College of Earth, Ocean, and Atmospheric Sciences

RESEARCH HIGHLIGHTS 2018

CAN WAVES POWER THE WORLD?

Oregon State University

Editors
Nancy Steinberg
Abby Metzger

Graphic Designer
Crystal Barnes

Contributing Writers
Mark Floyd
Abby Metzger
Nancy Steinberg
Tiffany Woods

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.

Contacts

College of Earth, Ocean, and Atmospheric Sciences
Oregon State University
104 CEOAS Admin Building
Corvallis, OR 97331-5503
541-737-3504

Roberta Marinelli, Dean

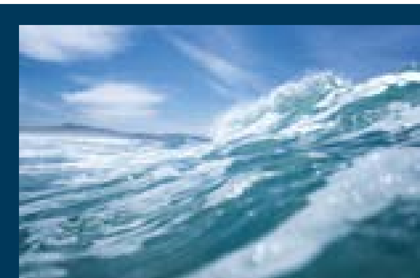
Eric Kirby, Associate Dean for Academic Programs

Philip Mote, Associate Dean for Strategic Initiatives

Tuba Özkan-Haller, Associate Dean for Research and Faculty Advancement

Amy Crumley, Director of Development
amy.crumley@osufoundation.org

On the Cover:
Oregon State University alumna Kelsea De Filippis (Graphic Design, 2017) knows first-hand the power of waves, as she is an avid Oregon surfer and surf instructor. She captured the force and beauty of Oregon's coastal ocean in her stunning cover image, taken during a surf session. De Filippis is currently an intern in the creative services division of Keen footwear in Portland. Her photography can be viewed at www.kelseadphotography.com.



MESSAGE FROM THE DEAN

Over the past year, Oregon State University celebrated its 150th anniversary as the state's land grant university. At the College of Earth, Ocean, and Atmospheric Sciences, we also honored decades of scientific innovation and transformation. We celebrated the 40-year anniversary of discovering hydrothermal vents and the unusual organisms and ecosystems around them. It was a startling find by OSU scientists that upended our understanding of life on Earth and propelled deeper inquiry into possible life on other planets. We reflected upon our proud tradition of inclusive excellence, noting that more than 50 years ago, OSU hired Dr. June Pattullo, the first woman in the nation to receive her Ph.D. in physical oceanography. In a time of constrained research funding, we undertook renovations to create a new repository for sediment cores and other marine geology samples from the world's oceans, including the Southern Ocean around Antarctica. Our faculty, graduate students and undergraduates continue to travel the world – by land, sea and air. They explore, discover and enable the next generation of scholars, policy makers and informed citizens to further understand and steward our changing planet. We are on the move! As dean, I am honored and inspired to be part of an institution with such an extraordinary legacy and future promise.

This fall, we will unveil a new strategic plan to lay the groundwork for continued excellence. The plan will elevate our already-strong programs in oceanography and geology, and intensify alliances among our climate, geography and geographic information science programs. Our renewed commitment to academic excellence includes more intentional, accessible and impactful experiential learning opportunities, and a greater effort to foster a diverse and welcoming community of students and scholars.

Rear Admiral Grace Hopper, an accomplished computer scientist, often said, "A ship in port is safe, but that's not what ships are for." As you will see in this snapshot of our many research achievements over the past year, this spirit of curiosity and adventure guides our pursuit of excellence. We look forward to a future of greater knowledge and awareness of our changing world, and bringing knowledge and awareness to action – and to you.

CEOAS DIVES INTO WAVE ENERGY

PacWave
TESTING WAVE ENERGY FOR THE FUTURE

PacWave is seeking partnerships and investment from corporations, foundations and individuals to realize its full potential. Contact Doug Brusa, director of development, to discuss supporting or partnering with PacWave: doug.brusa@osufoundation.org or 541-207-8686.

The vast store of energy in ocean waves, already familiar to surfers and fishermen, may one day contribute power to the U.S. grid. But before the swell can reliably light our lamps, devices that capture the ocean's energy must be developed and tested. A premier place to conduct these analyses is in the energetic environment of the Oregon continental shelf.

Oregon State University has received a $35 million grant from the U.S. Department of Energy to build a wave energy test facility located off the Oregon Coast, between Newport and Waldport. The project, called PacWave, will offer pre-permitted, grid-connected wave energy testing – providing a one-stop shop for companies developing this innovative technology.

PacWave's pre-permitted site offers multiple advantages. The regulatory process is done in advance of construction and applicable to all wave energy device types expected at the site for testing – saving potentially millions of dollars and allowing optimization of designs more rapidly. The facility will be able to test up to 20 wave energy converters in four berths, with a maximum power output of up to 20 MW. Each berth will have a dedicated, 5 MW-capable power and data transmission cable connection to an onshore grid-connection station.

The College of Earth, Ocean, and Atmospheric Sciences will provide administrative and project management support for PacWave. CEOAS has a strong reputation for launching and supporting large infrastructure projects, including the Ocean Observatories Initiative and design and construction of the next class of regional research vessels. The college will build upon its existing partnerships with coastal communities to support the mission of the test facility and advance carbon-free energy technology.

Burke Hales, CEOAS faculty member and principal investigator of PacWave, said the Oregon Coast offers several advantages for such a facility. "We have access to one of the most consistently energetic wave environments in the world, with proximity to a highly capable port and concentration of oceanographic and engineering expertise. CEOAS and OSU are eager to apply this expertise to developing a first-of-its-kind facility in the United States."

The project is currently in the design and permitting phase of development, with construction to follow. PacWave is anticipated to be operational in 2021.

CLIMATE

METHANE MYSTERY: NO SPIKE DURING ANCIENT PERIOD OF CLIMATE CHANGE

Ed Brook

Methane is less abundant than carbon dioxide in the Earth's atmosphere but is a more potent greenhouse gas, causing four times as much warming over the course of a century. Accordingly, spikes in the atmospheric concentration of methane could have significant consequences for Earth's climate. The scientific community has long been concerned that continued climate warming could promote the release of large amounts of methane from known methane reservoirs such as the Arctic tundra, and marine hydrate deposits, letting a very dangerous cat out of the bag.

As with many other climate-related questions, knowledge of the drivers of climate change in the Earth's past provides insight into our present and future climate. CEOAS scientists have recently discovered that the last Ice Age transition to a warmer climate some 11,500 years ago did not include a massive methane flux from marine sediments or the tundra. Instead, the likely source of rising levels of atmospheric methane at that time was from tropical wetlands.

While this certainly is good news, the study also points at a larger role of humans in the recent methane rise, CEOAS paleoclimatologist **Edward Brook** noted.

"Our findings show that natural geologic emissions of methane – for example, leakage from oil seeps or gas deposits in the ground – are much smaller than previously thought," Brook said. "That means that a greater percentage of the methane in the atmosphere today is due to human activities, including oil drilling, and the extraction and transport of natural gas."

The new study sheds light on the issue by analyzing methane in air bubbles that have been trapped in pristine ice cores from Antarctica's Taylor Glacier. Brook and colleagues measured levels of radiocarbon (a naturally occurring radioactive element) in atmospheric methane in the ancient air.

