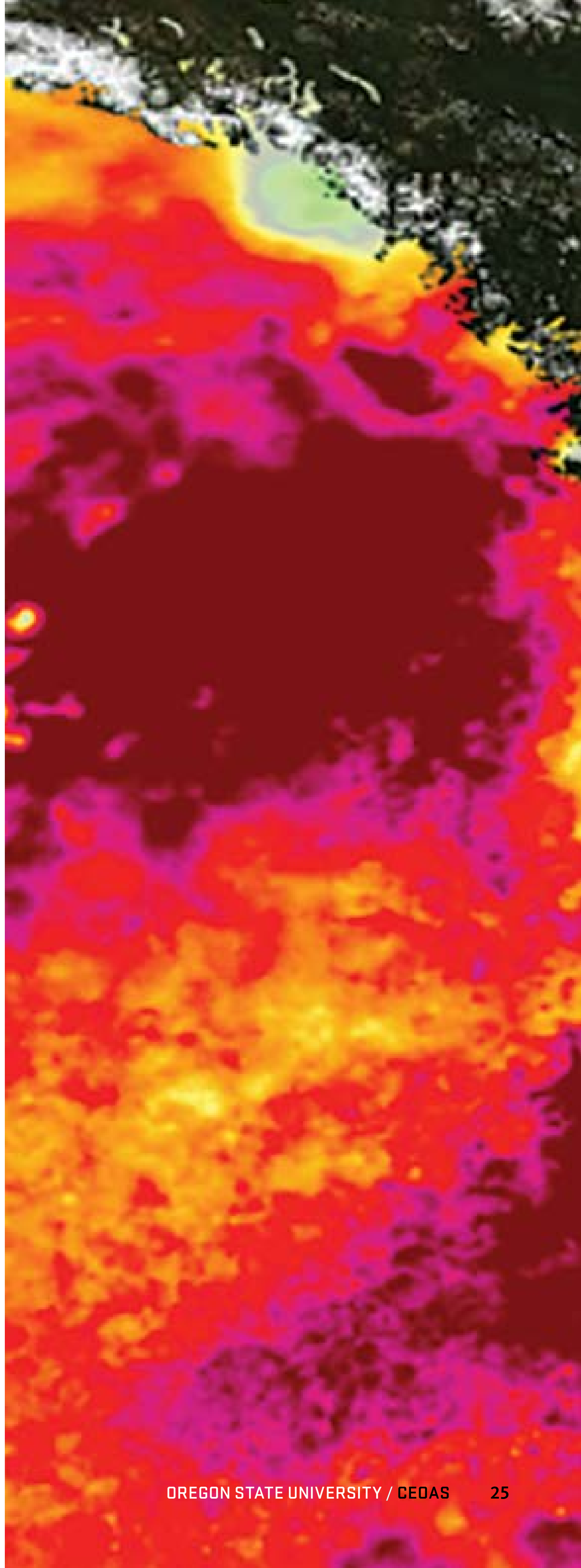
To find out, Fewings examined satellite data, which showed that winds off California were weakened for a two-week period immediately preceding the marine heat wave split, a period much longer than the two to five days of weakened winds seen in a typical year. Fewings hypothesized that this extended relaxed wind pattern explained the marine heat wave's split structure. Her group's case study of the event supports this idea, underscoring the importance of examining winds and temperature simultaneously.

