ENVIRONMENTAL SCIENCES AT THE UNIVERSITY OF VIRGINIA

RESPONDING TO ACCELERATING CHANGE

ANNUAL REPORT 2016-17

THE DEPARTMENT OF
ENVIRONMENTAL SCIENCES

Established in 1969, the University of Virginia's Department of Environmental Sciences was one of the first to look at fundamental environmental processes from a multidisciplinary perspective and the first in the nation to offer undergraduate, master's, and doctoral degrees in environmental sciences. Today, the faculty includes winners of the prestigious Tyler and Hutchinson awards as well as five professors who are among the most highly cited researchers in their fields.

Departmental field stations and facilities include the Anheuser-Busch Coastal Research Center in Oyster, Virginia, home of the National Science Foundation–sponsored Virginia Coast Reserve Long-Term Ecological Research program, the Virginia Forest Research Facility in nearby Fluvanna County, and the Blandy Experimental Farm near Front Royal, Virginia.

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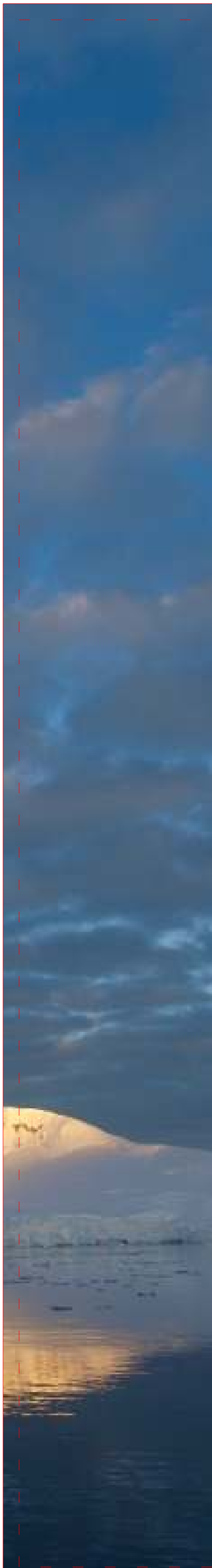


PHOTOGRAPH BY KELLY JACQUES, NATIONAL SCIENCE FOUNDATION

From the Chair

Environmental change has emerged as one of the most difficult and destabilizing challenges of our century. Sea level rise, desertification, and intensifying storms are just some of the consequences that have already begun disrupting long-established habitats and straining social, economic, and political systems. As a result of environmental change, governments must increasingly confront such issues as flooding, famine, vector-borne disease, and migration.

Their efforts to moderate or mitigate these effects will rest on the work of environmental scientists. Because this department encompasses the four environmental sciences—surface geology and geomorphology, atmospheric processes, hydrology, and ecology—it is well-positioned to provide the comprehensive view needed to advance these initiatives as well as train new environmental scientists.

This interdisciplinary approach has always characterized our research. A good example is work conducted at the Virginia Coast Reserve Long-Term Ecological Research center. The National Science Foundation has recognized the success of our collaborative efforts to understand coastal dynamics by renewing our grant to administer the program six times over thirty years.

But this department has never treated the environment in isolation, neglecting the impact of human activity. Faculty members have conducted pioneering research in such areas as the effects of acid rain on watersheds and streams and the indiscriminant use of nitrogen fertilizer on water quality.

Equally important, we have also studied the implications of the changing environment for people, providing insight, for instance, on the consequence of dying coral reefs on shoreline erosion and the effect of hotter temperatures on urban mortality rates. The three new faculty members we added this year increase our capacity to study human beings as both the agent and object of environmental change.

But we recognize that efforts to moderate or mitigate climate change require coalitions that extend far beyond environmental science, encompassing other disciplines and other institutions. This department has taken a major role in the University's Environmental Resilience Institute, working side by side with experts in such diverse fields as urban planning, public policy, engineering, law, and business. And it has long joined forces with nonprofits and government agencies.

Our role in all these endeavors is to produce what Professor Karen McGlathery calls actionable science, providing the necessary foundation in fact for effective solutions.

Michael L. Pace

Michael L. Pace, Chair

CAPTURED ON VIDEO

With filmmakers increasingly drawn to environmental themes, some faculty members are finding their projects the subject of full-length documentaries.

Advancing Environmental Science with Data from the Cold War

For environmental scientists, observational datasets—especially those accumulated over long periods of time—are extremely precious. During the Cold War, there were no groups that more actively committed to recording the natural world than the armed forces of the two superpowers, the United States and the Soviet Union. Thanks to the work of Professor **Hank Shugart**, much of the data collected by spy satellites, spy planes, and submarines from both nations has been made available to researchers.

Of course, the objective was to monitor military installations and troop movements. Measurements of natural processes were incidental.

Immediately after the fall of the Berlin Wall, Al Gore, then a Democratic senator from Tennessee, approached the U.S. intelligence community about the possibility of declassifying documents for environmental research. The CIA invited a group of scientists, including Shugart, to qualify for security clearances, examine the government's holdings, and make recommendations about material that could be released for scientific analysis. After Gore became Vice President, the group coalesced as MEDEA. "The members of the committee included the heads of agencies like the National Science Foundation and the U.S. Geological Survey," Shugart recalls. "It was a high-powered group."

ADD TO YOUR QUEUE: The work of MEDEA scientists is documented in a film by Paul Jenkins, *The Warning: How the US and Russian Secret Services Collaborated on Climate Change.*

Among its accomplishments, MEDEA arranged for the release of more than 860,000 satellite images taken between 1960 and 1972 by the U.S. Corona, Argon, and Lanyard programs. "At the time we became involved, the military had multiple tractor trailers loaded with film that had been sent back from space," Shugart says. "Military intelligence was going to recycle them for their silver."

PHOTOGRAPH BY PAUL JENKINS

Professor Howie Epstein and his graduate students have used these images to trace the greening of Siberia in response to global warming. Shugart used MEDEA data to conduct a similar study of vegetation changes in Mt. Kilimanjaro and Mt. Kenya.

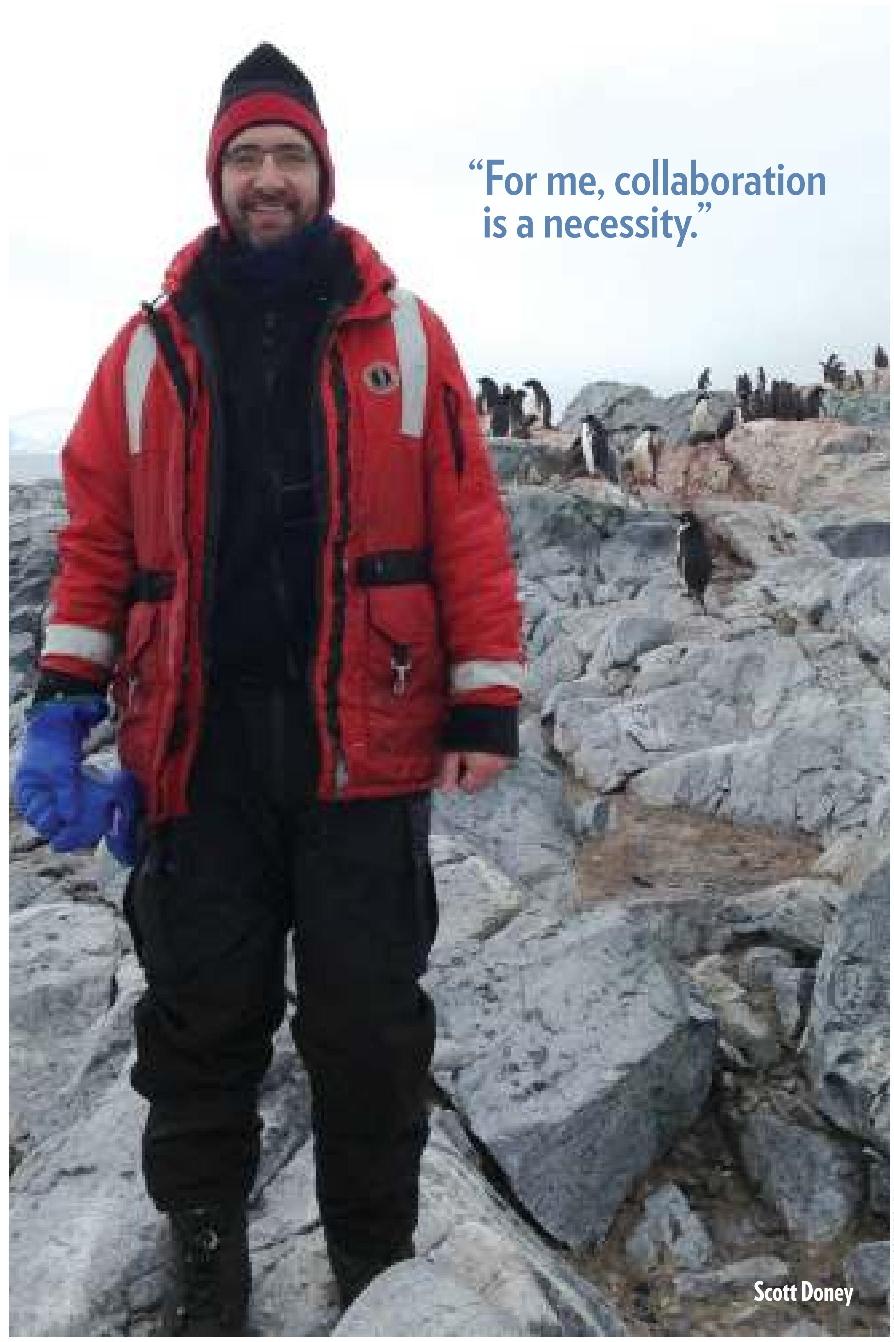
MEDEA also set the stage for collaboration with the Russians. For instance, in the late 1990s, MEDEA induced the governments of Russia and the United States to release data on the thickness of the Arctic sea ice, information that was originally used to estimate the threat posed by submarines that lurked below its surface. This information has been instrumental in creating a baseline for scientists monitoring the gradual thinning of the sea ice in subsequent decades due to climate change.

"For me personally, this was one of the most intellectually exciting and enjoyable things I have ever done," Shugart says. "The weird part was that for the longest time you couldn't really talk about it."

Modeling an Ocean in Flux

After more than two decades conducting research at the National Center for Atmospheric Research and the Woods Hole Oceanographic Institute, **Scott Doney** came to Charlottesville this year to devote more time to teaching. The inaugural Joe D. and Helen J. Kington Professor of Environmental Change, Doney was drawn by the broad mix of disciplines within the department as well as the quality of its students. Doney is a computational biogeochemist who spends much of his time analyzing ocean data and creating models that shed light on such issues as ocean acidification, marine ecosystem dynamics, and global carbon cycling.

"Much of the data I use depends on field observations as well as remote sensing, so for me, collaboration is a necessity," he say. "The possibilities within the department and at the University through the Environmental Resilience Institute are very exciting."