Ed Brook named Distinguished Professor

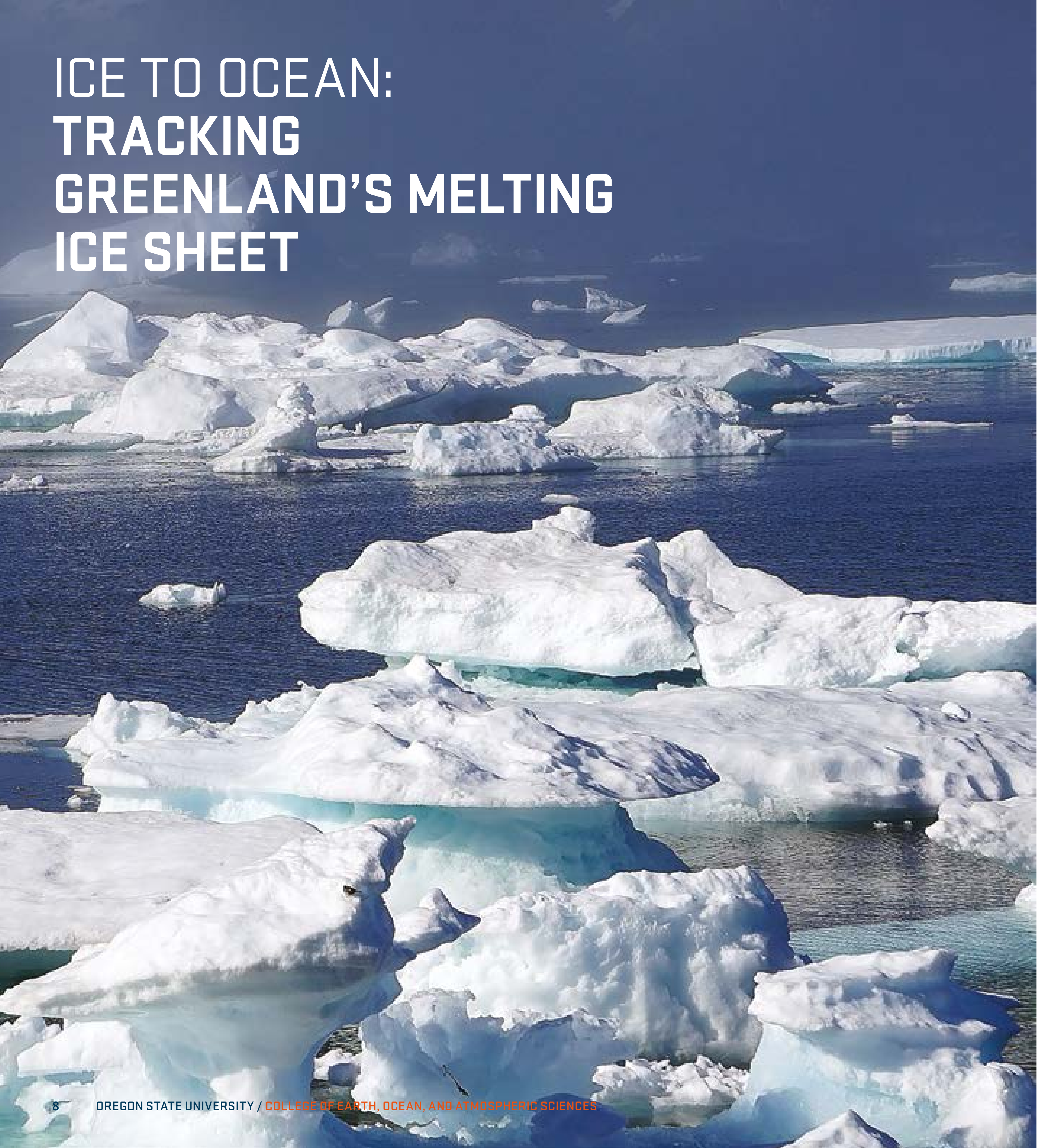
Oregon State University named Edward Brook as one of its 2018 Distinguished Professor recipients, the highest academic honor the university can bestow on a faculty member. Brook, who arrived at Oregon State in 2004, is one of the most recognized and highly regarded paleoclimatologists in the world. He is internationally known for the development of geochemical measurement techniques, and the insights they convey about the Earth's past. During his time in the College of Earth, Ocean, and Atmospheric Sciences, he created the Oregon State ice core laboratory, which has unique capabilities to measure greenhouse and other gases in small samples of air trapped in polar ice.

"A lot of people have painted the Arctic as a methane time bomb," Brook said, "but this shows that it may be more stable than we thought. Past performance isn't always a predictor of the future, but it is a good analog. We should be more concerned about anthropogenic sources of methane into the atmosphere, which continue to increase."

Their analysis of the ice cores suggests that the increase in methane during the last deglaciation had another source – likely from tropical wetlands, said **Christo Buizert**, a CEOAS researcher and co-author on the paper.

"Methane is not stored in the tropics for long periods of time, but produced every day by microbial activity in wetlands," Buizert said. "We know from other studies that rainfall increased in the tropics during the last warming period, and that likely created more wetlands that produced the additional methane."

ICE TO OCEAN: TRACKING GREENLAND'S MELTING ICE SHEET



The enormous ice sheet that covers much of Greenland is getting smaller, shedding previously land-based ice into the ocean. This additional volume of water is expected to drive sea-level rise over the coming decades, so understanding how sensitive Greenland's glaciers are to global warming is critical. CEOAS faculty members **Anders Carlson** and **Christo Buizert** are on the case.

They are part of an international collaboration that has discovered that the ribbon of ice more than 600 kilometers long that drains about 12 percent of the Greenland Ice Sheet has been smaller than it is today about half of the time over the past 45,000 years.

Interestingly, the loss of ice from the Northeast Greenland Ice Stream (NEGIS) took place not only during the warm Holocene period (the last 11,700 years of Earth's geological history), but also during the last Ice Age, thought to be very cold, the researchers say.

The findings suggest that NEGIS is particularly sensitive to environmental changes, which may amplify the influence of human-caused climate change. "There are some parts of the ice sheet that are relatively stable and others that show evidence of very rapid retreating – a pattern we're seeing today as well as thousands of years ago," said Carlson.

He said a variety of factors may help explain the ice mass loss, including warm summer temperatures and changes in the tilt of the Earth's axis and shape of its orbit. The tilt of Earth's axis was greatest around 10,000 years ago, exposing the Greenland Ice Sheet to warmer summers and breaking the planet out of the last Ice Age. In response, NEGIS showed significant ice loss.

Yet the ice sheet also diminished during the period preceding that maximum, about 41,000 to 26,000 years ago, which is thought to have been very cold. Buizert reconstructed air temperatures from that period using ice core analysis and found that while annual average temperatures indeed were much colder than today, summer temperatures (when ice melts) were not much colder.

"That period was also quite dry, and there wasn't nearly as much snowfall," Carlson said, "which may have driven the ice margin to be smaller."

The researchers were able to determine where the ice sheet margins were essentially by analyzing nearby rocks for "sunburn," Carlson said. When ice has retreated, the rocks become exposed to cosmic rays that hit the quartz in the rock and split the elements, creating beryllium-10. This cosmic bombardment leaves an elemental fingerprint that allows the researchers to reconstruct ice-free times over thousands of years.

"The anthropogenic forcing we are seeing today is having a significant impact on the ice sheet, and it already has retreated to levels that weren't predicted to occur until the end of the century," Carlson said.

EARTH

MEASURING MICROBES TO GAUGE RIVER FLOW

Byron Crump

A new study has provided a groundbreaking way to predict the flow rate of Arctic rivers with a surprising degree of accuracy based on the makeup and abundance of bacteria in the water.

The successful "genohydrology" approach is important because many Arctic rivers are remote and quite rugged, making deployment of flow meters to measure the water dangerous and expensive. The investigators also believe their model has the potential for adaptation to remote rivers around the world.

Byron Crump, a CEOAS ecologist and biogeochemist and co-author of the study, explained: "There is a seasonality to the microbial communities in these rivers, and as the rivers rise and fall with the seasons, that microbial profile changes. These rivers may share some of the same taxa, or types of bacteria, but abundance of the taxa is different and changes with the flow."

The researchers focused on six Arctic rivers – the Kolyma, Lena, Mackenzie, Ob, Yenisey and Yukon – and collected water samples from the river mouths. After extracting bacterial DNA from the samples, they broke down the genetic code and isolated a segment called the 16S rRNA gene. The segment is found in all bacteria, the scientists say, but contains variations that can be used to identify different bacterial strains.

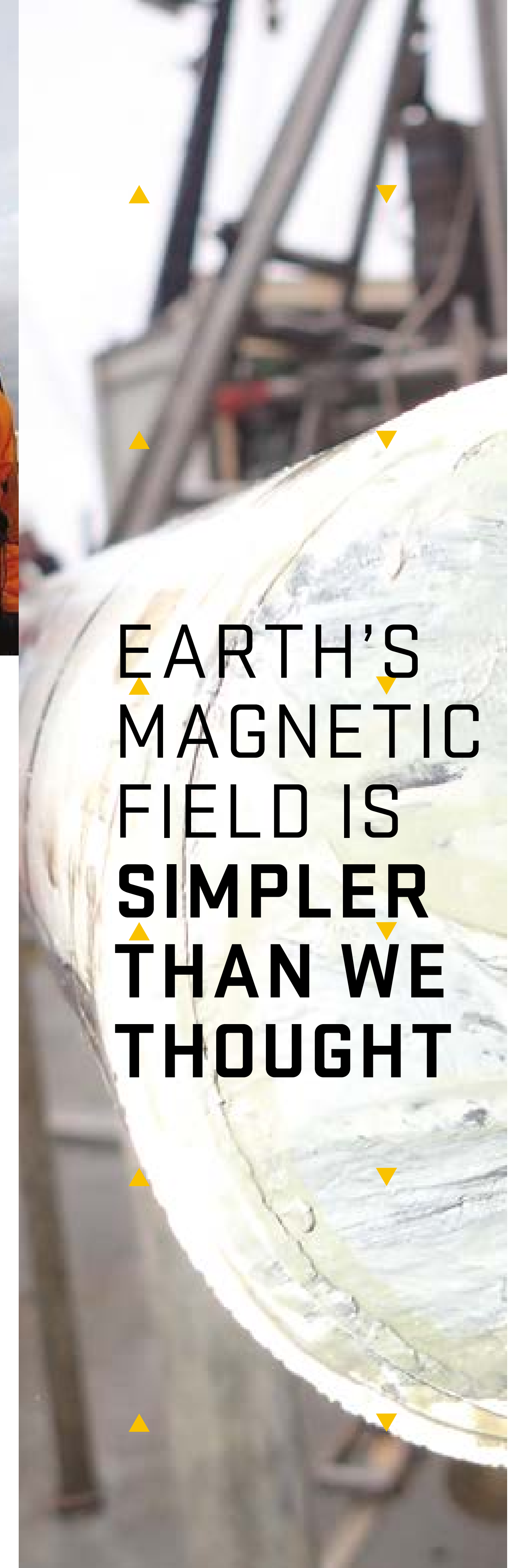
They found 148 strains – also known as operational taxonomic units – nine of which were found in at least five of the six Arctic rivers.