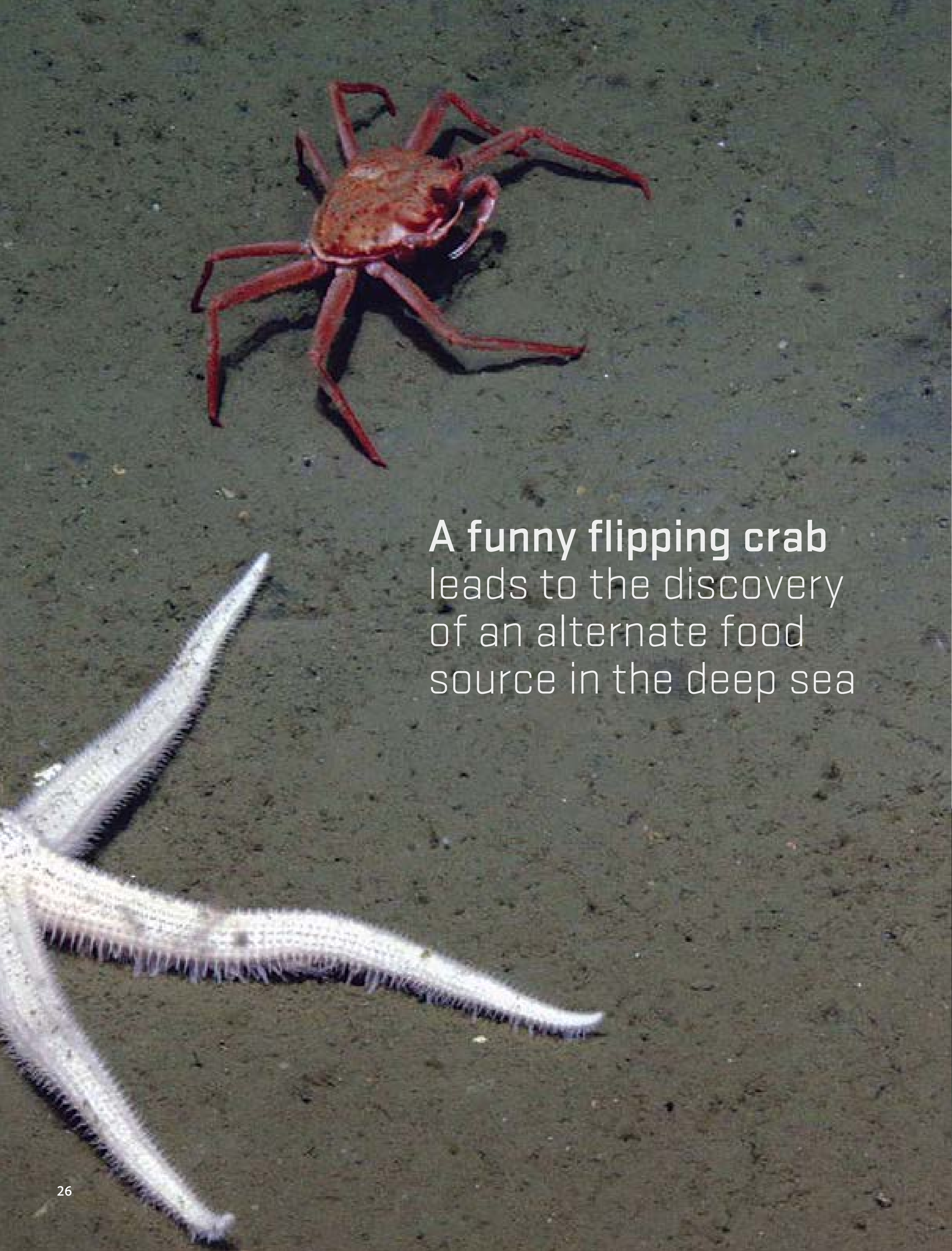
Fewings was able to further investigate wind as a major influence on the marine heat wave by calculating a heat budget for the surface ocean off the western continental U.S. She says to think of the upper ocean like a bank account for heat. Evaporation, sunshine and other sources of heat flux either add or take away from the balance. By looking at the transactions immediately preceding the marine heat wave split, Fewings and her collaborators discovered an imbalance.

"We looked at the deposits and withdrawals of heat by the air-sea interactions accumulated over the two weeks prior to the marine heat wave split. That's when we saw there had been mysterious activity, a balance you can't account for with the most obvious culprits," she said. "What we've shown for this region is that the exchange of heat between the ocean and atmosphere, including changes in sunshine, were making nearly their normal contributions to the budget, and yet we still had all this extra heat. Where did it come from?"