Scott Doney

PHOTOGRAPH BY SCOTT DONEY

Doney's long affiliation with the Palmer Station Antarctica Long Term Ecological Research (PAL LTER) program epitomizes the kind of collaborations he relishes. Doney is a co-principal investigator for the program, focusing on food-web, biogeochemical, and regional ocean-ice biophysical synthesis, modeling, and remote sensing. Given these interests, the Western Antarctic Peninsula is an ideal place to work.

"We have a rich dataset with over two decades of ship-based data and more recently mooring and robotic glider data in addition to satellite remote sensing," he says. "It is also fascinating from a modeling point of view because the region is undergoing substantial natural and anthropogenic climate change, making it an ideal natural laboratory for studying the effects of these changes on polar marine ecology and the carbon cycle."

ADD TO YOUR QUEUE: The work of the Palmer Station LTER project is captured by *Antarctic Edge: 70° South*. It is available on DVD, Netflix, and iTunes.

The PAL LTER is a multimillion dollar program that draws on the resources of the NSF, NASA, and other federal agencies. It is clear, however, that Doney enjoys more modest collaborations as well.

For the past few years Doney has been working with members of the Buzzards Bay Coalition, a nonprofit group dedicated to preserving the bay and its watershed. Coalition volunteers have long monitored water quality each summer, measuring such criteria as dissolved oxygen, temperature, and salinity. With funds from the John D. and Catherine T. MacArthur Foundation, Doney has been able to expand sampling at a limited number of sites throughout the year and add ocean carbonate measurements. "Among other questions, we are trying to determine if the same processes that lead to nutrient pollution and eutrophication can also lead to acidification," he says.

"I work with models, which are essentially abstractions," Doney says. "Partnering with local groups who treasure the natural environment consequently is very satisfying." ■

AT THE INTERSECTION OF ATMOSPHERIC CHEMISTRY AND BIOLOGY

Tracking the interactions between biological processes and atmospheric chemistry is essential for such issues as air pollution, carbon sequestration, and climate change.

Connecting Rice, Air Pollution, and Climate Change

According to Yale University's latest Environmental Performance Index of air quality worldwide, South Korea ranks near the bottom, 173rd out of 180 countries. Although a portion of its pollution drifts downwind from China, a significant portion is homegrown. Thanks to South Korea's network of coal-fired power plants and its reliance on diesel-powered vehicles, more than half of South Korea's citizens regularly breathe dangerously polluted air, characterized by high levels of particulates and ozone.

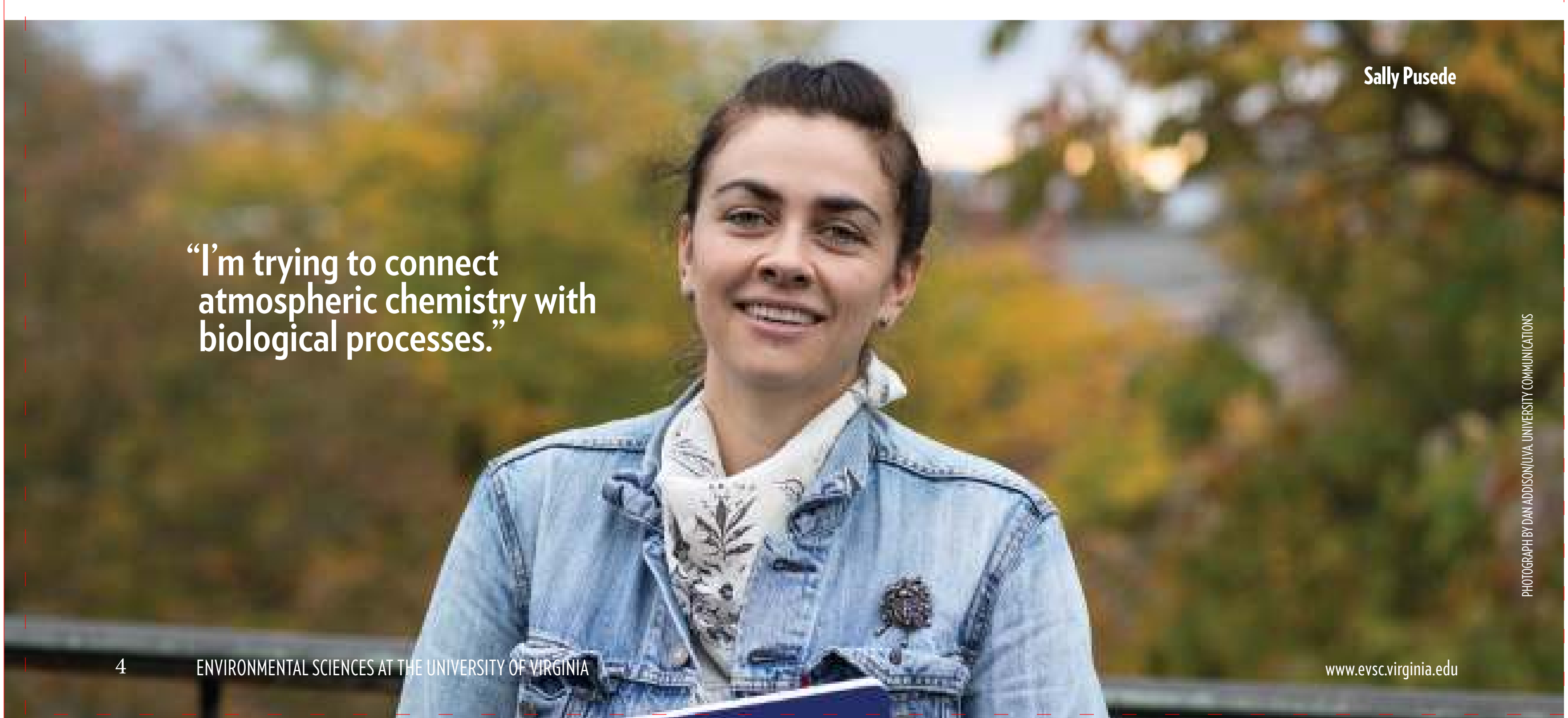
Assistant Professor **Sally Pusede** participated in KORUS-AQ (the Korean-U.S. Air Quality study), a project sponsored by NASA and Korea's National Institute of Environmental Research (NIER) to better understand the factors controlling air quality across urban, rural, and coastal interfaces in South Korea. As part of KORUS-AQ, Pusede worked with colleagues at NASA Langley Research Center to measure the pollutant carbon monoxide and greenhouse gases methane and nitrous oxide onboard the NASA DC-8.

KORUS-AQ scientists are now integrating observations from multiple aircraft, ground sites, and satellites with air quality models to understand how emissions, chemistry, and meteorology affect the composition of the local atmosphere. Pusede and environmental sciences undergraduate student Claire So (Class of 2017) have focused on using aircraft data to quantify the wide variety of molecules emitted from rice paddies, which cover almost 10 percent of the South Korean Peninsula. The NASA DC-8 sampling period corresponded to two months devoted to rice transplantation and paddy flooding.

Rice cultivation releases methane and nitrous oxide, two long-lived greenhouse gases, as well as volatile reactive compounds such as organic acids and alcohols. While paddy biogeochemistry is well described at the organismal scale, KORUS-AQ produced the first suite of measurements that can be used to test biogeochemical controls at regional spatial scales.

It was not easy. Pusede and So undertook the difficult task of teasing apart the rice signature from other sources such as forests, cities, and industry. "It is a very complex challenge, especially when the chemicals are long-lived," she says. "This makes it difficult to determine where they came from." So far, Pusede and So have quantified regional emissions and variability in emissions of methane and nitrous oxide from rice cultivation, but they are most interested in interactions between rice emissions and air pollution.

Pusede and So have found that the deposition of aerosol pollution suppresses methane emissions generated by rice paddies near large cities. But the interaction between atmospheric chemistry and biology doesn't end there. They are now in the process of looking at other molecules emitted by rice. "The small oxygenates emitted from the paddies may be involved in air pollution formation, for example, ozone production," she says. "It is starting to get really complicated!" ■



Sally Pusede

PHOTOGRAPH BY DAN ADDISON/UVA UNIVERSITY COMMUNICATIONS

Manuel Lerdau

PHOTOGRAPH BY JANE HALEY/UVA PUBLIC AFFAIRS

Exploring the Ozone Feedback Loop

Ozone in the troposphere, the lowest level of the atmosphere, can wreak havoc on individual plants by interfering with their metabolism, but, as it turns out, these effects are not as significant as they might seem. Professor **Manuel Lerdau**, working with Professor Hank Shugart and graduate students Bin Wang and Jacquelyn Shuman (now at the University Corporation for Atmospheric Research), discovered that high ozone levels do not necessarily translate over time into lost forest productivity or impaired ability to store carbon.

The reason: tree species vary in their tolerance for ozone. Advances in computing power enabled the team to model individual forest trees, link them to ecosystem and biogeochemical processes, and simulate the successional dynamics of species composition and structural change of a typical temperate deciduous forest in the Southeast. They found that after 500 years, there was virtually no difference in productivity or carbon sequestration between forests exposed to ozone stress and those that were not. Forest composition, however, was significantly altered. Not surprisingly, ozone-tolerant species predominated when ozone effects on growth and competitive ability were included in the model.

"This project reflects my interest in how biological processes, especially those of plants, insects, and microbes, interact with the atmosphere," Lerdau says. "We often find, as we did here, that they are affected by the composition of the atmosphere. They also play a role in determining that composition."

In this case, it is because ozone-tolerant species have an intriguing characteristic: they produce an abundance of isoprene, an organic compound that contributes to the production of atmospheric ozone. In other words, high ozone levels set in motion a positive feedback loop that can push ozone levels even higher.

These findings attracted attention of researchers from NASA's Jet Propulsion Laboratory (JPL), who read about the group's findings in *Scientific Reports* and reached out to Lerdau to explore this feedback loop. "Atmospheric chemists can't fully account for ozone formation unless they understand the biology of isoprene formation," he says. "I am going to be working with them to bridge our two fields at different spatial scales."

The plan is to continuously monitor isoprene production and other metrics during the growing season using instruments from research towers located in several forests. At the same time, they will launch an intensive aircraft campaign, flying over the towers and in surrounding areas to increase spatial coverage. They will then correlate their measurements with satellite data. "The goal is to be able to scale up, from the tower to the plane to the satellite, and do so over several growing seasons," Lerdau says. "We hope to develop a comprehensive view of the ozone feedback loop that can be used to inform climate models." ■

FACTORING HUMAN BEINGS INTO THE EQUATION

Human beings are now the prime driver of environmental change, but they are also being driven by the changes that they have put in motion.

Improving Resiliency to Sea Level Rise

Half of the world's population currently lives within 100 miles of the coast. Unfortunately, they face the prospect of finding themselves substantially closer over coming decades, thanks to sea level rise. Healthy coastal ecosystems provide a first line of defense for coastal communities, but in many areas of the world, these ecosystems have been severely damaged. Wetlands are filled for development, coral reefs are smothered by sediment, mangrove forest are replaced by shrimp farms, and the list of insults goes on and on.