"To make predictions of the flow, we looked for which type of bacteria was found to occur with different levels of discharge," said **Stephen Good**, a hydrologist with OSU's College of Agricultural Sciences. "We then looked at the bacteria from the river we wanted to predict and estimated the discharge based on this previously determined relationship between flow and bacterial abundance."

Using 33 years of discharge measurements from the rivers, Good and his colleagues created an algorithm that can estimate the flow of the rivers based on the microbial profile.

"If we put flow meters in the river, we'll get better measurements, but that isn't easy to do in many cases," Crump said. "The hydrologic community has needed another method to help predict flow, and this algorithm appears to be effective – and has the potential to be even better."

Good said the next step in the research is to incorporate other factors into his complex model, including precipitation, and to see if the method is applicable to other river systems. "The bacteria that we identified are likely to be found in other rivers, though not necessarily in the same amount, so the model will have to be adjusted," Good said. "We have ongoing work looking at this method throughout western Oregon, and we are already trying to incorporate precipitation into the process."



EARTH'S MAGNETIC FIELD IS SIMPLER THAN WE THOUGHT

The Earth's magnetic field creates a protective barrier against harmful radiation, without which life on the planet could not exist. The magnetic field also aids in human navigation and animal migrations in ways scientists are only beginning to understand. Centuries of human observation, as well as the much longer geologic record, show the field changes dramatically in strength and structure over time.

Changes in strength and polarity have long been known to occur in a globally coherent fashion over periods of 10s to 100s of thousands of years, forming the basis of a widely used geological technique for telling time known as magnetic stratigraphy. CEOAS scientists have now identified patterns in the Earth's magnetic field that evolve coherently across a large swath of the Northern Hemisphere on the order of 1,000 years. These observations demonstrate a previously unknown level of predictability in fine-scale changes of the field, offering a new magneto-stratigraphic approach with a significant increase in resolution to help date records of past environmental change.

"We can now look at the record on a scale possibly as short as a few centuries, compare events between ocean basins, and really get down to the nitty-gritty of how climate anomalies are propagated around the planet on a scale relevant to human society," said **Maureen "Mo" Walczak**, a post-doctoral researcher at Oregon State University and lead author on the study.

In spite of its importance, many questions remain unanswered about why and how changes to the Earth's magnetic field occur. The simplest form of magnetic field comes from a dipole: a pair of equally and oppositely charged poles, like a bar magnet.

"We've known for some time that the Earth is not a perfect dipole, and we can see these imperfections in the historical record," Walczak said. "We are finding that non-dipolar structures are not ephemeral, unpredictable things. They are very long-lived, recurring in persistent locations throughout at least the past 10,000 years."

Some 800,000 years ago, a magnetic compass' needle would have pointed south because the Earth's magnetic field was reversed. These reversals typically happen every several hundred thousand years.

While scientists are well aware of the pattern of reversals in the Earth's magnetic field, a secondary pattern of geomagnetic "wobble" within periods of stable polarity, known as paleomagnetic secular variation, or PSV, may be a key to understanding why some geomagnetic changes occur.

The researchers were able to identify the pattern by studying two high-resolution sediment cores from the Gulf of Alaska that allowed them to develop a 17,400-year reconstruction of the PSV in that region. They then compared those records with sediment cores from other sites in the Pacific Ocean. The physical orientation of the mineral magnetite in the sediment provides a kind of geomagnetic "fingerprint" of past conditions, indicating the direction and intensity of the magnetic field.

"As it turns out, the magnetic field is somewhat less complicated than we thought on these time scales," said **Joseph Stoner**, a CEOAS paleomagnetic specialist. "It is a fairly simple oscillation that appears to result from recurrent geomagnetic intensity variations at just a few locations with large spatial impacts. We're not yet sure what drives this variation, though it is likely a combination of factors including convection of the Earth's outer core."

Walczak added, "This is something of a Holy Grail discovery, constituting an important first step in better understanding the magnetic field and synchronizing sediment core data at a finer scale."

WHAT MOVES **MOUNTAINS?**

Third-year Ph.D. student **Ellen Lamont** is fascinated by what makes mountains grow. Now she's going to pursue that question by studying the tallest of all mountain ranges, the Himalayas. Lamont, a student of CEOAS geologist **Andrew Meigs**, has been awarded a prestigious 2018 Fulbright scholarship to travel to India to paint a picture of mountain growth and evolution using the Himalayas as her laboratory.

"If I'm going to study mountains, I figured I might as well start with the crème de la crème of mountains, where it's complicated and crazy and impressive and majestic," she declared.

Her project will address a long-standing debate among mountain geologists: Which force is more important in forming mountains, climate (precipitation, erosion) or tectonic activity (processes that deform the Earth's crust) beneath the surface?

"Of course it's not necessarily one or the other, but the discussion centers on whether one is dominant, or how the two are balanced," Lamont explained. "The debate hasn't progressed in the past 20 years."

She and Meigs believe that the key to moving the debate forward lies in the foreland of mountain ranges, or the area where material builds up and where tectonic plates collide, like the Himalayas. Most work on mountain formation has focused on characterizing faults and timelines in the hinterland, the area behind the mountain wedge. Lamont believes that the debate stagnates in the hinterland, and the foreland is where the solution lies.

"We think we can look at the foreland in a new way," Lamont explained. "What we want to know is, when did the foreland grow, and how was growth divided among individual faults? When did the faults develop, in what order, and how do they vary spatially?"

This timeline can then be compared to what is observed in the hinterland. "If we see that the foreland has been developing more recently than the hinterland, we'll know that tectonics is likely the dominant force. If it's the other way around, climate is likely dominant," Lamont said.

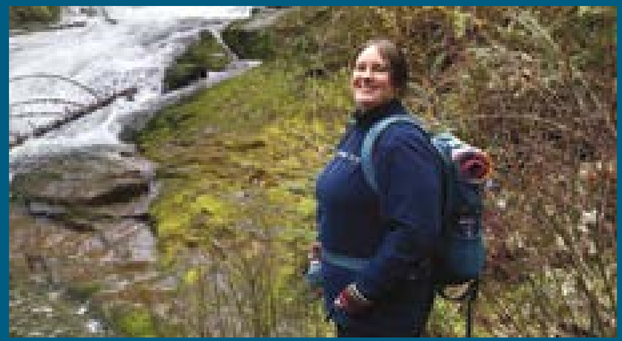
In order to determine that timeline, Lamont will do two things: map the faults in the foreland of her study site, and age rock samples. The aging process is a fairly new technique, in which, Lamont explained, a thermostat is turned into a timer. In hinterland rocks, scientists examine the decay of uranium in a volcanic mineral, apatite, to determine whether the helium atoms that the uranium sheds as it ages are released or retained. When the apatite crystals are first formed deep in the Earth, the helium atoms diffuse away, but as the minerals rise through the crust, eventually they will pass a threshold of depth and temperature at which the helium is retained in the crystal structure.

In the messy, complicated foreland, rocks are eroded from the hinterland, moved by rivers, and generally reworked. Those rocks can also be reburied and reheated, essentially restarting the geological timer when the remaining helium is released. Lamont will try to age reburied mineral grains that were then brought to the surface again by a foreland fault, in order to constrain the age of the fault itself.

"If it works, we can apply this method to any mountain range in the world," Lamont said.

One challenge of the work is that she needs to collect very large rock samples to find very few grains of apatite – the needles in very heavy, ungainly haystacks. She might smash apart a 10-kilogram sample the size of a basketball to find six grains of mineral she can work with. She hopes to do some pre-processing of samples in India, and perhaps bring the samples to the lab in Germany where she originally learned the technique.

Lamont will be in India from August 2018 to spring 2019.



