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COLLEGE OF COMPUTER, MATHEMATICAL, AND NATURAL SCIENCES

ODYSSEY

CONFRONTING CLIMATE CHANGE ›

ODYSSEY

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ON THE COVER

The Earth and moon seen from space. Credit: NASA Visible Earth Image Gallery/Faye Levine.

Message from the Dean

Dear Science Terps,

Since we published the last issue of *Odyssey* magazine, more than a thousand members of our campus community worked together to create an ambitious vision for the future of our university. I am grateful that many of you participated in forums; served on planning committees; and submitted questions, ideas and suggestions. As a result, Science Terps helped shape, inspire and decide where the University of Maryland is headed.

The resulting vision outlined in the new strategic plan, "*Fearlessly Forward: In Pursuit of Excellence and Impact for the Public Good*," presents a bold reimagining of what our university must be to uphold and expand our mission of service to humanity. The vision is ambitious and fearless.

To improve the lives of every person on Earth, we will reimagine teaching and learning; accelerate solutions to the grand challenges of our time through creativity and discovery; and forge a diverse and inclusive community where our differences are celebrated and equity is relentlessly pursued. Together, we will dedicate ourselves to advancing the public good because our individual well-being is enduringly bound to our collective well-being.

As we **take on humanity's grand challenges**, faculty, staff, students and alums from our college will pursue new ideas, interests and capabilities that will profoundly impact and improve our campus, state, nation and the world.

This issue of *Odyssey* magazine is dedicated to experts working at the forefront of climate change, a worldwide issue that presents unprecedented challenges, but also opportunities to explore new and better paths forward.

Through our strong partnerships with NASA and NOAA, researchers in our Department of Atmospheric and Oceanic Science, Department of Geology, Earth System Science Interdisciplinary Center, among others, are working hard to better understand climate change and mitigate its effects. On the pages that follow, you can read about their efforts, and those of our alums, to tackle these imminent threats to human safety and prosperity that demand immediate solutions to move *Fearlessly Forward*.

Amitabh Varshney
Dean
College of Computer, Mathematical, and Natural Sciences

Amitabh Varshney photo by John T. Consoli

CONFRONTING CLIMATE CHANGE

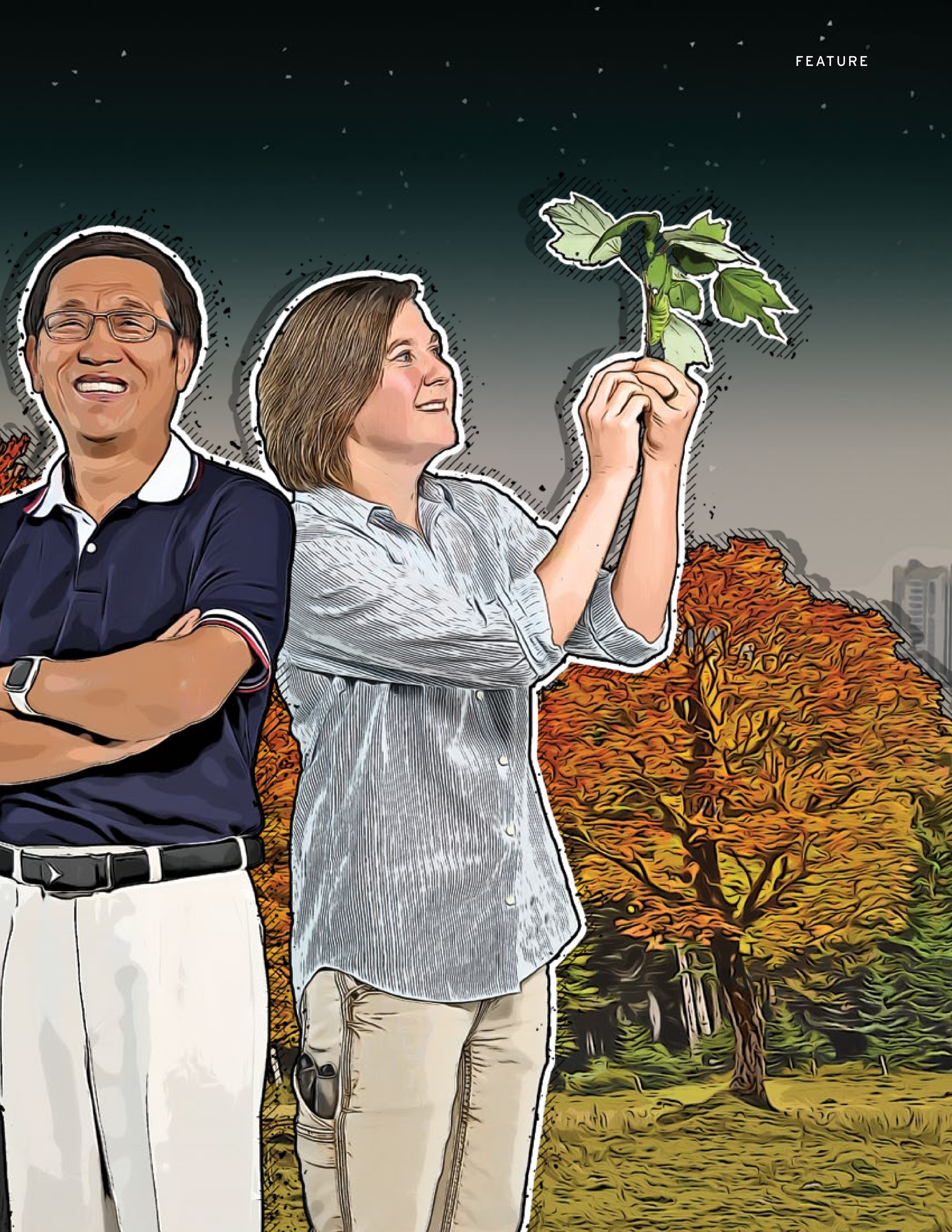
WE SEE THE SIGNS EVERYWHERE—OUR PLANET'S FUTURE IS IN JEOPARDY.