Karen McGlathery

PHOTOGRAPH COURTESY OF THE VIRGINIA COAST RESERVE LONG-TERM ENVIRONMENTAL RESEARCH PROGRAM

"If we are to minimize the disruption from rising sea level and storms, we must protect and restore our damaged coastal ecosystems," says Professor **Karen McGlathery**. "We also must also find ways to apply lessons learned about these ecosystems to boost the resiliency of our urban and suburban environment." McGlathery has been deeply involved in both these efforts.

Over the last 30 years, department faculty members working under the auspices of the Virginia Coast Reserve Long Term Ecological Research (VCR-LTER) program have focused on 60 miles of undeveloped barrier islands, lagoons, and marshlands along Virginia's Eastern Shore in collaboration with The Nature Conservancy. During this time, they have discovered that coastal ecosystems are resilient to sea level rise and storms to a certain degree, but can be pushed past a tipping point by accelerated sea level rise or more extreme or frequent storms. This is critical for managing the coasts to protect coastal communities.

Faculty members have also explored ways to return coastal ecosystems to a more productive state. For instance, McGlathery, the VCR-LTER's lead principal investigator, and others have participated over the last decade in the most successful seagrass recovery project in the world, restoring an ecosystem that was obliterated 80 years ago by disease and a hurricane. In another effort, Associate Professor Matt Reidenbach and Professor Pat Wiberg are developing more effective ways to restore oyster reefs. Oysters not only filter water and improve its clarity, but the reefs they form serve as protective barriers for wetlands, shielding them from the small storms that are most damaging to them.

Successfully incorporating such natural defenses in an urban environment, however, is necessarily an interdisciplinary task. In 2016, the University's Board of Visitors created the Environmental Resilience Institute, which McGlathery directs, with the idea of mobilizing a broad response to environmental challenges. Reidenbach, for instance is working with faculty of the Architecture and Engineering schools as well as a member of the University's Institute of Environmental Negotiation to frame a long-term development strategy for Virginia's urban coastal communities. Its goal is to boost their resilience while enhancing the productivity of the marine environment.

We are in the midst of a paradigm shift," McGlathery says. "Coastal flooding is the new normal. Because we can no longer expect to keep the ocean out, we need to learn to live with water." ■

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Highlighting Commonalities between Urban and Rural Ecosystems

Rural and urban ecosystems are commonly seen as polar opposites—one pristine and the other degraded—but for **Larry Band**, the newly appointed Ernest H. Ern Professor of Environmental Sciences, a more productive view is to see them as part of a single continuum, with insights from one ecosystem applicable to the other. Accordingly, Band, an eco-hydrologist, is an investigator at both the Coweeta Long Term Ecological Research (LTER) site in southwestern North Carolina and the Baltimore Ecosystem Study, one of two urban sites in the National Science Foundation's LTER network.

"What we have tried to do is emphasize the commonalities between Baltimore and Coweeta," Band says. "Rather than declare differences, we draw on research at both sites to generate abstract ecological principles about how water, carbon, and nutrients are coupled as part of their ecosystem metabolism."

Coweeta LTER is located in a fully forested Southern Appalachian watershed, and as such is part of one of the most biodiverse and productive ecosystems in the temperate world. Baltimore, on the other hand, is an older urban center with little of its original forest cover. It has seen its population and employment decline with the boom of suburbs, producing remarkable inequality and extensive urban decay. Research in Coweeta and Baltimore, however, can reveal knowledge about one that can benefit the other.

Coweeta is an emergent forest system that has repeatedly recovered from extensive disturbance and tree loss to past logging and disease. "In Coweeta, we have an example of a forested ecosystem that spontaneously self-assembled in a stable and resilient form," Band says. "It conserves water, retains nitrogen, maximizes the sequestration of atmospheric carbon and has a productive and protective canopy."

Baltimore Office of Sustainability has similar objectives for the Baltimore ecosystems. It wants to reduce urban flooding, cut nitrogen loss to the Chesapeake Bay, and alleviate urban heat islands, partially by restoring its urban ecosystem in the form of green infrastructure.

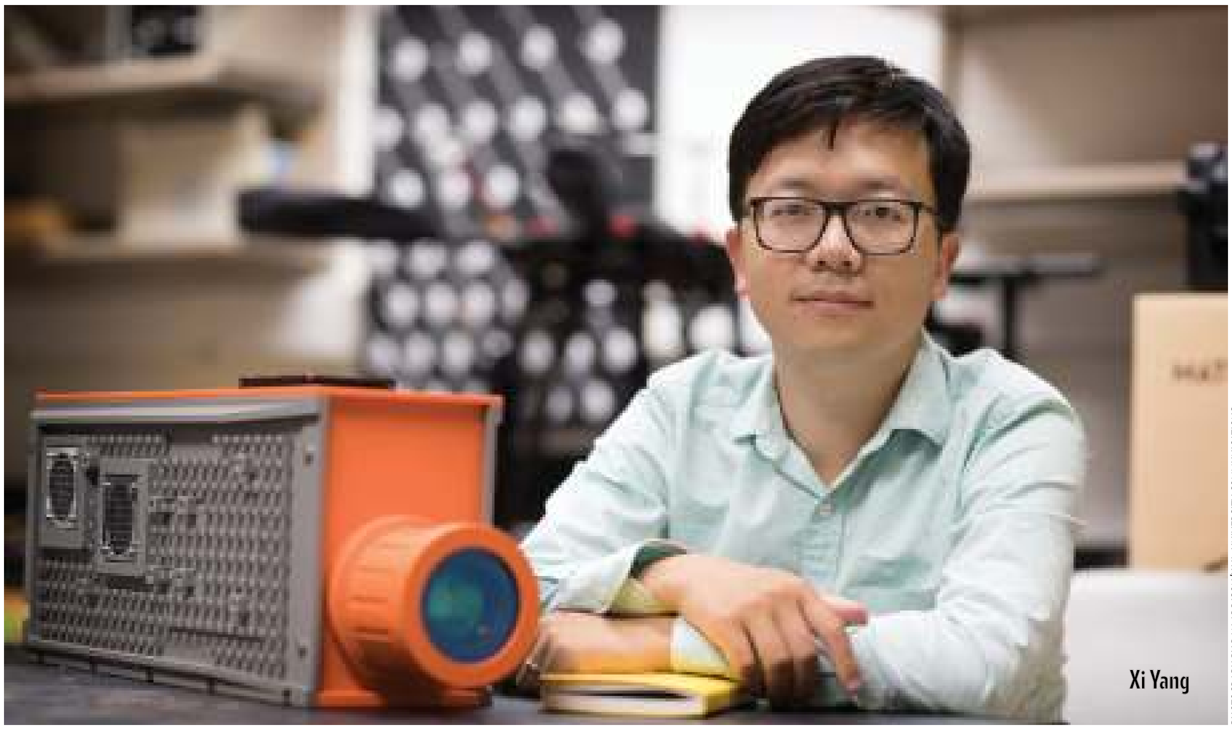

Larry Band

The challenge for Baltimore is two-fold. Because the landscape is constrained by its urban infrastructure, a resilient ecosystem will not emerge spontaneously. The other challenge is that efforts to strengthen the resilience of the system depend on the interests and cooperation of its citizens. "In Baltimore, human beings are the dominant species," Band observes. "Understanding social and economic structures is a critical part of understanding its ecology. Applying some of the organizing principles that provide ecosystem resilience in Coweeta to its urban design may improve both environmental health and human quality of life in Baltimore."

The goal is to redesign the Baltimore environment to be more like Coweeta, within the limits of a major city. At the same time, as more and more people build second homes in the Coweeta area, the lessons learned in Baltimore will be increasingly applicable there. ■

ASSESSING SHIFTS IN CLIMATE

The climate is changing, but there is still a need for insight into the speed of this change as well as for better tools to measure its effects.


Xi Yang

PHOTOGRAPH BY DAN ADDISON/U.VA. UNIVERSITY COMMUNICATIONS

Measuring Photosynthesis and Forest Function

There is no better diagnostic tool to judge the health of a forest or farm than the rate of photosynthesis. The more robust the process, the more chemical energy plants have in the form of carbohydrates to drive their growth and productivity. Because one of the raw materials for these carbohydrates is carbon dioxide, the rate of photosynthesis provides an indicator of the efficiency with which plants sequester carbon, a vital question in this age of climate change. And because the other is water, monitoring the rate of photosynthesis can help scientists better correlate the effects of drought on carbon fluxes.

Until recently, however, the measurements that researchers employed to assess photosynthesis on a large scale were imprecise. One of most common was the "greenness" of an ecosystem, a subjective gauge that even when used judiciously suffers from a critical flaw: it can take weeks in some cases for declining photosynthesis to make an appreciable difference in the color of vegetation.

A method developed by Assistant Professor **Xi Yang** is making it possible to measure photosynthesis more accurately and in real time. Yang and colleagues at Brown University and the Marine Biology Laboratory in Woods Hole, Massachusetts, discovered that spectrometers aboard satellites, designed to track carbon dioxide or ozone concentrations, were also detecting faint fluorescence coming from croplands and forest canopies. "If we could demonstrate that this was a byproduct of photosynthesis, we would have a way to measure the function of vegetation over large spatial scales," Yang says.

Yang and his colleagues installed an eddy covariance system on a tower in the 3,000-acre Harvard Forest in Petersham, Massachusetts. The eddy covariance system measured the fluxes of carbon dioxide and oxygen associated with photosynthesis. They found that their on-the-ground observations tightly correlated with satellite data from the same area, clinching the connection. They also found that a spectrometer on the tower produced results that matched the eddy covariance system, which meant that easy-to-use spectrometers could be used for local observations.

> "We are interested in how climate change in a boreal region affects the water cycle there."

Yang has now set out to demonstrate the value of this technology. With funding from NASA, he traveled to the North Slope of Alaska, where he is using a spectrometric instrument he designed to assess plant activity. "We are interested in how climate change in a boreal region—with the longer growing season that has resulted—affects the water cycle there," he says.

Yang has also adapted his spectrometer for use on airplanes and drones. He has flown above UVA as well as the department's Virginia Forest Research Facility. "We hope to be able to identify landscape level variation in photosynthesis and tie that to the microclimate," he says. ■

Building a Research Agenda to Understand Tropical Widening

For more than a decade, the scientific consensus is that the tropics, the region around the equator, have been expanding rapidly, beginning in the early 1980s. While the heart of the tropics are lush and forested, its edges, advancing north and south, are hot and dry. If these arid regions continue their march toward the poles, they will provoke a massive and destabilizing migration of species and in many cases of people. Biodiversity will suffer, and shifting currents and weather patterns will affect the productivity of farms and fisheries. Life in cities like San Diego, Santiago, and Melbourne will be very different.

There is little agreement, however, about the causes of this shift, how fast it is occurring, or even how to measure it. To address these issues, the U.S. Climate Variability and Predictability (CLIVAR) program—a consortium of agencies that includes the National Aeronautics and Space Administration, the National Ocean and Atmospheric Administration, the National Science Foundation, the Department of Energy, and the Office of Naval Research—created a working group to study the problem. Assistant Professor **Kevin Grise** cochairs the group.