From first-generation to Fulbright

Lamont's path to the Fulbright required perseverance. A daughter of a mechanic and a school cafeteria worker in western Pennsylvania, she was a first-generation college student. While her family was supportive of her quest for education, she had to navigate the first steps toward academia by herself. "I didn't really know anything about college," she explained. "I knew people went, but it was a pretty abstract concept."

First-gen students at all levels face unique challenges. While there are resources to support other underrepresented groups in academia, support for first-gens lags behind, especially above the undergraduate level. "For a lot of us, entering academia means changing social status, and navigating that can be difficult," she said.

In addition to her research, Lamont will use her Fulbright to conduct extensive outreach activities. One important target of her outreach will be other first-gen students, in order to help them know that they're not alone.

PLANKTON DISPERSAL: TO TRAVEL FAR, PACK LIGHT AND FIND A FAST TRAIN

When it comes to marine plankton, the smaller you are the farther you travel.

A new international study found that the size of plankton, and the strength and direction of currents, are key to how they are dispersed in the ocean – much more so than differences in temperature, salinity and nutrient availability.

From a species standpoint, "There are pros and cons to being small," said **James Watson**, a CEOAS geographer and oceanographer and co-author on the study. "When you're small, you are more abundant and you ride the currents farther, which means you have more opportunities to find a good spatial niche.

"The down side is that when you're small, you get beat up a lot. You get eaten by bigger organisms. There are advantages to being small and fast, but there also are advantages to being big and strong."

The question of how plankton and other small marine organisms are distributed in the ocean is important, scientists say, because climate change is rapidly warming marine waters all over the globe, and it isn't yet clear how this will affect biological communities.

This new study found that the complex network of ocean currents is a key to how organisms disperse, and the size of the organisms plays an important role in how far they disperse. The larger the plankton body size, the smaller the connection between distant communities, said lead author **Ernesto Villarino**, a researcher with AZTI, a marine technology center in Spain.

"The ocean is the largest continuous environment on Earth, and over long time scales, all marine ecosystems are connected by ocean currents," Villarino said. "Biological connectivity, or the exchange of individuals across geographically separated sub-populations, is not uniform, as there are barriers that hinder their dispersal."

In their study, the researchers looked at different plankton, fungi, algae and other micro-organisms up to fish larvae "about the size of your pinkie fingernail," Watson said.

"The big question is what will happen as the oceans warm," Watson said. "There are already very warm regions in the ocean, and we are beginning to find out which organisms in these areas are more heat-tolerant. In theory, those will begin to populate other regions as they also warm.

"However, our results suggest that will more likely happen if there is clear connectivity via ocean currents, and the smaller organisms are more likely to travel farther and faster."

Photo collage courtesy of Kelsey Swieca

PACIFIC COD: **SCIENCE TO SUSTAIN A FISHERY**

If you've ever eaten fish sticks, you've likely eaten Pacific cod. Its firm, mild, white flesh lends itself nicely to frying, but it can also be baked, steamed, sautéed and used in soups and chowders. Pacific cod is tasty, plentiful and affordable, and is the second largest single species fishery in the U.S., behind walleye pollock. The species' economic importance, and some major gaps in our understanding of its ecology, inspired CEOAS professor **Lorenzo Ciannelli** and his post-doc, **Patricia Puerta**, to learn more about its life history and ecology, and to understand how we can better manage the species.

Pacific cod are economically important in places far from Alaska, including Newport and Astoria, Ore: While most of the fishery takes place in the frigid waters of Alaska's Bering Sea, made famous by the television show "Deadliest Catch," a significant number of cod boats and crew travel there from Oregon ports. This distant-water fishery creates economic vibrancy for Oregon coastal communities, and provides an important source of protein for populations worldwide.

While fishermen know a lot about how to catch Pacific cod in the Bering Sea, scientists don't know much about the species' basic life history. How fast do they grow? How big are they, on average, at a given age? Does that growth vary from place to place and year to year? This information is crucial for modeling cod life histories, a critical step in developing management approaches for a sustainable fishery.

Ciannelli and Puerta are filling some of these knowledge gaps by collecting cod otoliths, bones found in the fishes' inner ear, to determine the range of size-at-age for the Bering Sea stock. Size-at-age is exactly what it sounds like: the size that a fish attains at a given age. This relationship is very important to understand when it comes to managing fish stocks, as the annual stock assessment is based on the number of fish at a given age. But surveys of the fish in the field can't measure ages; instead they measure sizes as a way to estimate fish ages.

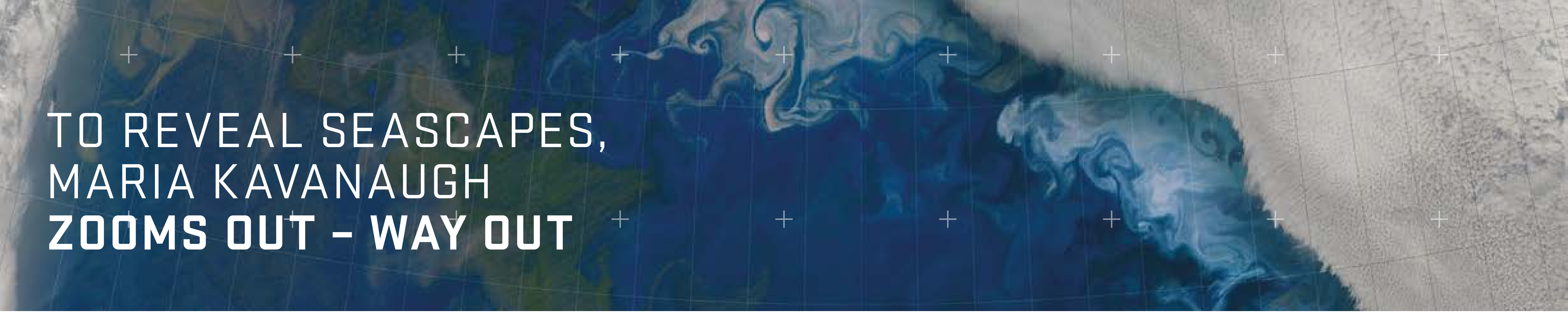
Unfortunately, the relationship between the two metrics is not fully understood in this species, because their growth rates are highly variable. What if the relationship between age and size differs substantially and systematically from place to place?

"Three fish that are the same age but from different parts of the Bering Sea could differ significantly in length, just like three different two-year-old children could be very different heights," explained Puerta. "Imagine having to guess the age of a child based only on their height."

This is where the otoliths come in. These tiny bones are marked by rings that are laid down annually, much like the rings of a tree. By counting the rings, scientists can determine the ages of individual fish.

The Bering Sea cod population has been in good shape for decades (although commercial catches in 2017 were very low), so this research is not about "rescuing" a threatened species. Instead, it's a way of getting out ahead of an issue, and planning for the future. As Ciannelli pointed out, "Now is the time, when we have actually a good healthy stock, to gather the data that we need in order to preserve the healthy status of the species and in order to be able to monitor it in an effective way for many years to come."

Patricia Puerta



TO REVEAL SEASCAPES, MARIA KAVANAUGH **ZOOMS OUT – WAY OUT**

CEOAS Assistant Professor **Maria Kavanaugh** reviews a series of dynamic seascapes, pointing out impressionistic swirling eddies of color. These works of art, rendered on a computer screen, are mapped mosaics of regions in the ocean that have unique physical and biological characteristics, analogous to terrestrial landscapes, identified and characterized using satellite data.

"Landscapes are patches of unique habitats arranged in an orderly, hierarchical way on the planet, shaped mostly by geology and climate. The ocean is actually shaped similarly," Kavanaugh explained. "The ocean contains smaller-scale features like eddies embedded in gyres, which are embedded in ocean basins. Instead of geology and climate, in the ocean it's forces like currents and climate that control the mosaic."

Using satellite data on phytoplankton, sea surface temperature and other parameters, Kavanaugh and her colleagues identify distinct ocean regions so they can ask a range of questions: how do these regions shift and change size with changes in climate conditions? Is one area changing more rapidly than the regions around it? Does a region in the Pacific Ocean have an analogous region in the Atlantic? Is a particular piece of the patchwork mosaic more resilient to change than others?

"It can be difficult to ask these kinds of questions in the ocean because the ocean is always moving. We can't repeatedly drop a bucket in the water somewhere and expect to sample the same parcel of water again," Kavanaugh said. "It's more of a challenge than studying a grove of trees that you can return to periodically."

That's why satellites are useful, as they can take images of vast areas of ocean simultaneously. Kavanaugh's particular interest is phytoplankton. Satellite imagery can differentiate among large functional groups of phytoplankton, which is enough information to determine whether a "good" food source is available for upper levels of the food web. "It's like being able to differentiate between a tree and a bush on the OSU campus — we couldn't tell if we have, say, oak trees specifically. With respect to phytoplankton, we can differentiate groups of different cell sizes, which often tells us about the quality of that species as a food source," Kavanaugh said. With information about the lower levels of the food web, scientists can make inferences about upper levels.