As global temperatures rise, greenhouse gases reach record levels and extreme weather events strike more frequently, we must ask the question: What will it take to solve the grand challenge of climate change?

Researchers in the University of Maryland's College of Computer, Mathematical, and Natural Sciences (CMNS) are fiercely committed to the fight against global warming. These scientists are tapping into satellite data to predict crop-killing droughts before they happen, identifying trees that adapt to climate change instead of worsening it, and unraveling the complex relationship between airborne pollutants and weather conditions. Grand challenges demand bold ideas and real-world solutions. In CMNS, we lead *Fearlessly Forward*.

STORY BY ***KIMBRA CUTLIP***
RESEARCHER PHOTOS BY ***JOHN T. CONSOLI*** AND ***ADAM WOOD***
COMPOSITES BY ***FAYE LEVINE***
ART EFFECTS BY ***NUWAN PANDITHA***

Beijing cityscape photo by Zhanqing Li
Earth photo by NASA
Trees photo by Mario Dobelmann/Unsplash



Uganda photo by Kimberly Slinski
Landsat 7 rendering by NASA

KIMBERLY SLINSKI

Predicting DROUGHTS FROM SPACE

Kimberly Slinski can't stop droughts from happening, but she can see them coming. Her warnings help entire regions of the world prepare for water shortages, crop failures and food insecurities that follow severe droughts. As an assistant research scientist in the Earth System Science Interdisciplinary Center, Slinski uses satellite data to monitor water availability in drought-prone regions around the world.

"If we can see a drought coming, then governments can move resources around to prepare for it and aid organizations can plan relief efforts in advance," she said.

Droughts are hard to predict in places where water monitoring stations are few and far between like East Africa, Haiti, Central America and Afghanistan. These are also some of the most food-insecure regions on the planet, where crop failures and livestock deaths due to water shortages can spell hunger and starvation for the people living there. Unfortunately, as the climate changes, extreme droughts are becoming more frequent, especially in these parts of the world.

Slinski knows how hard it can be for resource managers on the ground to see a drought coming. In 2008, she worked as a hydrological engineer in Uganda, helping predict water shortages for the nongovernmental organization Action Against Hunger.

"We were on the ground trying to figure out ways to best monitor water availability in these areas where there isn't a lot of monitoring data," Slinski said. "We would look at the different watering holes that farmers bring their cattle to and try to determine which ones were the bellwethers. Which one or two ponds could we use to say, 'If this one goes dry, the whole region will go dry'? And it made me think, there's a lot of satellite data out there that could be used to monitor these ponds. We need to learn how to leverage that."

That's exactly what Slinski did. She went back to school and earned a Ph.D. in hydrology. Now she's the technical lead for NASA's Famine Early Warning Systems Network (FEWS NET) team. Slinski guides an international group of researchers at NASA in using satellite data to analyze and predict water conditions on the ground. She and her team look at soil moisture, streamflow, snowpack, snowmelt and a variety of other factors to create water availability forecast models.

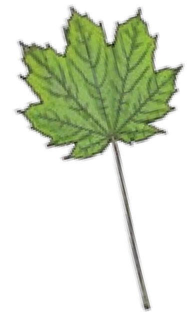
The data they collect is fed into FEWS NET where experts in nutrition, economic markets and household food security combine the risk of drought with data on political stability, household conditions and other factors. FEWS NET reports help advise decision-makers as they work to prevent humanitarian crises in some of the most vulnerable places.

"There's a substantial body of scientific evidence that says extreme events like drought are going to continue to happen more frequently," Slinski said. "These early warning systems are a critical tool for disaster risk reduction, especially in the places that will be hardest hit by the effects of climate change."

Good leaders know that a critical key to success is using the right tool for the job.

KARIN BURGHARDT

Choosing Trees TO COOL CITIES WISELY



As cities around the world scramble to adapt to climate change, Karin Burghardt wants to make sure they're choosing their tools wisely. Specifically, she studies how cities can select the right trees to plant as part of their strategy to adapt to climate change—because planting the wrong ones could make the effects of climate change worse.