The next obvious culprit in her heat budget investigation was ocean currents, but currents alone could not explain the abnormal warming. This left only changes in wind and associated vertical mixing of cold water as a possible explanation. The unusually long relaxed wind apparently brought less cold water to the surface from the deeper ocean, allowing the warm water to accumulate off California. "The persistently relaxed wind was like saving a little bit every day for an extended length of time. Eventually you're going to build up a large extra amount," she explained.

Fewings' research will help coastal managers and scientists anticipate where the warm water may appear in the future. She and her collaborators are already beginning to examine the connection between winds and sea surface temperatures in other eastern ocean boundary upwelling systems, including Chile-Peru and Benguela. And because marine heat waves are becoming more common globally, predicting their spatial expression will be key to understanding their impacts – both to our economy and to our ecosystem.





A funny flipping crab leads to the discovery of an alternate food source in the deep sea

Back in 2012, deep-sea researchers at the College of Earth, Ocean, and Atmospheric Sciences and their colleagues on a research expedition were amused by some video footage they took of a tanner crab on Clayoquot Slope off the coast of British Columbia.

Marine ecologist **Andrew Thurber** was one of the scientists on the cruise. "A crab was getting lifted off the seafloor by methane building up in an ice-like form on its chest before the methane floated away and dropped the crab on its head," he explained.

The footage of the flipping crab was comical, but also informative. The researchers realized that crabs were actually feeding at a methane seep on the seafloor, consuming materials within and around bacterial mats that had formed near the seep. This is one of the first observations of a commercially harvested species using methane as an energy source.

There are many implications, the researchers say, and surprisingly most of them are good. The discovery actually may mean that methane seeps could provide some seafloor-dwelling species an important hedge against climate change – because nearly all models predict less food will sink into the deep sea in coming years.

"The thinking used to be that the marine food web relied almost solely on phytoplankton dropping down through the water column and fertilizing the depths," Thurber said. "Now we know that this viewpoint isn't complete, and there may be many more facets to it.

"Tanner crabs likely are not the only species to get energy from methane seeps, which really haven't been studied all that much. We used to think there were, maybe, five of them off the Pacific Northwest coast, and now research is showing that there are at least 1,500 seep sites – and probably a lot more.

"Methane may be a very important and underappreciated energy source for marine organisms," Thurber added.

Another dense aggregation of crabs was seen feeding on a diversity of microbes that derive energy from methane in 2014 around the nearby Barkley Canyon seep, suggesting that the crabs may be using the seep as a source of "trophic support," noted study lead author **Sarah Seabrook**, a CEOAS Ph.D. candidate.

"Using novel methods, we found chemical evidence of methane tracers in their guts, and biogeochemical evidence in the animals' tissues," she said.

Seabrook and Thurber's findings raise questions about whether the use of methane seeps as a food source is more widespread than just tanner crabs.

Thurber said Oregon, Washington and California are all beginning to include the distribution and importance of methane seeps in management decisions off their respective coasts. This work can help inform decisions by providing a previously undocumented link between harvested species and the energy released at methane seeps.