"U.S. CLIVAR funds working groups to focus and energize research in critical areas," Grise says. "These groups synthesize the state of knowledge in a field and identify issues for future research. Their guidance helps program managers at funding agencies set priorities."

In addition to serving as cochair of the 19-person group, Grise heads one of its research thrusts, dedicated to summarizing current understanding of the drivers of tropical widening. These range from anthropogenic causes such as air pollution, climate change produced by greenhouse gases, and the stratospheric ozone hole on one hand and natural variability like the Pacific Decadal Oscillation on the other. Climate models implicate human activity for the shift, but they fail to account for the speed of the change that has been observed over the last few decades. Grise's group concluded that natural variability plays a more important role that previously recognized in the speed of tropical widening and that effects may be different in the Northern and Southern Hemispheres.

The working group's efforts, themselves, have also led to advances in knowledge. "Just the process of synthesizing existing research has led to new discoveries," Grise says. "We estimate that we will be producing more than a dozen papers on our findings, but there remain many questions yet to be answered." ■

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BEFORE AND AFTER

Changes in policy or regulation often provide an opportunity for researchers to gain a fundamental understanding of environmental processes.

Tracking the Return of Drakes Estero

For more than 40 years, Drakes Estero, a 2,500-acre network of interlocking lagoons 25 miles northwest of San Francisco, was home to one of the largest shellfish farms in California, which raised millions of oysters each year. The farm closed in 2014, and two years later the National Park Service (NPS), which manages Drakes Estero as part of the Point Reyes National Seashore, began remediation of this vital estuary by removing aquaculture infrastructure and debris. Its goal is to restore this federally protected marine wilderness to a more pristine condition by reducing the presence of invasive species while allowing critical native species to flourish.

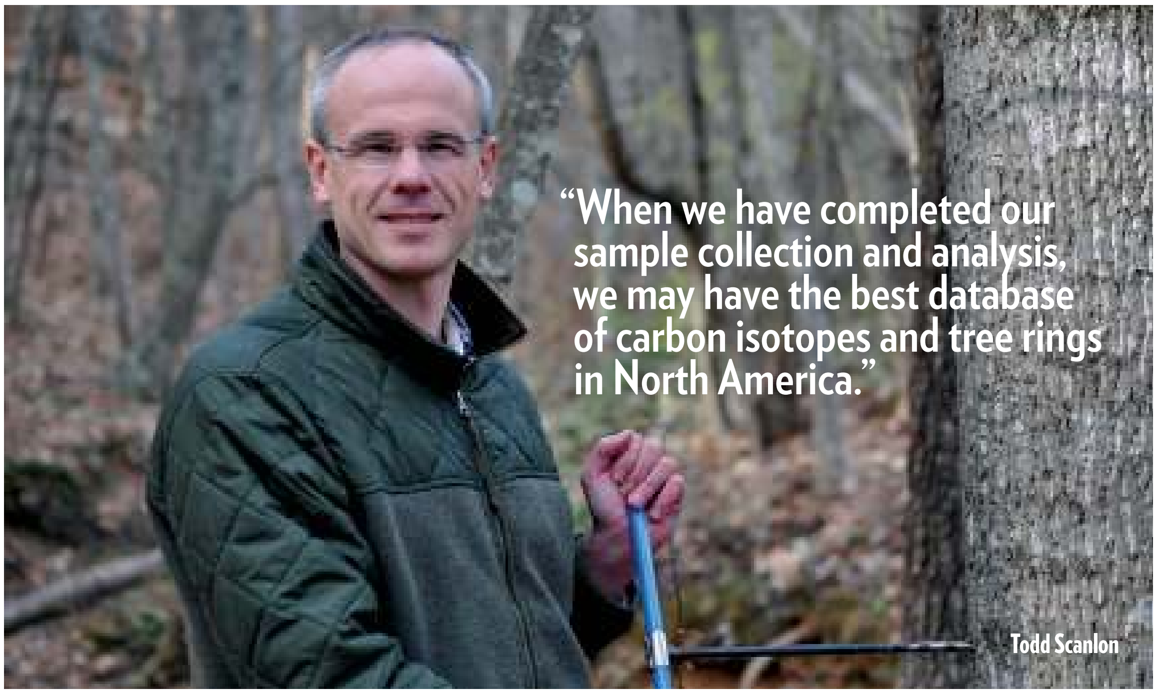

Max Castorani

"The scale of this coastal restoration project is remarkable," says Assistant Professor **Max Castorani**, an ecologist who joined the department in 2017. "From a research perspective, it represents an unmatched opportunity to study ecological resilience." The NPS is supporting Castorani and a colleague at UCLA to track the recovery of seagrass meadows—habitat-forming marine plants that carpet the seafloor of Drakes Estero—following the removal of 5 miles of oyster racks and nearly 1,300 tons of underwater plastic, wood, and shell debris. Seagrasses are highly valued in estuaries worldwide because they improve ecological function and support a rich diversity of invertebrates, fish, shorebirds, and marine mammals.

Castorani is broadly interested in the ways that coastal marine ecosystems and their associated biodiversity respond to disturbances. His work combines long-term observations, experiments, and models. At Drakes Estero, he is creating a baseline map of existing seagrass meadows and restored areas using a variety of devices including drones and then repeating these observations periodically. He will also combine these aerial measurements with underwater data gathered by the NPS. The goal is to determine how fast seagrass meadows recover and how the physical environment influences regrowth.

Because the aquaculture debris was spread unevenly across Drakes Estero, Castorani has a unique opportunity to address a second issue. "Our research will uncover how the scale and intensity of disturbance affects recovery rates," Castorani says. Furthermore, Castorani plans to expand the scope of this research project by studying how marine wildlife utilize the seagrass meadows as they recover. "Common, short-lived species that strongly depend on seagrass will likely track its recovery," he says. "Rare or long-lived species may take longer to colonize restored areas."

Castorani hopes that his findings will help NPS officials track the progress of the restoration. "In partnership with managers, this information will enable us to optimize seagrass restoration and monitoring. Effective seagrass conservation and management are important because these critical habitats are in decline globally due to human activities such as coastal development and industry." ■



PHOTOGRAPH BY JOANNE SCANLON

Connecting Acid Deposition and Groundwater Levels

For environmental scientists, the passage of the Clean Air Act Amendments in 1990 marked the beginning of an air quality experiment on a national scale. One of the 1990 amendments required major emission reductions of sulfur dioxide (SO2) and nitrogen oxides (NOx), the primary precursors of acid rain. The law was a striking success. As a result of the amendments, acid rain has dropped 65 percent since 1976, according to the Pacific Research Institute.

"These changes give us an opportunity to link the effects of acid deposition on carbon sequestration and water vapor emissions in forests and, by extension, its implications for climate change," says Associate Professor **Todd Scanlon**. Scanlon, a hydrologist, and Professor Howie Epstein, an ecologist, have received a grant from the National Science Foundation to investigate this connection.

In addition to making many lakes, streams, and wetlands toxic to aquatic animals, acid deposition robs the soil of essential nutrients like calcium, magnesium, and potassium. As a result, Scanlon, Epstein, and their colleagues at other universities conjecture that trees may have had to pump more water from the soil to obtain an adequate supply of nutrients, causing a subsequent loss of water flowing in streams. In this case, the extra water being drawn from the soil would have reduced their water use efficiency. This is a measure of how much water vapor plants lose through transpiration per unit absorbed through photosynthesis. In addition, the difficulty trees have in securing the sufficient nutrients might slow their growth, reducing their potential as carbon sinks.

"In periods of high acid deposition, we hypothesize that trees might pull less carbon dioxide from the air, while emitting more water vapor," Scanlon says.

With the decline in acid deposition over the last 20 to 30 years, forests soils have been able to retain more nutrients. To achieve the same growth rates, trees might be able to reduce the amount of water they pump through their systems, decreasing their demand for groundwater and lowering their water vapor emissions. They also may be growing more vigorously.

Scanlon and his colleagues are turning to tree ring analysis in eleven watersheds from Virginia to Maine to reveal the impact of rising and falling acid deposition on the amount of carbon dioxide absorbed and water vapor emitted. The width of the tree rings is a proxy for growth rate, and analysis of carbon isotopes in each ring provides an indicator of water use efficiency. Because of their underlying bedrock mineralogy and geological histories, each of the 11 watersheds responded to acid deposition differently. "When we have completed our sample collection and analysis, we may have the best database of carbon isotopes and tree rings in North America," said Scanlon.

If their analysis confirms their hypothesis, the response of forests to changing levels of acid deposition will have to be added to the land surface components of global climate models. "Because carbon dioxide and water vapor are the two most important greenhouse gases," Scanlon says, "it is vital to accurately model the land-atmosphere exchange." ■

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Awards, Appointments, and Publications

UNDERGRADUATE STUDENTS

The department recognizes fourth-year students who have done outstanding work in specific environmental sciences. This year, the Michael Garstang Atmospheric Sciences Award went to **Hyojin Claire So**, the Mahlon G. Kelly Prize in ecology went to **Leah M. Reichle** and **Jessie A. Thuma**, and the Hydrology Award went to **Filip D. Kawka**.

Yvonne V. Dinh was selected to receive the Hart Family Award for Undergraduate Research in Environmental Sciences. It provides funds to assist a full-time environmental sciences major conducting a supervised research project.

Allison M. Jensen received the Wallace-Poole Prize, awarded each year to the graduating student majoring in environmental sciences who has at least a 3.8 GPA and who is judged the most outstanding student in the class. She also was this year's recipient of the Trout Unlimited Award. Established by the Thomas Jefferson Chapter of Trout Unlimited, this award is presented for "significant contributions to research concerning cold-water fisheries or related ecosystems."

The Bloomer Scholarship, which provides $1,800 toward tuition, is given to an outstanding undergraduate environmental sciences major with a focus on geology. This year's winner was **Lily W. Wincele**.

Elizabeth S. Milo was honored for making the best undergraduate student presentation at the 33rd annual Environmental Sciences Student Research Symposium. Jaime F. Anderson created the best undergraduate poster presentation.

To be chosen for the College's distinguished majors program, students must achieve an overall GPA of 3.4 or above. This year, the department selected **Savannah M. Artusi**, **William G. Dillon**, **Lindsay L. Edwards**, **Jessica A. Flester**, **Kiera F. Givens**, **Allison M. Jensen**, **Carolyn A. Pugh**, **Leah M. Reichle**, **Hyojin Claire So**, and **Jessie A. Thuma** as distinguished majors.

Curtis Davis, a third-year civil and environmental engineering major with a minor in environmental sciences, recently won a University of Virginia Harrison Undergraduate Research Award. He is co-advised by Professors Sally Pusede and Manuel Lerdau. Funded by the family of the late David A. Harrison III, the Harrison Awards were first presented in 2000. Each year, approximately 40 awards of up to $3,000 each are granted on a competitive basis to undergraduate students.

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GRADUATE STUDENTS

Sharon Wilson Purdy was the winner of the Maury Environmental Sciences Prize, the department's premier award. Established by Dr. F. Gordon Tice in 1992, the award recognizes and honors outstanding undergraduate or graduate students for their contributions to environmental sciences, their ability to communicate their findings, and their efforts to promote a better understanding of the environment.