Kavanaugh's doctoral work with CEOAS oceanographer **Ricardo Letelier** was a proof-of-concept project: she determined that satellite phytoplankton data could, indeed, be used as the basis to describe seascape mosaics. "We could identify patches containing different phytoplankton communities and biogeochemical functioning, and we could see those patches expand and contract on seasonal scales as well as interannually in the North Pacific," she explained.

Kavanaugh has received NASA funding to expand the seascapes approach to two areas: the Arctic, and then (drumroll, please) the global ocean. The Arctic project will present a particular challenge, as cloud cover for six months of the year and the long, dark Arctic winter pose problems for today's satellites. For this project, she will partner with a number of existing monitoring programs to answer questions about marine species-habitat relationships and how they could change with a warming Arctic.

As this method and framework evolves, Kavanaugh expects it will inform a range of ecological and management questions. For example, in 2014 and 2015, satellite data revealed low productivity water close to the Oregon coast associated with a warm water phenomenon known as "the blob." The invasion of this water resulted in an abnormally small, compressed and shallow area of higher phytoplankton productivity, which matched NOAA data on where schools of anchovy were aggregated. Whales following the small fish into the shallow nearshore are at increased risk of entanglement with gear fixed to the bottom, such as Dungeness crab pots.

With the new NASA-funded project underway, the seascape paradigm will have been tested in a broad range of marine regions, from polar to subtropical. Kavanaugh is excited to determine how helpful this approach can be in characterizing the dynamic global ocean. "Marine species and pelagic habitats are not constrained by geopolitical boundaries. If we can examine how seascapes have changed and evolved over time, how pieces of the mosaic have shrunk or grown," Kavanaugh said, "we might be able to help inform decisions about marine ecosystem management across international waters and the high seas."

Maria Kavanaugh

MAPPING THE **MISSING MILLIONS**

Jamon Van Den Hoek

You may have unwittingly undertaken crowdsourcing by asking your Facebook friends for a recommendation for a good recipe using chanterelle mushrooms, or the best plumber in town, or what brand of laptop to buy. CEOAS assistant professor of geography **Jamon Van Den Hoek** uses the hive mind for a different cause: he will enlist thousands of volunteers to use a smart phone app to help find informal settlements occupied by internally displaced people, or IDPs.

IDPs are people who have been forced to leave their home, but not their country, fleeing violent conflict, natural disaster or some other precipitating event. They have not crossed borders or asked for asylum because they have not left their own country, making it more difficult to track them. Remaining in a war-torn nation can often put IDPs at tremendous risk.

The ultimate objective of Van Den Hoek's project, recently funded by NASA, is to use satellite imagery to find IDP settlements that are not currently included in national or global maps of human settlements, and to begin to assess the status of those settlements with respect to United Nations sustainable development goals. IDPs are tough to track, even for the U.N., which monitors international refugees. The U.N. does know this much: There are more IDPs now than ever before, and they outnumber international refugees.

> Jamon Van Den Hoek will enlist thousands of volunteers who will use a smart phone app to help find settlements occupied by internally displaced people, or IDPs.

"IDPs are a unique group," explained Van Den Hoek. "They are floating populations. Their settlements could be temporary; some could be seasonal, they can be planned or unplanned. They are often unaccounted for in census data. We sometimes refer to them as the 'missing millions.'" Because international refugee camps are often more permanent and planned, aid agencies and governments tend to know where these settlements are, and the U.N. can document conditions there. When it comes to assessing sustainable development at refugee camps, census and satellite data can answer many relevant questions: Does the settlement have running water? Is there agriculture, and therefore a food source, nearby? Is the site impacted by drought?

But the ephemeral nature of IDP settlements makes answering these questions difficult. The problem is not the availability of data – sophisticated satellites provide massive amounts of geospatial information, covering the entire surface of the Earth. The problem is interpreting that data, finding the time and eyes to examine the images for evidence of temporary settlements.

This is where crowdsourcing comes in. Van Den Hoek and his colleague, CEOAS assistant professor of geography **David Wrathall**, will collaborate with the Humanitarian OpenStreetMap Team (HOT), a group that uses open-source mapping to assist in humanitarian response to disasters and political crises. The researchers will be tapping into an existing smart phone app, called MapSwipe, that HOT and its partners developed.

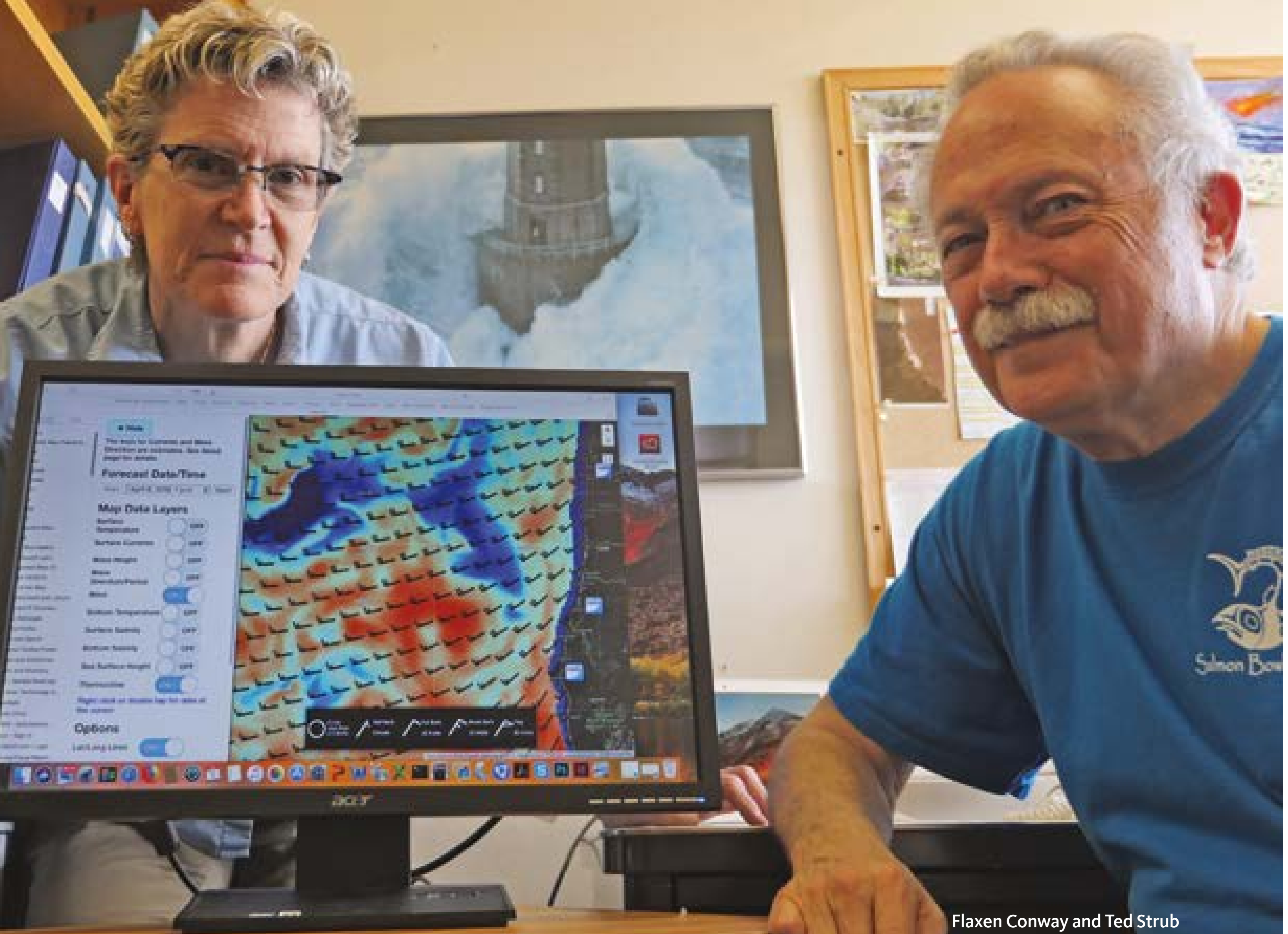
MapSwipe presents users with a six-cell grid of satellite images and asks them to find a feature, usually a road or a building. Following a simple instruction – "you are looking for buildings" – the user taps on those cells that contain the desired feature. The activity feels almost like a video game, right down to the "rewards" that users receive for completing numbers of tasks. Each set of cells is sent to several users, and cells that receive multiple positive responses are forwarded to an expert for confirmation. Currently about 10,000 people use MapSwipe.