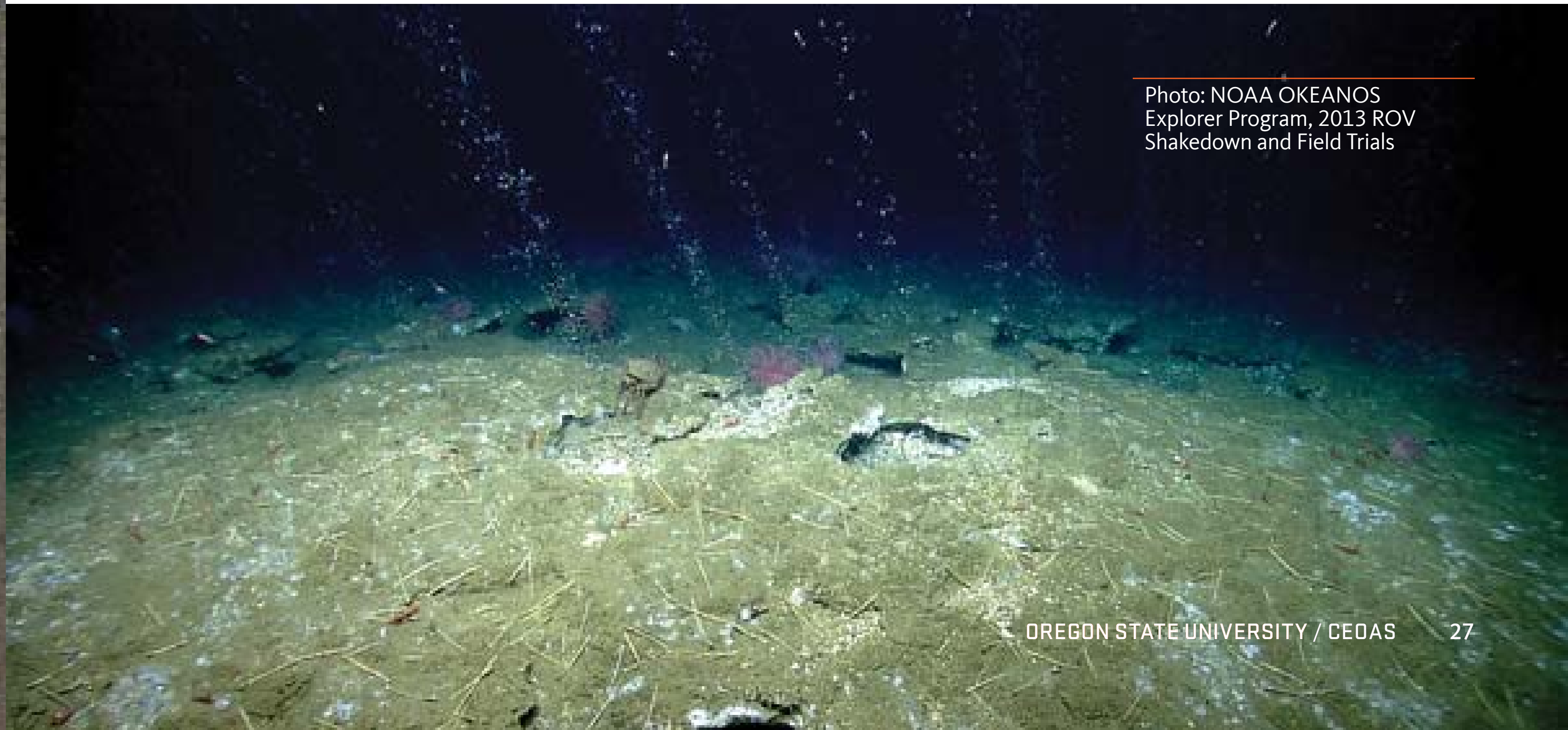


Photo: NOAA OKEANOS Explorer Program, 2013 ROV Shakedown and Field Trials

Ancient community of undersea microbes may resemble early life on Earth and on other planets

Far beneath the surface of the northeast Pacific Ocean – and nearly a quarter-mile below the seafloor – lives a community of hydrogen-consuming microbes that scientists say are like those found on ancient Earth.

Buried deep within rock, these primitive microbes provide a glimpse into the history of our own planet, according to researchers in the College of Earth, Ocean, and Atmospheric Sciences.

They also may embody the type of life-sustaining metabolism most likely to exist on other planets that contain water and volcanic rock.

In a recent study, the scientists described how this community of microbial organisms survives using an ancient metabolic pathway for energy generation and carbon fixation.

"We went into the study expecting to find one kind of microbe, and we found others – similar, but a more ancient lineage dependent upon hydrogen," said lead author **Amy Smith**, who conducted much of the research as a doctoral student at Oregon State University.

"Most microbial lineages have metabolisms that have evolved over time, but these are some of the earliest, most primitive ones around," said Smith, who now is a post-doctoral researcher at Woods Hole Oceanographic Institution.