The department offers a series of awards honoring exceptional graduate students in environmental sciences specialties. **Melissa Hey** earned the Graduate Award in Ecology, **Ross T. Palomaki** won the Graduate Award in Atmospheric Sciences, **Amy E. Ferguson** won the Arthur A. Pegau Award in Geoscience, and **Emily Victoria S. Long** received the Ellison-Edmundson Award in Interdisciplinary Studies.

Kelsey S. Huelsman received the Thomas Jefferson Conservation Award, which supports basic research related to the conservation of the Earth's resources.

Lillian R. Aoki was this year's winner of the Joseph K. Roberts Award, given to a student who presents the most meritorious research paper at a national meeting.

Ross T. Palomaki won the Michael Garstang Award, which supports graduate student research in interdisciplinary atmospheric sciences.

Michael V. Saha received the Jay Zieman Research Publication Award, named after the late Jay Zieman, long-time chair of the department.

Brynn S. Cook was honored for making the best overall presentation at the 33rd annual Environmental Sciences Student Research Symposium. **Lillian R. Aoki** made the best graduate student presentation and **Amy E. Ferguson** produced the best graduate student poster.

Amy E. Ferguson and **Brynn S. Cook** won R.J. Huskey Graduate Research Exhibition poster presentation awards. The 2017 Huskey Graduate Research Exhibition, sponsored by the UVA Graduate School of Arts & Sciences, showcases graduate students' recent innovative research.

This year, **Lillian R. Aoki** won the Moore Research Award. Based on merit, this award was initiated to help sponsor the dissertation and thesis work of environmental sciences graduate students. **Alexandra M. Parisien**, **Cal D. Buelo**, **Jacob Malcomb**, and **Stephanie A. Roe** received Exploratory Research Awards, which support preliminary research leading to a thesis or dissertation proposal.

Atticus E. L. Stovall and **Ariel L. Firebaugh** received Fred Holmsley Moore Teaching Awards, which are bestowed on graduate teaching assistants distinguished by their ability to instill excitement, wonder, and confidence in students. An endowment set up by Fred H. Moore funds this award, along with matching donations from Mobil Oil Company.

Laura E. R. Barry and **Jessica A. Munyan** were awarded Presidential Fellowships in Data Science from the University for the 2017–18 academic year.

Solianna Herrera, **Emily Victoria S. Long**, and **Cal D. Buelo** won Virginia Space Grant Consortium Graduate Fellowships for 2017–18.

STAFF

William B. Tomanek won the Department Chair's Award, which recognizes an individual who has performed extraordinary service to the department.

Donna H. Fauber won the Graduate Student Association Award, which recognizes a member of the department who has been particularly helpful to the graduate student body.

FACULTY

Peter Berg was elected as a Fellow of the Association for the Sciences of Limnology and Oceanography (ASLO). This honor recognizes his exceptional contributions to advancing the field of aquatic sciences.

Thomas Biggs won the department's Environmental Sciences Organization Award, which is given to a member of the department who has been particularly helpful to undergraduate majors.

Linda Blum is a board member of the Chesapeake Bay Sentinel Site Cooperative, sponsored by the National Oceanic and Atmospheric Administration. At the University, Professor Blum serves on the College and Graduate School of Arts & Sciences Committee on Faculty Rules and participated in the Faculty Panel at Days on the Lawn.

David Carr is an associate editor of the *American Journal of Botany*. He serves on the Domain Science and Education Coordination Committee of the National Ecological Observatory Network. He served as a member of the Promotion and Tenure Committee of the UVA Department of Biology.

Robert Davis is a member of the University's Commencement and Convocations Committee.

Stephan De Wekker is an associate editor of the *Journal of Applied Meteorology and Climatology* as well as an associate editor of *Atmosphere*. He also served as a member of the Earth Observatory Science Advisory Team at the National Aeronautics and Space Administration. Professor De Wekker was a co-organizer of the 17th Conference on Mountain Meteorology, sponsored by the American Meteorological Society.

Paolo D'Odorico, the Ernest H. Ern Professor of Environmental Sciences, was honored with the annual Paul A. Witherspoon Lecture Award from the Hydrology Section of the American Geophysical Union, which recognizes significant and innovative contributions in hydrologic sciences by a mid-career scientist. The award is an acknowledgement that the awardee shows exceptional promise for continued leadership in hydrologic sciences.

Howard E. Epstein is a review editor of *Frontiers in Interdisciplinary Climate Studies* and a member of the board of directors of the Arctic Research Consortium of the United States. At the University, he is co-director of the College Science Scholars program and served on the College and Graduate School of Arts & Sciences Committee on Graduate Educational Policy and Curriculum. He is also an advisor to the Jefferson Scholars Foundation Graduate Selection Committee.

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James N. Galloway, the Sidman P. Poole Professor of Environmental Sciences, served as a member of the Environmental Protection Agency's Science Advisory Board as well as the Board of Scientific Counselors to its Office of Research and Development. He is also an associate editor of *Environmental Development*. In addition, Professor Galloway is a trustee of the Marine Biological Laboratory at Woods Hole, Massachusetts, and a member of the Board of Trustees of the Bermuda Institute of Ocean Sciences (formerly the Bermuda Biological Station for Research). At the University, he serves as chair of the Environmental Resilience Coordinating Committee and is a member of the University Committee on Sustainability.

Kevin Grise is co-chair of the Changing Width of the Tropical Belt Working Group, which is sponsored by the United States Climate Variability and Predictability Program. His paper, "Is climate sensitivity related to dynamical sensitivity?" was selected as an Editor's Highlight by the *Journal of Geophysical Research: Atmospheres*. At the University, he served as a judge at the annual Huskey Graduate Research Exhibition.

Janet S. Herman is president of the Karst Waters Institute. At the University, she serves as the chair of the College and Graduate School of Arts & Sciences Committee on Educational Policy and Curriculum.

Alan D. Howard served on the Fellows Selection and Awards Committees of the American Geophysical Union.

William Keene (retired) received an Editor's Citation from *Geophysical Research Letters* for excellence in refereeing.

Deborah Lawrence spent the year as a Fellow at Stanford University's Center for Advanced Study in the Behavioral Sciences. She serves on proposal review panels for the U.S. Department of Energy. At the University, Professor Lawrence served on the Dean's Committee on Targets of Opportunity and the Dean's Committee on Diversity and Inclusion, all for the College and Graduate School of Arts & Sciences. She is a trustee of the Virginia Chapter of The Nature Conservancy.

Manuel Lerdau serves on proposal review panels for the U.S. Department of Energy. At the University, he is a member of the University's Sexual Assault Board and of the Sustainability @UVA initiative.

Stephen A. Macko serves on the Committee on Education of the European Geosciences Union and is editor-in-chief of *Nitrogen*. At the University, he is the Environmental Sciences representative to the Faculty Senate and chairs the Policy Committee. He is also a member of the Faculty Advisory Committee to the Honor Committee and a member of the University Libraries Committee.

Karen J. McGlathery is the University's associate vice president for research, sustainability, and the environment. She also serves as the lead principal investigator of the Virginia Coast Reserve Long-Term Ecological Research (LTER) program, sits on the national LTER Science Council, and advises the Florida Coastal Everglades LTER and the Moorea Coral Reef LTER. In addition, Professor McGlathery is an associate editor of *Ecosystems* and a member of the board of the Foundation of the State Arboretum of Virginia. At the University, she serves on the Dean's Committee on Academic Priorities for the College and Graduate School of Arts & Sciences as well as the Environmental Politics Search Committee. This year, the department awarded Professor McGlathery its Maury-Tice Prize for research excellence.

Aaron L. Mills is a member of the Committee on Environmental Microbiology and the Public and Scientific Affairs Board of the American Society for Microbiology. At the University, he serves as secretary of the Faculty of Arts & Sciences and as a member of the University Assessment Advisory Committee and the Institutional Biosafety Committee.

Michael Pace chairs the department. This year, he received the Naumann-Thienemann Medal from the International Society of Limnology (SIL). The award is the highest honor that can be bestowed internationally for outstanding scientific contributions to limnology. Professor Pace was also elected president of the Association for the Sciences of Limnology and Oceanography (ASLO) and will serve as president-elect from 2016 to 2018. He also serves as chair of its Finance Committee and as a member of its Publications Committee. He served as an associate editor of *Ecosystems* and as a member of the NatureNet Science Fellows Review Committee.

John Porter is a member of the national LTER Network Information System Advisory Committee and advisor to the Luquillo LTER.

Sally Pusede is an associate editor at *Atmospheric Chemistry and Physics*.

G. Carleton Ray served as a member of the Board of Trustees of the Bahamas National Trust.

Matthew Reidenbach is an associate editor of *Advances in Water Research* and served on the Awards Committee of the Coastal and Estuarine Research Federation. At the University, he is a member of the Jefferson Scholars Foundation Undergraduate Selection Committee.

T'ai Roulston is an associate editor of *Ecosphere* and served as a member of the Biology Faculty Search Committee.

William Ruddiman (retired) was awarded the Distinguished Career Award from the Geological Society of America's Quaternary Geology & Geomorphology Division.

Todd Scanlon served as a reviewer for the Harrison Undergraduate Research Awards and as a member of the Committee on Personnel Policy in the College and Graduate School of Arts & Sciences.

Herman H. Shugart, the W. W. Corcoran Professor of Environmental Sciences, is a member of the Biomass Mission Assessment Group for the European Space Agency as well as the Intelligence Science and Technology Experts Group at the National Academy of Sciences, Engineering, and Medicine. He is also an associate editor of *Ecosystems* and *Ecological Processes* and a member of the editorial boards of *PeerJ* and *Forest Ecosystems*. He is a trustee of the 500-Year Forest Foundation. In addition, he served on the Subcommittee on Earth Science of the NASA Advisory Council Science Committee. At the University, Professor Shugart serves as a member of the General Education Committee (Curriculum Planning) for the College and Graduate School of Arts & Sciences and is a member of the board of the University of Virginia Press.

David E. Smith serves the University as a member of the Executive Leadership Network, the Facilities Management Advisory Board, the Committee on Undergraduate Admission, and the Human Resources Advisory Council.

Vivian Thomson directs the Environmental Thought and Practice interdisciplinary major.

Patricia Wiberg is an associate editor of *ESurf*. She serves on the executive committee of the American Geophysical Union's Earth & Planetary Surface Processes Focus Group and chaired the Steering Committee of the National Science Foundation's Community Surface Dynamics Modeling System, a modeling community of approximately 1,100 members. At the University, she is a member of the Steering Committee of the College and Graduate School of Arts & Sciences as well as the Provost's Promotion and Tenure Committee.

Xi Yang serves on proposal review panels for NASA.

PEER-REVIEWED PAPERS, BOOK CHAPTERS, AND BOOKS

(Summer 2016 through Spring 2017)

Aneece, I., and **H. Epstein**. 2017. Identifying invasive plant species using field spectroscopy in the VNIR region in successional systems of north-central Virginia. *International Journal of Remote Sensing* 38: 100–122. doi:10.1080/01431161.2016.1259682.