One contribution of this work will be to determine what, exactly, IDP settlements look like from space. "No one's ever done this," Van Den Hoek said. "Settlement appearance will vary from site to site: there will be differences between those with formal versus informal planning; there will be differences among countries, conditions and building materials – all of these will affect how a settlement looks." He and Wrathall plan to ground-truth some of the likely settlement sites in person later in the project.

Once the settlement sites are identified, the researchers will take on the still-daunting task of examining the status of the settlements with respect to sustainable development goals. They will use other satellite data to examine parameters like agricultural productivity, changes in precipitation, access to roads and any others that might relate to sustainable development.

Ultimately, Van Den Hoek and his colleagues would like to get this information into the hands of organizations that can help IDP populations. However, the very first step is to find the displaced people.

With a little help from 10,000 friends.



Flaxen Conway and Ted Strub

GETTING AHEAD OF HAZARDS: **COLLABORATION WITH FISHERMEN LEADS TO OCEAN-FORECASTING WEBSITE**

Imagine being able to check ocean conditions as easily as the weather. Fishermen and surfers could assess waves and currents before heading out into the water. Tourists could avoid hazardous coastal conditions. Scientists could look for markers of harmful algal blooms that wreak havoc on shellfish and threaten human health.

A forecasting system that could help ocean-goers avoid these hazards may not be that far off. A new tool allows commercial fishermen to check ocean conditions of the Pacific Northwest coastline with an easy-to-use, interactive online map. With continued support, the online map may be able to do much more to keep tourists, boaters and others safe.

The tool is at nvs.nanoos.org/Seacast on the website of the Northwest Association of Networked Ocean Observing Systems (NANOOS), a partnership of entities that gather and disseminate data on the ocean. The new site is the culmination of multiple years of research based on conversations with fishermen that aimed to make ocean forecasts as accessible as weather forecasts.

Talks started in 2012 when **Colin Duncan**, a CEOAS graduate student, asked fishermen about their ocean forecasting needs. He also met with NANOOS scientists to learn about their work and how it could help the fishing community. His thesis laid the foundation for the creation of Seacast.org, an experimental site that displays forecasts for sea conditions such as wave height and surface currents.

After Duncan graduated, OSU undergraduate computer science students added more features to the site. Then in 2016, Oregon Sea Grant provided funding that allowed Marine Resource Management (MRM) student **Jessica Kuonen** to advance the project under the guidance of **Flaxen Conway**, a community outreach specialist with Oregon Sea Grant and director of CEOAS' MRM program.

Kuonen and the computer science team met on several occasions with fishermen to get their input on how Seacast.org could be more useful. Based on fishermen's requests, the web developers improved the site and added new fields, including bottom temperature and salinity. They also added a feature that allows users to see various forecasts of ocean conditions precisely where they click their cursor on the map.

"The future of enhancing the usefulness of ocean condition forecasts ultimately lies with the data provider and end-user communities and their willingness to cooperate," she wrote in her thesis. "The genesis for this type of engagement could be cooperative research, where fishermen collect observations from the ocean environment and provide feedback to help validate and improve the models."

In 2018, the data and design from Seacast.org began a transition toward a more permanent home within the NANOOS website, said **Ted Strub**, a CEOAS oceanographer who was the lead on the project.

"Without more funding, Seacast.org can't be maintained," he said. "It was always the plan for the experimental site to be transitioned to a more permanent site. We just didn't know who would actually do that. It is a measure of her forward vision that Jan Newton, the executive director of NANOOS, was willing to use her resources to support the conversion of the experimental site to the more operational system."

WATER

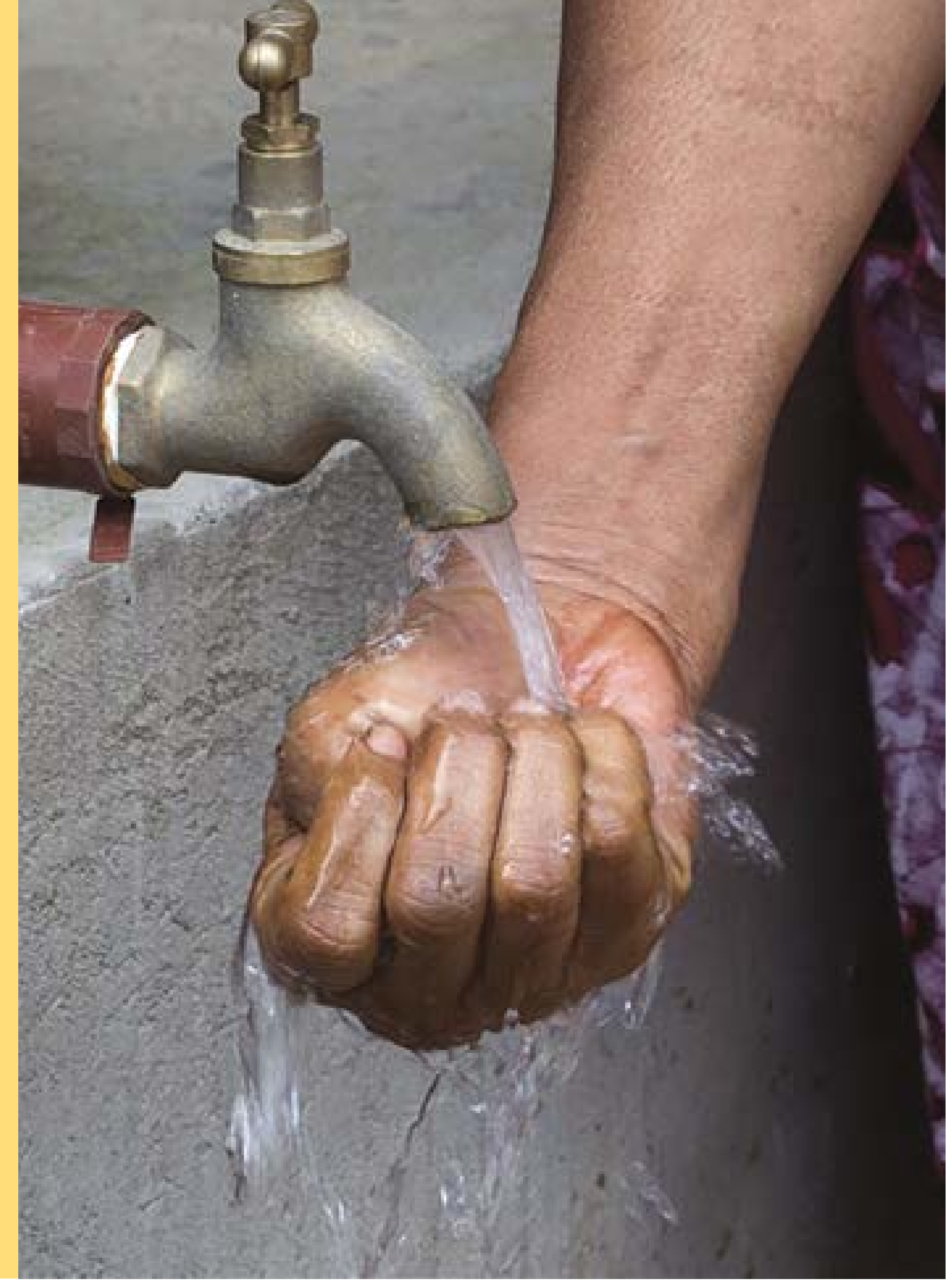
GLOBAL HOTSPOTS **FOR WATER CONFLICT**

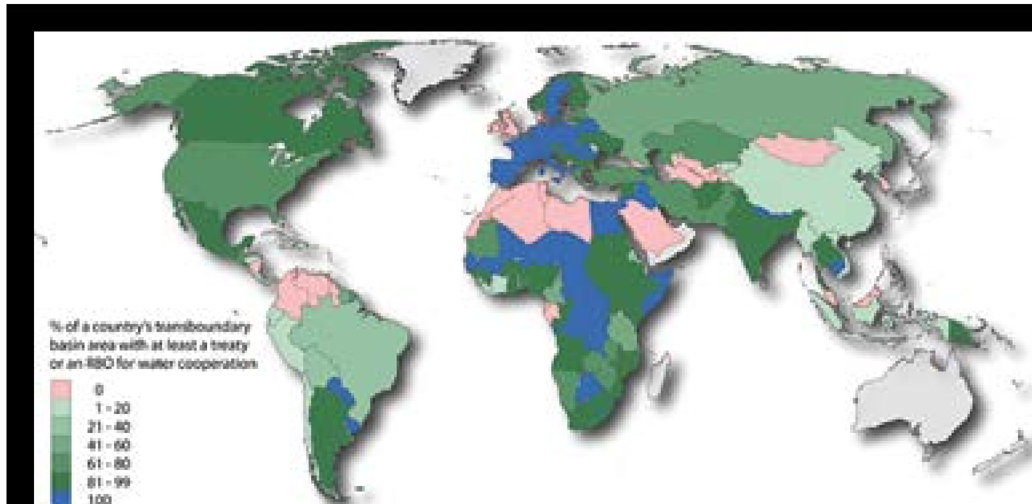
More than 1,400 new dams or water diversion projects are planned or already under construction worldwide, many on rivers flowing through multiple nations, fueling the potential for increased water conflict between neighboring countries.