Gaining access to the microbes was a Herculean task. The study site is on the east flank of the Juan de Fuca Ridge, about 190 kilometers off the coast of Washington's Olympic Peninsula, and some 2.6 km below the ocean surface. Technicians with the International Ocean Discovery Program drilled a borehole through 260 m of ocean sediment, and another 90 m of basalt rock.

The researchers put microbial mineral "traps" into the borehole – PVC plastic chambers with small holes connected to a pump to suck water through the mineral chambers. They retrieved the traps four years later and found at least 11 different species of primitive microbes colonizing the minerals.

Amy Smith, lead author of the study, sampling bacteria aboard the E/V *Nautilus*. Image courtesy of Ocean Exploration Trust/Nautilus Live

"These microbes live in an environment without any oxygen, and they probably first arose back when Earth had little or no oxygen before photosynthesis ever took place," said **Martin Fisk**, a CEOAS marine geologist and co-author of the study. "Instead of feasting on organic carbon, they make a living by consuming hydrogen made in chemical reactions in the absence of life deep in subsurface rock.

"All you need is some water over volcanic rock and you have an environment much like Earth about 4 billion years ago – and likely on billions of planets in space."

The research not only has implications for life on other planets, it casts a new light on our own ocean system.

"We are biased as humans to the rich life at the surface of the Earth and its oceans, but there is an entire world of life deep within the Earth that moves at a much slower pace – consistent with deep Earth processes that also move at a much different pace," said **Frederick "Rick" Colwell**, a CEOAS microbiologist and co-author on the study.

Meet our new faculty

Christo Buizert, previously an assistant professor (senior research) with CEOAS, has now been appointed assistant professor of polar paleoclimatology. He earned a Ph.D. in geophysics from the University of Copenhagen, Denmark and has an applied physics degree from the Delft University of Technology, Netherlands. Buizert's research centers on climate change and climate dynamics of the Quaternary period, with a focus on Earth's polar regions.

Maria Kavanaugh previously served the college as an assistant professor (senior research), and has now been appointed a tenure-track assistant professor in ocean ecology and biogeochemistry; she will have expanded teaching responsibilities to assist with CEOAS' growing undergraduate oceanography program. Kavanaugh earned her Ph.D. in biological oceanography from Oregon State University. Her current research involves synthesizing Earth/ocean observations to classify four-dimensional seascapes, quantify habitat-species relationships and monitor characteristic biodiversity in open ocean and coastal environments.

Brodie Pearson has been appointed as an assistant professor of physics of oceans and atmospheres with a focus on computational physical oceanography. His research interests include numerical modeling, turbulence and geophysical fluid dynamics, and he eagerly anticipates collaborations that focus on physical oceanography and sea-ice processes. Pearson holds a Ph.D. in atmospheric, oceanic, and climate science from the University of Reading (UK), and he comes to OSU from his position as a visiting assistant professor with Brown University.

Erin Pettit, previously an assistant professor at the University of Alaska Fairbanks, has been appointed associate professor. Pettit is a glacier geophysicist whose research focuses on the impacts, both local and global, of changing snow and ice. She specifically studies the dynamics of glaciers and ice sheets and their response to changing environmental conditions, primarily through large interdisciplinary field campaigns in Antarctica, Greenland, Alaska and the Cascade Range. She received her Ph.D. in geophysics from University of Washington.

Pamela Sullivan has been appointed associate professor of hydrogeology. Sullivan earned a Ph.D. in geosciences from Florida International University and was previously an assistant professor of geography and atmospheric science with the University of Kansas. A highly interdisciplinary ecohydrologist, she examines the interactions among climate, vegetation and geology within freshwater systems.