Berg, P., D. Koopmans, M. Huettel, H. Li, K. Mori, and A. Wüest. 2016. A new robust oxygen-temperature sensor for aquatic eddy covariance measurements. *Limnology and Oceanography Methods* 14: 151–167. doi:10.1002/lom3.10071.

Birch, S.P.D., A.G. Hayes, W.E. Dietrich, **A.D. Howard**, and 17 additional authors. 2017.Geomorphic mapping of Titan's polar terrains: Constraining surface processes and landscape evolution. *Icarus* 282: 214–236. doi:10.1016/j.icarus.2016.08.003.

Bratsch, S.N., **H. Epstein**, M. Buchhorn, D.A. Walker, and H.A. Landes. 2017. Relationships between hyperspectral data and components of vegetation biomass in Low Arctic tundra communities at Ivotuk, Alaska. *Environmental Research Letters* 12: 025003. doi:10.1088/1748-9326/aa572e.

Brazhnik, K., C. Hanley, and **H. H. Shugart**. 2017. Simulating changes in fires and ecology of the 21st century Eurasian boreal forests of Siberia. *Forests* 8: 49. doi:10.3390/f8020049.

Brazhnik, K., and **H.H. Shugart**. 2017. Model sensitivity to spatial resolution and explicit light representation for simulation of boreal forests in complex terrain. *Ecological Modelling* 352:90–107.

Carr, J.A., **P. D'Odorico**, **K.J. McGlathery**, and **P.L. Wiberg**. 2016. Spatially explicit feedbacks between seagrass meadow structure, sediment and light: habitat suitability for seagrass growth. *Advances in Water Resources* 93: 315–25. doi:10.1016/j.advwatres.2015.09.001.

Chipman, L., **P. Berg**, and M. Huettel. 2016. Benthic oxygen fluxes measured by eddy covariance in permeable Gulf of Mexico shallow-water sands. *Aquatic Geochemistry* 22: 529–554. doi:10.1007/s10498-016-9305-3.

Davis, R.E., E. Dougherty, C. McArthur, Q.S. Huang, and M.G. Baker. 2016. Cold, dry air is associated with influenza and pneumonia mortality in Auckland, New Zealand. *Influenza and Other Respiratory Viruses* 10(4): 310–313. doi:10.1111.irv.12369.

Davis, K.F., J. Gephart, K.A. Emery, A.M. Leach, **J.N. Galloway**, and **P. D'Odorico**. 2016. Meeting future food demand with current agricultural resources. *Global Environmental Change* 39: 125–132.

De Palma, A., **T.H. Roulston**, et al. 2016. Predicting bee community responses to land-use changes: effects of geographic and taxonomic biases. *Scientific Reports* 6: 31153. doi:10.1038/srep31153.

D'Odorico, P., J.L. Natyzak, **E.A. Castner**, K.F. Davis, K.A. Emery, J.A. Gephart, A.M. Leach, **M.L.Pace**, and **J.N. Galloway**. 2017. Ancient water supports today's energy needs. *Earth's Future* 5: 515–519. doi:10.1002/2017EF000544.

Duine, G.-J., T. Hedde, P. Roubin, P. Durand, M. Lothon, F. Lohou, P. Augustin, and M. Fourmentin. 2017. Characterisation of valley flows within two confluent valleys under stable conditions: observations from the KASCADE field experiment. *Q. J. Roy. Meteor. Soc.* 143: 1886–1902. doi: http://onlinelibrary.wiley.com/doi/10.1002/qj.3049/full.

Duine, G.-J., T. Hedde, P. Roubin, and P. Durand. 2016. A simple method based on routine observations to nowcast down-valley flows in shallow, narrow valleys. *J. Appl. Meteor Climatol* 55 (7): 1497–1511. doi:10.1175/JAMC-D-15-0274.1.

Firebaugh, A.L., and **K.J. Haynes**. 2016. Experimental tests of light-pollution impacts on nocturnal insect courtship and dispersal. *Oecologia* 182: 1203–1211. doi:10.1007/s00442-016-3723-1.

Foster, A.C., J.A. Walter, **H.H. Shugart**, J. Sibold, and J. Negron. 2017. Spectral evidence of early-stage spruce beetle infestation in Engelmann spruce. *Forest Ecology and Management* 384: 347–357. doi:10.1016/j.foreco.2016.11.004.

Foster, A.C., J.K. Shuman, **H.H. Shugart**, K.A. Dwire, P.J. Fornwalt, J. Sibold, and J. Negron. 2017. Validation and application of a forest gap model to the southern Rocky Mountains. *Ecological Modelling* 351: 109–128. doi:10.1016/j.ecolmodel.2017.02.019.

Frossard, A.A., L.M. Russell, **J.R. Maben**, M.S. Long, **W.C. Keene**, J.S. Reid, J. Kinsey, D.J. Kieber, P.K. Quinn, and T.S. Bates. 2017. Measurements of generated and ambient marine aerosol particles in August 2012 on board the R/V Ronald H. Brown during the Western Atlantic Climate Study (WACS). *University of California San Diego Library Digital Collections*. https://doi.org/10.6075/J04F1NNX.

Frossard, A.A., L.M. Russell, **J.R. Maben**, M.S. Long, **W.C. Keene**, J.S. Reid, J. Kinsey, D.J. Kieber, P.K. Quinn, and T.S. Bates. 2017. Measurements of generated and ambient marine aerosol particles in May and June 2010 on board the R/V Atlantis during the California Nexus (CalNex) Experiment. *University of California San Diego Library Digital Collections*. https://doi.org/10.6075/J00P0WX6.

Fuentes, J.D., M. Chamecki, **T.H. Roulston**, B. Chen, and K.R. Pratt. 2016. Air pollutants degrade floral scents and increase insect foraging times. *Atmospheric Environment* 141: 361–374. doi:10.1016/j.atmosenv.2016.07.002.

Gephart, J.A., L. Deutsch, **M.L. Pace**, M. Troell, and D.A. Seekell. 2017. Shocks to fish production: identification, trends, and consequences. *Global Environmental Change* 42: 24–32. doi:10.1016/j.gloenvcha.2016.11.003

Glud, R.N., **P. Berg**, H. Stahl, A. Hume, M. Larsen, B.D. Eyre, and P.L.M. Cook. 2016. Benthic carbon mineralization and nutrient turnover in a Scottish sea loch: An integrative in situ study. *Aquatic Geochemistry* 22: 443–467. doi:10.1007/s10498-016-9300-8.

Grise, K.M., and B. Medeiros. 2016. Understanding the varied influence of midlatitude jet position on clouds and cloud radiative effects in observations and global climate models. *Journal of Climate* 29: 9005–9025. doi:10.1175/JCLI-D-16-0295.1

Grise, K.M., and L.M. Polvani. 2016. Is climate sensitivity related to dynamical sensitivity? *Journal of Geophysical Research-Atmospheres* 121: 5159–5176. doi:10.1002/2015JD024687.

Gultepe, I., H.J.S. Fernando, E.R. Pardyjak, S.W. Hoch, Z. Silver, E. Creegan, L.S. Leo, Z. Pu, **S.F.J. De Wekker**, and C. Hang. 2016. An overview of the MATERHORN Fog Project: observations and predictability. *Pure Appl. Geophys.* 173: 2983–3010. doi:10.1007/s00024-016-1374-0.

He, Y.L., J.H. Huang, **H.H. Shugart**, X.D. Guan, B. Wang, and K.L. Yu. 2017. Unexpected evergreen expansion in the Siberian forest under warming hiatus. *Journal of Climate* 30: 5021–5039. doi:10.1175/JCLI-D-16-0196.1.

Heckman, R.W., and **D.E. Carr**. 2016. Effects of soil nitrogen availability and native grass diversity on exotic forb dominance. *Oecologia* 182: 803–813. doi:10.1007/s00442-016-3692-4.

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Heckman, R.W., C. McColley, M.N. Slater, and **D.E. Carr**. 2017. The role of community composition in grassland response to two methods of exotic forb removal. *Weed Research* 57: 44–53. doi:10.1111/wre.12235.

Holm, J.A., S.J. Van Bloem, **H.H. Shugart**, and G.R. Larocque. 2017. Shifts in biomass and productivity for a subtropical dry forest in response to simulated elevated hurricane disturbances. *Environmental Research Letters* 12(2): 025007.

Howard, A.D., J.M. Moore, O.M. Umurhan, and 11 additional authors. 2017. Present and past glaciation on Pluto. *Icarus* 287: 287–300. doi:10.1016/j.icarus.2016.07.006.

Howard, A.D., J.M. Moore, O.M. White, and 14 additional authors. 2017. Pluto: Pits and mantles on uplands north and east of Sputnik Planitia. *Icarus* 293: 218–230. doi:10.1016/j.icarus.2017.02.027.

Hutton, M.O., A.M. Leach, A. Leip, **J.N. Galloway**, M. Bekunda, C. Sullivan, and J.P. Lesschen. 2017. Toward a nitrogen footprint calculator for Tanzania. *Environmental Research Letters* 12: 034016. doi:10.1088/1748–9326/aa5c42.

Ju, X.T., B.J. Gu, Y.Y Wu, and **J.N. Galloway**. 2016. Reducing China's fertilizer use by increasing farm size. *Global Environmental Change* 41: 26–32. doi:10.1016/j.gloenvcha.2016.08.005.

Kanter, D.R., J.A. Wentz, **J.N. Galloway**, W.R. Moomaw, and W. Winiwarter. 2017. Managing a forgotten greenhouse gas under existing US law: An interdisciplinary analysis. *Environmental Science & Policy* 67: 44–51. doi:10.1016/j.envsci.2016.11.003.

Leach, A.M., K.A. Emery, J. Gephart, K.F. Davis, J.W. Erisman, A. Leip, **M.L. Pace**, **P. D'Odorico**, J. Carr, **L. Cattell Noll**, **E. Castner**, and **J.N. Galloway**. 2016. Environmental impact food labels combining carbon, nitrogen, and water footprints. *Food Policy* 61: 213–223. doi:10.1016/j.foodpol.2016.03.006.

Li, W., **H. Epstein**, Z. Wen, J. Zhao, J. Jin, G. Jing, J. Cheng, and G. Du. 2017. Community-weighted mean traits but not functional diversity determine the changes in soil properties during wetland drying on the Tibetan Plateau. *Solid Earth* 8: 137–147. doi:10.5194/se-8-137-2017.

Li, W., J. Zhao, **H. Epstein**, G. Jing, J. Cheng, and G. Du. 2016. Community-level trait responses and intra-specific trait variability play important roles in driving community productivity in an alpine meadow on the Tibetan Plateau. *Journal of Plant Ecology* 10: 592–600. doi:10.1093/jpe/rtw069.

Liang, X., A.M. Leach, **J.N. Galloway**, B. Gu, S.K. Lam, and D. Chen. 2016. Beef and coal are key drivers of Australia's high nitrogen footprint. *Scientific Reports* 6: 39644. doi:10.1038/srep39644.