A new analysis commissioned by the United Nations uses a comprehensive combination of social, economic, political and environmental factors to identify areas around the world most at-risk for "hydro-political" strife. This river basins study, part of the U.N.'s Transboundary Waters Assessment Program, was co-authored by CEOAS hydrologist **Eric Sproles**.

The analysis suggests that risks for conflict are projected to increase over the next 15 to 30 years in four hotspot regions – the Middle East, central Asia, the Ganges-Brahmaputra-Meghna basin, and the Orange and Limpopo basins in southern Africa.

Additionally, the Nile River in Africa, much of southern Asia, the Balkans in southeastern Europe, and upper South America are all areas where new dams are under construction and neighboring countries face increasing water demand, may lack workable treaties, or worse, haven't discussed the issue.





Percentage of a country's transboundary basin area with at least a treaty or a River Basin Organization (RBO) for water cooperation. More information on the United Nations Transboundary Waters Assessment Program is available at www.geftwap.org.

"If two countries have agreed on water flow and distribution when there's a dam upstream, there usually is no conflict," said Sproles. "Such is the case with the Columbia River basin between the United States and Canada, whose treaty is recognized as one of the most resilient and advanced agreements in the world."

The conflict over water isn't restricted to human consumption, the researchers say. There is a global threat to biodiversity in many of the world's river systems, and the risk of species extinction is moderate to very high in 70 percent of the area of transboundary river basins.

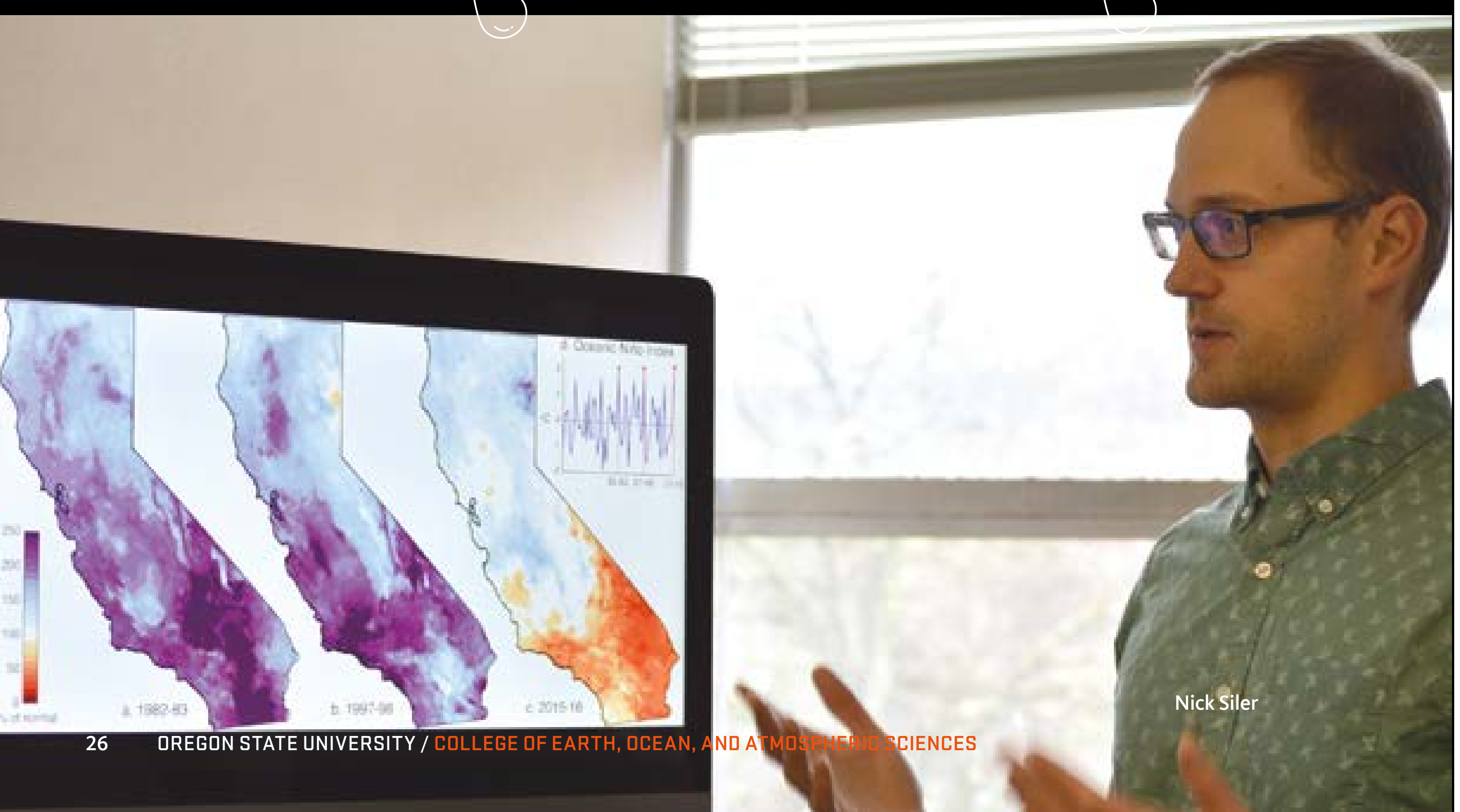
The Nile River is one of the more contentious areas of the globe. Ethiopia is constructing several dams on tributaries of the Nile in its uplands, which will divert water from countries downstream, including Egypt. Contributing to the tension is drought and a growing population more dependent on a water source that may be diminishing.

"When you look at a region, the first thing you try to identify is whether there is a treaty and, if so, is it one that works for all parties and is flexible enough to withstand change," Sproles said. "It's easy to plan for water if it is the same every year – sometimes even when it's low. When conditions vary – and drought is a key factor – the tension tends to increase and conflict is more likely to occur."

This baseline assessment is an important first step in managing hydro-political strife, and has been recommended by the U.N. Economic Commission for Europe as a starting point for assessing the U.N.'s sustainable development goals for water cooperation.

ATMOSPHERE

IMPROVING FORECASTS **FOR FARMERS**



Nick Siler

In the fall of 2015, California was bracing for unbelievable rain. Ominous headlines warned of a "Godzilla" El Niño event that promised a punishingly wet winter. The California Department of Transportation even increased its maintenance staff by 25 percent, readying sandbags and plows in case of floods, mudslides or worse.

But as winter progressed, the torrential rains never materialized. And in Southern California, where El Niños have historically had the greatest impact, the Godzilla winter turned out to be among the driest on record. With all our satellites and simulations, why did predictions miss the mark?

Nick Siler, then a post-doctoral fellow at the Scripps Institution of Oceanography, wondered the same thing. "The seasonal forecast models all predicted wetter-than-average conditions, so it was a failure of the models and not just some scientists overstating things," said Siler, a recently hired assistant professor of atmospheric sciences in the College of Earth, Ocean, and Atmospheric Sciences.

Getting seasonal forecasts right in California is surprisingly hard, Siler explained. Rain there can be "flashy," arriving suddenly and strongly. Water managers have to plan for floods and also ensure enough water is stored in reservoirs to make it through the summer. "It doesn't rain often, but when it does, it comes in these very big storms, what we sometimes call atmospheric rivers. So, it's actually a very tricky place to try and manage water resources," Siler said.

Siler recalled a scientific meeting where one presenter compared precipitation forecasts in California to observed records over the past 10 years. More often than not, the forecast models were wrong. "Most models actually had negative predictive skill in California, meaning you'd be better off betting the opposite of whatever the model predicts," he said.

To investigate the forecast failings during the 2015-16 winter, Siler and his collaborators compared the El Niño event to previous strong El Niños and found a wide range of differences in the atmospheric responses across the globe. By running a series of experiments with a global climate model, his team found that the key to those differences stemmed in part from sea surface temperatures in the Indian Ocean.

That's right – California's left-hook dry winter may have been caused by warmer sea surface temperatures in the distant tropics.

"The Indian Ocean has been warming faster than the rest of the tropical oceans, and what we found is that a warm Indian Ocean relative to the rest of the tropics tends to push the storm track farther north, which is consistent with a drier California," he said. "The forecast models seem to have trouble capturing this pattern, for reasons we don't fully understand."