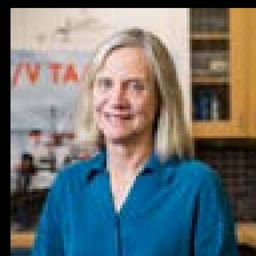
Maureen Walczak, formerly a CEOAS postdoctoral associate, has been appointed assistant professor (senior research). She earned her Ph.D. in oceanography from Oregon State University and was an ARC Super Science Fellow Postdoctoral Scholar at the Australian National University. Her research focuses on reconstruction of properties of past ocean environments using marine sediment cores. Walczak is also the lead scientist for OSU's Marine Sediment Sampling (MARSSAM) Facility, a unique coring and dredging facility funded by the National Science Foundation.

Faculty awards

Ed Brook
Professor
European Geosciences Union Hans Oeschger Medal

David Noone
Professor
American Geophysical Union Atmospheric Sciences Ascent Award

Jessica (JC) Creveling
Assistant Professor
Geological Society of America Donath Medal



Clare Reimers
Professor
Oregon State University Distinguished Professor

Fellow of The Oceanography Society

Rob Holman
Professor Emeritus
Fellow of The Oceanography Society

Roger Samelson
Professor
Fellow of The Oceanography Society

Alan Mix
Professor
Fellow of The Explorers Club

Professor Clare Reimers has had a very good year indeed. Two of the three state-of-the-art research vessels designed by CEOAS' Regional Class Research Vessel project, for which she is the project scientist, are under construction in Louisiana. Funding for the third received Congressional approval. And she was honored with two high-profile awards.

In March 2019, Reimers, an internationally renowned marine biogeochemist, was named an Oregon State University Distinguished Professor, the highest honor the university bestows. In May 2019, she was designated a Fellow of The Oceanography Society. This award recognized her groundbreaking research, as well as her dedication to training the next generation of ocean scientists, including her participation in the UNOLS-chief scientist training cruises for early career scientists.

Student awards

Nora Boylan, M.S. student, advised by Michael Campana: Washington Hydrogeology Seminar 2019 Nadine L. Romero Graduate Student Scholarship

Adrienne Chan, M.S. student, advised by Clare Reimers: NSF Graduate Research Fellowship

Jianghui Du, Ph.D. student, advised by Alan Mix: American Geophysical Union Harry Elderfield Student Paper Award

Cedric Hagen, Ph.D. student, advised by Jessica Creveling: NSF Graduate Research Fellowship

Brianna Haugen, M.S. student, advised by Flaxen Conway: 11th International Conference on Climate Change: Impacts and Responses, Emerging Scholar Award

Katlyn Haven, M.S. student, advised by Lorenzo Ciannelli: Alaska Sea Grant Marine Resources Fellowship

Meghan King, M.S. student, advised by Jessica Creveling: Geological Society of America (GSA) student research grant

Ellen Lamont, Ph.D. student, advised by Andrew Meigs: Oregon Sylff Graduate Fellowship and GSA AGeS2 grant

Kelsey Lane, M.S. student, advised by Jennifer Fehrenbacher: NSF Graduate Research Fellowship to continue on her Ph.D.

Jordan Lubbers, Ph.D. student, advised by Adam Kent: GSA Student Lipman Research Award

Pichawut Manopkawee, Ph.D. student, advised by Adam Kent: GSA Student Research Grant

Emily Mazur, M.S. student, advised by Shelby Walker: National Academy of Sciences Gulf Research Program Science Policy Fellowship

Keiko Nomura, M.S. student, advised by James Watson: Honorable Mention, NSF Graduate Research Fellowship

Erin Peck, Ph.D. student, advised by Rob Wheatcroft: Oregon Sea Grant Robert E. Malouf Marine Studies Scholarship; Runner-up, Student Poster Award, State of the Coast Conference; GSA AGeS2 grant

Alexander C. Smith, Ph.D. student, advised by Jamon Van Den Hoek: Fulbright-Hays Doctoral Dissertation Research Abroad Award

Marie Takach, Ph.D. student, advised by Frank Tepley: GSA Student Lipman Research Award and Mineralogical Society of America Grant for Student Research in Mineralogy and Petrology

Kellie Wall, Ph.D. student, advised by Anita Grunder: American Association of Petroleum Geologists Grants-in-Aid Harry and Joy Jamison Named Grant