Ludeman, D.A., **M.A. Reidenbach**, and S.P. Leys. 2017. The energetic cost of filtration by demosponges and their behavioral response to ambient currents. *Journal of Experimental Biology* 220 (6): 995–1007. doi:10.1242/jeb.146076.

Ma, J.Y., **H.H. Shugart**, X.D. Yan, C.G. Cao, S. Wu, and J. Fang. 2017. Evaluating carbon fluxes of global forest ecosystems by using an individual tree-based model FORCCHN. *Science of the Total Environment* 586: 939–951. doi:10.1016/j.scitotenv.2017.02.073.

Macko, S.A. 2016. "Environmental Aspects of Hydrocarbon Exploration in the Arctic." In *Challenges of the Changing Arctic: Continental Shelf, Navigation, and Fisheries*, M.H. Nordquist, J.N. Moore, and R. Long, editors, 130–144. Brill Academic: The Netherlands.

Moore, J. M., **A.D. Howard**, O.M. Umurhan, and 13 additional authors. 2017. Sublimation as a landform-shaping process on Pluto. *Icarus* 287: 320–333. doi:10.1016/j.icarus.2016.08.025.

Murphy, A.E., K.A. Emery, I.C. Anderson, **M.L. Pace**, M.J. Brush, and J.E. Rheuban. 2016. Quantifying the effects of commercial clam aquaculture on C and N cycling: an integrated ecosystem approach. *Estuaries and Coasts* 39: 1746–1761. doi:10.1007/s12237-016-0106-0.

Murphy, E.A.K. and **M.A. Reidenbach**. 2016. Oxygen transport in periodically ventilated polychaete burrows. *Marine Biology* 163: 208. doi:10.1007/s00227-016-2983-y.

Oreska, M.P.J., **K.J. McGlathery**, and **J.H. Porter**. 2017. Seagrass blue carbon spatial patterns at the meadow-scale. *PLoS ONE* 12(4): e0176630. doi:10.1371/journal.pone.0176630.

Oreska, M.P.J., B. Truitt, R.J. Orth, and M.W. Luckenbach. 2017. The bay scallop (*Argopecten irradians*) industry collapse in Virginia and its implications for the successful management of scallop-seagrass habitats. *Marine Policy* 75: 116–124. doi:10.1016/j.marpol.2016.10.021.

Ormerod, S.J., and **G.C. Ray**. 2016. Connecting the shifting currents of aquatic science and policy. *Aquatic Conservation: Marine and Freshwater Ecosystems* 26: 995–1004. doi:10.1002/aqc.2708.

Ott, L.E., B.N. Duncan, A.M. Thompson, G.S. Diskin, Z. Fasnacht, A.O. Langford, M. Lin, A.M. Molod, J.E. Nielsen, **S.E. Pusede**, K. Wargan, A. Weinheimer, and Y. Yoshida. 2016. Frequency and impact of summertime stratospheric intrusions over Maryland during DISCOVER-AQ (2011): New evidence from NASA's GEOS-5 simulations. *Journal of Geophysical Research-Atmospheres*, 121: 3687–3706. doi:10.1002/2015JD024052.

Pace, M.L., R.D. Batt, C.D. Buelo, S.R. Carpenter, J.J. Cole, J.T. Kurtzweil, and G.M. Wilkinson. 2017. Reversal of a cyanobacterial bloom in response to early warnings. *Proceedings of the National Academy of Sciences USA* 114: 352–357. doi:10.1073/pnas.1612424114.

Pace, M.L., and J.A. Gephart. 2017. Trade: a driver of present and future ecosystems. *Ecosystems* 20: 44–53. doi:10.1007/s10021-016-0021-z.

Pal, S., **S.F.J. De Wekker**, and G.D. Emmitt. 2016. Investigation of the Spatial Variability of the Convective Boundary Layer Heights over an Isolated Mountain: Cases from the MATERHORN-2012 Experiment. *Journal of Applied Meteorology and Climatology* 55: 1927–1952. doi:10.1175/JAMC-D-15-0277.1.

Palomaki, R.T., **N.T. Rose**, **M. Van den Bossche**, **T.J. Sherman**, and **S.F.J. De Wekker**. 2017. Wind Estimation in the Lower Atmosphere Using Multirotor Aircraft. *J. Atmos. Oceanic Technol.* 34: 1183–1191. doi:10.1175/JTECH-D-16-0177.1.

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Porter, J.H. 2016. "Sharing Information: Many hands make light work." In *Long-term Ecological Research: Changing the nature of scientists*, edited by M.R. Willig and L.R. Walker, 381–390. Oxford University Press: New York.

Porter, J.H., and C.C. Lin. 2017. "Chapter 24: Ecology: Concepts and Practices" (Traditional Chinese Edition). In *Ecoinformatics: a new paradigm for ecology*, edited by J. Manuel C. Molles,555–568. McGraw-Hill International Enterprises: Taipei, Taiwan.

Roulston, T.H., S. Cruz Maysonet, A.L. Moorhouse, S. Lee, and A.N. Emerson. 2017. Natural history of *Symmetrischema lavernella* (Lepidoptera: Gelechiidae): a moth with two feeding strategies and the ability to induce fruit formation in the absence of pollination. *The Canadian Entomologist* 149: 326–337. doi:10.4039/tce.2016.65.

Ruddiman, W.F. 2016. The Early Anthropogenic hypothesis. *Oxford Research Encyclopedia of Environmental Science*. doi:10.1093/acrefore/9780199389414.013.192.

Saha, M.V., **T.M. Scanlon**, and **P. D'Odorico**. 2016. Suppression of rainfall by fires in African drylands, *Geophysical Research Letters*, 43: 8527–8533. doi:10.1002/2016GL069855.

Shibata, H., **J.N. Galloway**, A.M. Leach, L.R. Cattaneo, **L. Cattell Noll**, J.W. Erisman, B. Gu, X. Liang, K. Hayashi, L. Ma, T. Dalgaard, M. Graversgaard, D. Chen, K. Nansai, J. Shindo, K. Matsubae, A. Oita, M.C. Su, S. I. Mishima, and A. Bleeker. 2017. Nitrogen footprints: Regional realities and options to reduce nitrogen loss to the environment. *Ambio* 46: 129–142. doi:10.1007/s13280-016-0815-4.

Shuman, J.K., A.C. Foster, **H.H. Shugart**, A. Hoffman-Hall, A. Krylov, T. Loboda, D. Ershov, and E. Sochilova. 2017. Fire disturbance and climate change: implications for Russian forests. *Environmental Research Letters* 12 (3): 035003. doi:10.1088/17748-9326/aa5eed.

Smith, T.M., and R.L. Smith. 2017. *Elementi di Ecologia* (Elements of Ecology: Italian Language) 9th edition. Pearson Italia: Milano, Italy.

Stocking, J.B., J.P. Rippe, and **M.A. Reidenbach**. 2016. Structure and dynamics of turbulent boundary layer flow over healthy and algae-covered corals. *Coral Reefs* 35: 1047–1059. doi:10.1007/s00338-016-1446-8.

Stoken, O.M., **A.L. Riscassi**, and **T.M. Scanlon**. 2016. Association of dissolved mercury with dissolved organic carbon in U.S. rivers and streams: The role of watershed soil organic carbon. *Water Resources Research* 52: 3040–3051. doi:10.1002/2015WR017849.

Sulman, B.N., D.T. Roman, **T.M. Scanlon**, L. Wang, R. and K.A. Novick. 2016. Comparing methods for partitioning a decade of carbon dioxide and water vapor fluxes in a temperate forest. *Agricultural and Forest Meteorology*: 226–227, 229–245, doi:10.1016/j.agrformet.2016.06.002.

Tanentzap, A.J., B.W. Kielstra, G.M. Wilkinson, M. Berggren, N. Craig, P.A. del Giorgio, J. Grey, J.M. Gunn, S.E. Jones, J. Karlsson, C.T. Solomon, and **M.L. Pace**. 2017. Terrestrial support of lake food webs: Synthesis reveals controls over cross-ecosystem resource use. *Science Advances* 3: e1601765. doi:10.1126/sciadv.1601765.

Tang, J., C. Körner, H. Muraoka, S. Piao, M. Shen, S.J. Thackeray, and **X. Yang**. 2016. Emerging opportunities and challenges in phenology: a review. *Ecosphere* 7 (8): e01436. doi:10.1002/ecs2.1436.

Tselioudis, G., B.R. .Lipat, D. Konsta, **K.M. Grise**, and L.M. Polvani. 2016. Midlatitude cloud shifts, their primary link to the Hadley cell, and their diverse radiative effects. *Geophysical Research Letters* 43: 4594–4601. doi:10.1002/2016GL068242.

Umurhan, O.M., **A.D. Howard**, and 13 additional authors. 2017. Modeling glacial flow on and onto Pluto's Sputnik Planitia. *Icarus* 287: 301–319. doi:10.1016/j.icarus.2017.01.017.

Van den Bossche, M., and **S.F.J. De Wekker**. 2016. Spatiotemporal variability of surface meteorological variables during fog and no-fog events in the Heber Valley, UT; selected case studies from MATERHORN-Fog. *Pure Appl. Geophys.* 173: 3031–3048. doi:10.1007/s00024-016-1352-6.

Van den Bossche, M., **N.T. Rose**, and **S.F.J. De Wekker**. 2017. Potential of a low-cost gas sensor for atmospheric methane monitoring. *Sensors and Actuators B: Chemical* 238: 501–509. doi:10.1016/j.snb.2016.07.092.

Vu, K.T., J.H. Dingle, R. Bahreini, P.J. Reddy, E.C Apel, T.L. Campos, J.P. Digangi, G.S. Diskin, A. Fried, S.C. Herndon, A.J. Hills, R.S. Hornbrook, G. Huey, L. Kaser, D.D. Montzka, J.B. Nowak, **S.E. Pusede**, D. Richter, J.R. Roscioli, G.W. Sachse, S. Shertz, M. Stell, D. Tanner, G.S. Tyndall, J. Walega, P. Weibring, A.J. Weinheimer, G. Pfister, and F. Flocke. 2016. Impacts of the Denver Cyclone on regional air quality and aerosol formation in the Colorado Front Range during FRAPPÉ 2014. *Atmospheric Chemistry and Physics* 16: 12039–12058, doi:10.5194/acp-16-12039-2016.

Walker, D.A., A.L. Breen, L.A. Druckenmiller, L.W. Wirth, W. Fisher, M.K. Raynolds, J. Šibík, M.D. Walker, S. Hennekens, K. Boggs, T. Boucher, M. Buchhorn, H. Bültmann, D.J. Cooper, F.J.A. Daniëls, S.J. Davidson, J.J. Ebersole, S.C. Elmendorf, **H.E. Epstein**, W.A. Gould, R.D. Hollister, C.M. Iverson, M.T. Jorgenson, A. Kade, M.T. Lee, W.H. MacKenzie, R.K. Peet, J.L. Peirce, U. Schickhoff, V.L. Sloan, S.S. Talbot, C.E. Tweedie, S. Villarreal, P.J. Webber, and D. Zona. 2016. The Alaska Arctic Vegetation Archive (AVA-AK). *Phytocoenologia* 46: 221–229. doi:10.1127/phyto/2016/0128.