Siler hopes that this work will eventually improve the forecast models, which could help water managers plan for the year ahead. In an agricultural Mecca like California, getting water availability right is critical. "California water resource managers rely a lot on seasonal forecasts. The climate prediction center at NOAA issues these forecasts every month, and water resource managers pay a lot of attention to them," he said. "These forecasts will never be perfect, but we can probably do better."

At Oregon State, Siler continues to study the water cycle, trying to better understand both its current variability and response to climate change. Siler hopes to collaborate with local growers, using his research to help them succeed.

"Precipitation matters to everybody, but perhaps more so to farmers" he said. "I think it would be great to work with people in the farming communities around here to study aspects of climate variability and climate change that could impact their livelihoods."

IN THE FOOTPRINTS OF CLOUDS: **HUNTING FOR ATMOSPHERIC COLD POOLS**

Cold, invisible phantoms creep over the surface of the tropical ocean, contributing to the formation of towering clouds and influencing local and global weather patterns. CEOAS atmospheric scientist **Simon de Szoeke** tracks them from the deck of a ship, like some atmospheric science version of the show "Ghost Hunters."

The phantoms he chases are cold pools, puddles of cold air several hundred meters deep at the very bottom of the atmospheric boundary layer. Cold pools are found over land and sea, but de Szoeke has found that over the tropical ocean they play a particularly important role in the atmospheric heat budget.

Simon de Szoeke

Heat is a currency exchanged among the ocean, the boundary layer (the kilometer-thick layer of the atmosphere closest to Earth's surface), and the atmosphere above it. Transactions among these "banks" drive weather and climate dynamics. De Szoeke has determined that heat deposited into the boundary layer from the ocean is balanced by two nearly equal withdrawals. One is turbulent mixing between the atmospheric boundary layer and the dry overlying atmosphere. The other occurs when cold downdrafts, the source of cold pools, flush into the boundary layer. Cold air entering the boundary layer is equivalent to a loss of heat.

De Szoeke likens these cold pools to "footprints" of convection. Over the tropical ocean, convection occurs as warm, moist air rises. As the air rises water droplets condense into clouds, warming the air and driving convection further upward. Cloud droplets can coalesce into larger drops that fall as rain. Rain evaporates and cools the air through which it falls, creating cold downdrafts that form extensive puddles of cold air – cold pools – that spread out on the ocean's surface.

Current climate models don't seem to do justice to the important role of these atmospheric puddles, and many questions remain about their role in tropical and global climate and weather. To fill some of these gaps and gather additional critical data on the subject, de Szoeke went hunting for cold pools in summer 2011 on a research cruise in the equatorial Indian Ocean.

De Szoeke and collaborators installed instruments on the deck of the R/V Roger Revelle to measure temperature, moisture and other parameters at the bottom of the boundary layer. They watched while the vertical radar and other equipment collected data.

"You can actually see the cold pools from the ship," de Szoeke marveled. "Over the ocean they form gusts at the front, so you can see a difference in wave structure on the ocean's surface, with more whitecapping."

Results from that cruise indicated that cold pools are drier than their surroundings, contradicting current ideas that cold pools contribute their moisture to generate more convection. "If you're measuring a cold pool coincident with rain, they can be quite moist. But I saw lots of cold pools that were not associated with rain, and they were, on average, a little drier than their surroundings," de Szoeke said.

This work to understand cold pools will contribute an important refinement for climate and weather models. The tropical heat budget is central to forecasting rain in the tropics and understanding formation of winter storms and other large-scale processes that affect our lives and livelihoods. More insights will result from new observations de Szoeke and colleagues recently made at sea in the summer of 2018. He'd like to get a better grip on the ages of the cold pools he observes, for example, as well as refine models of the role of cold pools in heat exchange in the boundary layer.

"These findings may improve models, leading to better prediction of future climate. If we want to know how much it's really going to warm up, we need to know what's going to happen with clouds, and to do that we need to know how they work now," he explained.

NEW FACULTY

Rene Boiteau has been appointed as an assistant professor in ocean ecology and biogeochemistry. His research seeks to describe and quantify the fundamental molecular-scale chemical, biogeochemical and microbiological processes that govern metal cycling in the oceans. Boiteau received his Ph.D. in 2016 from the Massachusetts Institute of Technology / Woods Hole Oceanographic Institution. Prior to his fall 2018 arrival at CEOAS, he served as the Linus Pauling Distinguished Postdoctoral Fellow at Pacific Northwest National Laboratory.

Melanie Fewings, previously a member of the Marine Sciences faculty at the University of Connecticut, has been appointed as an associate professor of physical oceanography. Fewings received a Ph.D. from the Massachusetts Institute of Technology / Woods Hole Oceanographic Institution in 2007. Her expertise is in mesoscale and coastal ocean observations and coastal air-sea interaction, with an emphasis on satellite measurements of ocean surface winds and wind stress. She is also interested in satellite infrared and microwave measurements of sea surface temperature.

AWARDS

Professor **Ed Brook** has won many awards himself, but now he's played an important role in recognizing others. Brook provided ancient air, 12,000 years old, from some of his lab's Greenland ice cores, to be sealed into glass globes and used in striking award trophies. The trophies were designed and created by artist Walter Kitundu for the 2017 C40 Cities Bloomberg Philanthropies Awards, which recognize cities around the world that are demonstrating climate action leadership.

Faculty Awards

Jack Barth, Professor:
Fellow of the American Meteorological Society

Kim Bernard, Assistant Professor:
NSF CAREER award

Ed Brook, Professor:
Oregon State University Distinguished Professor

Christo Buizert, Assistant Professor:
2018 Outstanding Early Career Scientist Award, European Geosciences Union

Jim Moum, Professor:
Fellow of the Oceanography Society

Emily Shroyer, Associate Professor:
American Meteorological Society's Nicholas Fofonoff Award

Student Awards

Qay-liwh Ammon, Undergraduate, Environmental Sciences: 2017-18 Udall Scholarship, Tribal Public Policy

Mia Arvizu, Undergraduate, Environmental Sciences: Selected for the 2018 Polaris Project team, Woods Hole Research Center

Heather Bervid, Ph.D. student, advised by Andrew Meigs: NSF Graduate Fellowship

Natasha Christman, Ph.D. student, advised by Byron Crump: NSF Graduate Research Fellowship

Katlyn Haven, M.S. student, advised by Lorenzo Ciannelli: National Research Traineeship Fellowship on Emerging Technologies in Fisheries Science

Ellen Lamont, Ph.D. student, advised by Andrew Meigs: Fulbright scholarship

Emily Lemagie, Ph.D. student, advised by Jim Lerczak: Best student poster, 2017 Eastern Pacific Ocean Conference

MacKenzie Mark-Moser, M.S. student, advised by Andrew Meigs: Geological Society of America student research grant

Melissa McCracken, Ph.D. student, advised by Aaron Wolf: 2018 Richard A. Herbert Memorial Scholarship from the American Water Resources Association

Marina Marcelli, M.S. student, advised by Andrew Meigs: U.S. Geological Survey Pathways Fellowship

Holly A. Mondo, M.S. student, advised by Michael Campana: Best oral presentations, Spring 2018 PNW Research Symposium

Jennifer Moskel, M.S. student, advised by Emily Shroyer: Honorable Mention, NSF Graduate Research Fellowship

Jaime Osorio, Ph.D. student, advised by John Dilles: second prize, student poster, Society of Economic Geologists

Zachary Pinard, Undergraduate, Environmental Sciences: 2017 National Oceanic & Atmospheric Administration Hollings Scholarship

Juan Carlos Cuellar Quispe, M.S. student, advised by John Dilles: Fulbright visiting scholarship

Travis Roth, Ph.D. student, advised by Anne Nolin: best paper of the year for Hydrology and Earth System Science

Sarah Seabrook, Ph.D. student, advised by Andrew Thurber: best student talk at the International Symposium on Chemosynthesis-Based Ecosystems

Radhika Shah, Undergraduate, Environmental Sciences: 2017 National Oceanic & Atmospheric Administration Hollings Scholarship

Michelle Talal, Ph.D. student, advised by Mary Santelmann: Best Poster at the Annual Environmental Joint Campus Conference at University of Oregon, 1st Place Photo in the Ecological Society of America Photo Contest

Zachary Wallace, M.S. student, advised by Yvette Spitz: NASA Earth and Space Science Fellowship 2018

Jennifer Wong-Ala, M.S. student, advised by Lorenzo Ciannelli: NSF Graduate Research Fellowship

Oregon State University
College of Earth, Ocean, and Atmospheric Sciences

104 CEOAS Administration Building
Corvallis, OR 97331-5503
541-737-3504
ceoas.oregonstate.edu