Walker, D.A., F.J.A. Daniëls, I. Alsos, U.S. Bhatt, A.L. Breen, M. Buchhorn, H. Bültmann, L.A. Druckenmiller, M.E. Edwards, D. Ehrich, **H.E. Epstein**, W.A. Gould, R.A. Ims, H. Meltofte, M.K. Raynolds, J. Sibik, S.S. Talbot, and P.J. Webber. 2016. Circumpolar Arctic vegetation: A hierarchic review and roadmap toward an internationally consistent approach to survey, archive and classify tundra plot data. *Environmental Research Letters* 11: 05505. doi:10.1088/1748-9326/11/5/055005.

Walter, J.A., J.C. Neblett, **J.W. Atkins**, and **H.E. Epstein**. 2017. Regional- and watershed-scale analysis of red spruce habitat in the southeastern United States: implications for future restoration efforts. *Plant Ecology* 218: 305–316. doi:10.1007/s11258-016-0687-5.

Walter, J.A., D.M Johnson, and **K.J. Haynes**. 2017. Spatial variation in Allee effects influences patterns of range expansion. *Ecography* 40: 179–188. doi:10.1111/ecog.01951.

Walter, J.A., **A.L. Firebaugh**, P.C. Tobin, and **K.J. Haynes**. 2016. Invasion in patchy landscapes is affected by dispersal mortality and mate-finding failure. *Ecology* 97: 3389–3401. doi:10.1002/ecy.1583.

Wang, W., J.A. Smith, P. Ramamurthy, M.L. Baeck, E. Bou-Zeid, and **T.M. Scanlon**. 2016. On the correlation of water vapor and CO2: application to flux partitioning of evapotranspiration. *Water Resources Research* 52: 9452–9469. doi:10.1002/2015WR018161.

Wang, C.T., G. Wang, Y. Wang, H. Zi, **M. Lerdau**, and W. Liu. 2017. Effects of long-term experimental warming on plant community properties and soil microbial community composition in an alpine meadow. *Israel Journal of Ecology and Evolution*. doi:10.1080/15659801.2017.1281201.

Wang, B., **H.H. Shugart**, and **M. Lerdau**. 2017. An individual-based model of forest volatile organic compound emissions—UVAFME-VOC v1.0. *Ecological Modelling* 350: 69–78. doi:10.1016/j.ecolmodel.2017.02.006.

Ward, J.W., J.G. Warden, A.M. Bandy, A.E. Fryar, G.M. Brion, **S.A. Macko**, C.S. Romanek, and M.S. Coyne. 2016. Use of nitrogen-15-enriched Escherichia coli as a bacterial tracer in karst aquifers. *Ground Water* 54: 830–839. doi:10.1111/gwat.12426.

Wells, S., G.C. Ray, K.M. Gjerde, A.T. White, N. Muthiga, J.E. Bezaury Creel, B.D. Causey, **J. McCormick-Ray**, R. Salm, S. Gubbay, G. Kelleher, and J. Reti. 2016. Building the future of MPAs—lessons from history. *Aquatic Conservation: Marine and Freshwater Ecosystems* 26 (Supplement 2): 101–125. doi:10.1002/aqc.2680.

White, O.L., J.M. Moore, W.B. McKinnon, J.R. Spencer, **A.D. Howard**, and 19 additional authors. 2017. Geological mapping of Sputnik Planitia on Pluto. *Icarus* 287: 261–286. doi:10.1016/j.icarus.2017.01.011.

Wilson, S.A., **A.D. Howard**, J.M. Moore, and J.A. Grant. 2016. A cold-wet middle-latitude environment on Mars during the Hesperian-Amazonian transition: Evidence from northern Arabia valleys and paleolakes. *Journal of Geophysical Research: Planets* 121: 1667–1694. doi:10.1022/2016JE005052.

Wisniewski, J.A., A.P. McLaughlin, **P.J. Stenger**, J. Patrie, M.A. Brown, J.M. El-Dahr, T.A.E. Platts-Mills, N.J. Byrd, and P.W. Heymann. 2016. A comparison of seasonal trends in asthma exacerbations among children from geographic regions with different climates. *Allergy and Asthma Proceedings* 37: 475–481. doi:10.2500/aap.2016.37.3994.

Wu, J., C. Chavana-Bryant, N. Prohaska, S.P. Serbin, K. Guan, L.P. Albert, **X. Yang**, W.J. van Leeuwen, A.J. Garnello, G. Martins, Y. Malhi, F. Gerard, R.C. Oliviera, and S.R. Saleska. 2017. Convergence in relationships between leaf traits, spectra and age across diverse canopy environments and two contrasting tropical forests. *New Phytol* 214: 1033–1048. doi:10.1111/nph.14051.

Yan, H., S.-Q. Wang, J.-B. Wang, H.-Q. Lu, A.-H. Guo, Z.-C. Zhu, R.B. Myneni, and **H.H. Shugart**. 2016. Assessing spatiotemporal variation of drought in China and its impact on agriculture during 1982–2011 by using PDSI indices and agriculture drought survey data. *Journal of Geophysical Research: Atmospheres* 121: 2283–2298. doi:10.1002/2015JD024285.

Yang, H., **X. Yang**, Y. Zhang, M.A. Heskel, X. Lu, J.W. Munger, S. Sun, and J. Tang. 2017. Chlorophyll fluorescence tracks seasonal variations of photosynthesis from leaf to canopy in a temperate forest. *Global Change Biology* 23: 2874–2886. doi:10.1111/gcb.13590.

Yang, X., J. Tang, J.F. Mustard, et al. 2016. Seasonal variability of multiple leaf traits captured by leaf spectroscopy at two temperate deciduous forests. *Remote Sensing of Environment* 179: 1–12. doi:10.1016/j.rse.2016.03.026.

Yu, Q., **H. Epstein**, R. Engstrom, and D. Walker. 2017. Circumpolar arctic tundra biomass and productivity dynamics in response to projected climate change and herbivory. *Global Change Biology* 23: 3895–3907. doi:10.1111/gcb.13632.

Zhang, Y., L. Guanter, J.A. Berry, C. van der Tol, **X. Yang**, J. Tang, and F. Zhang. 2016. Model-based analysis of the relationship between sun-induced chlorophyll fluorescence and gross primary production for remote sensing applications. *Remote Sensing of Environment* 187: 145–155. doi:10.1016/j.rse.2016.10.016.

Zhang, A.Z., G.S. Jia, **H.E. Epstein**, and J.J. Xia. 2017. ENSO elicits opposing responses of semi-arid vegetation between Hemispheres. *Scientific Reports* 7: 42281. doi:10.1038/srep42281.

Zhou, F., P. Ciais, K. Hayashi, J. **Galloway**, D.G. Kim, C. Yang, S. Li, B. Liu, Z. Shang, and S. Gao. 2016. Re-estimating NH3 Emissions from Chinese Cropland by a New Nonlinear Model. *Environ. Sci. Technol.* 50: 564–572. doi:10.1021/acs.est.5b03156. ■

ENVIRONMENTAL SCIENCES
University of Virginia
291 McCormick Road
P.O. Box 400123
Charlottesville, VA 22904-4123

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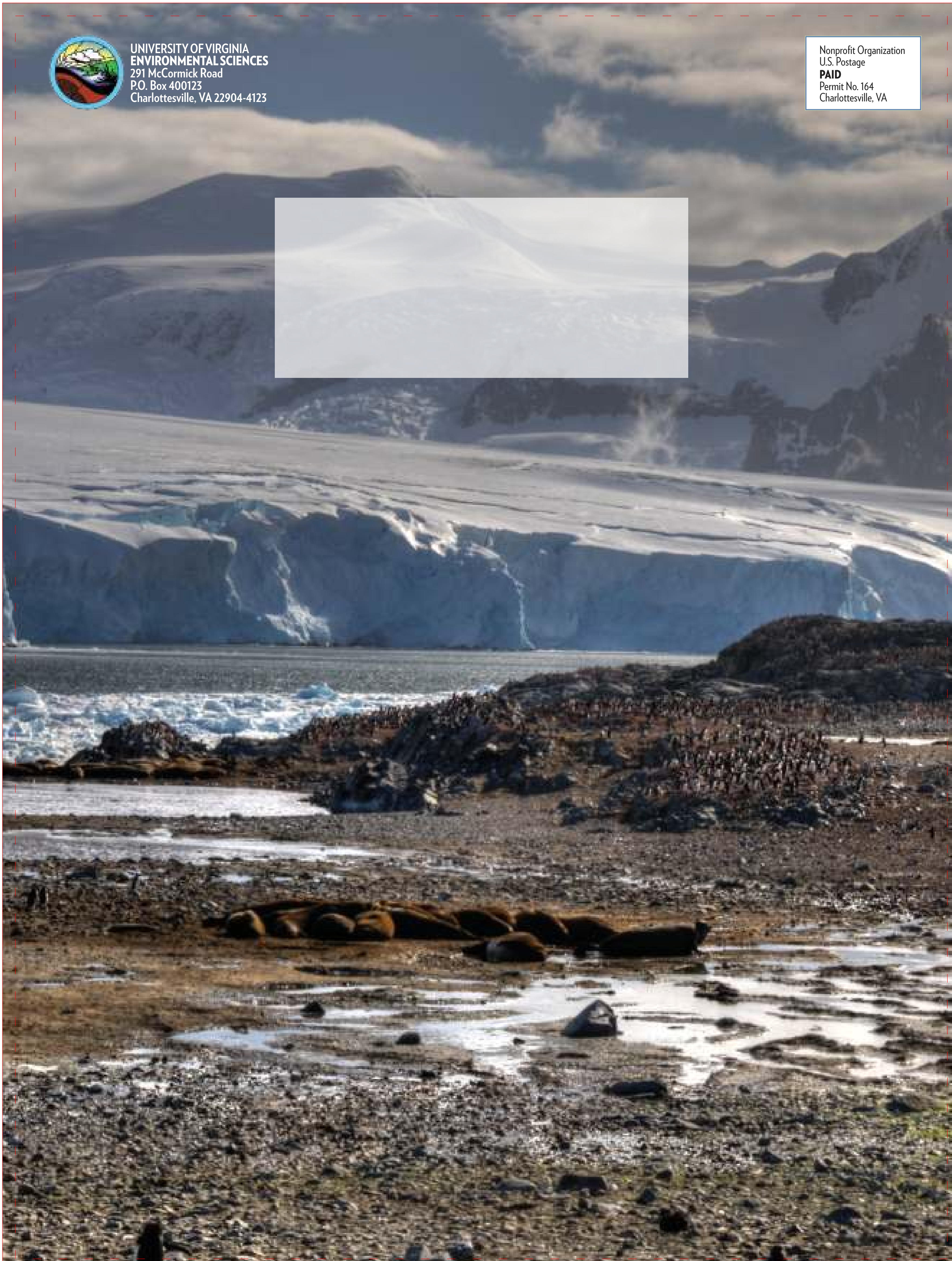

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