"We need to understand how the tree species we select today might affect the health of the city's entire tree canopy 40 years down the line," said Burghardt, an assistant professor of entomology.

Urban areas absorb heat more than rural spaces and can be 7 degrees Fahrenheit hotter than surrounding landscapes, according to the U.S. Environmental Protection Agency. To combat this "heat island" effect, city managers plant shade trees to cool buildings and streets, reduce energy use, absorb runoff from severe storms and help capture greenhouse gases. But they often don't think much about the potential consequences of the trees they choose.

"People have selected trees for city planting based on particular traits they like, such as purple leaves or a lot of flowers or fall leaf color," Burghardt explained. "But these trees may come from areas with very different climates, and they may not actually have traits that allow them to be adapted to urban stressors, like high temperatures or pest outbreaks, which are expected to increase as a result of climate change."

Burghardt collaborates with researchers from Johns Hopkins University and the U.S. Forest Service to understand how the genetic traits of different street trees in Baltimore might affect the trees' ability to resist pests and higher temperatures.

"We have to think about the lag time, because after planting trees, you're waiting 30, 40 years before really getting the full benefits of that tree," Burghardt said. "And selecting for traits that aren't related to resilience to climate change may have undesired consequences."

Part of the team's concern is that trees planted today won't survive climatic conditions of the future, but perhaps more important is the impact cultivated street trees may have on the fragments of wild forest within cities. Those fragments are critical buffers against rising temperatures and increased flooding, and they provide vital habitat and migratory pathways for wildlife.

"Pollen from street trees could potentially fertilize wild trees in the forest fragments," Burghardt said. "If they do, the question is, will they be adding traits that are less suited to those forest environments, especially with the climate conditions we expect 30 or 40 years from now?"

With funding from the U.S. Department of Agriculture, Burghardt and her colleagues sample maple trees in Baltimore streets, parks and yards to understand how genes could be moving through different populations that make up the city's tree canopy.

"If we're introducing traits from tree varieties that are really poor at dealing with the climate conditions coming down the road, then we might not only be losing our street trees in the future, we could actually be losing the canopy from wild forest fragments as well," she said.

Burghardt hopes that arming city managers and planners with this information will help them select the trees to get the job done properly and without unintended consequences.

Leaf photos by Faye Levine
Street photo by pxfuel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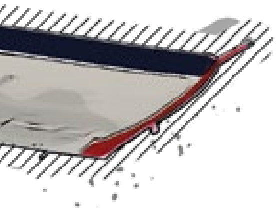


ZHANQING LI

Balancing THE CLIMATE BUDGET

Trying to predict, combat and prepare for climate change is a bit like managing the budget of a major multinational corporation. But instead of knowing where all the money goes, you have to know where all the energy goes.

How much sunlight hits the planet? How much of it heats the ground and ocean versus how much is absorbed or reflected by gases and water vapor in the atmosphere? And how does the concentration of those gases—particularly greenhouse gases like carbon dioxide—change over time due to human activities and natural processes?

These are huge and complex accounting questions that Zhanqing Li has been helping to answer for decades. In the mid-1990s, Li discovered that aerosols—tiny airborne particles—in clouds played a major role in trapping and reflecting heat. His work redefined how scientists view the role of clouds in Earth's climate, and his model is used today by NASA as part of the foundation for calculating the global energy budget.

Now, the professor in the Department of Atmospheric and Oceanic Science and the Earth System Science Interdisciplinary Center focuses on understanding the interaction between clouds, pollution and climate.

"Cloud variation is still the most difficult issue for understanding the energy budget and making climate predictions," Li said. "It is a very complex and interesting story. Aerosols from pollution change the microphysics of clouds to influence how much energy they trap or radiate to space and how they hold water and produce rain. This can hide the total effects of greenhouse gases."

Li's research, for example, showed that aerosol pollution from sources like factories, cars and fossil fuel-based power plants has a significant cooling effect on global climate. It's not as much as the warming effect of greenhouse gases that come from the same sources, but when scientists calculate the benefits of reducing emissions from those sources, the cooling effect of aerosols is an important budget item that has to be factored in.

"These dynamics are very important to understand because as countries work to reduce greenhouse gases and pollution, there will be changes due to a reduction in aerosols that they need to understand and prepare for," he said.

The interaction between aerosols and clouds also has important local effects. In highly polluted areas in China, Li found that clouds need to be much thicker to produce rain, and when they do, they tend to produce more thunderstorms and fewer drizzles. But aerosols complicate the picture, because in lower concentrations, some aerosols suppress thunderstorms and increase the number of light rains.

That means the types of aerosols pumped into the air could tamp down or ramp up local thunderstorms, which increase floods in urban areas and harm crops. By identifying these complicated interactions, Li provides critical information policymakers need to prepare their communities for future weather conditions as they try to clean their air of pollution and greenhouse gases. ■

Plane photo by Dara Zarbaf
Shanghai cityscape photo by Photologic/Unsplash

Alumni CLIMATE **CRUSADERS**

FIGHTING AGAINST CLIMATE CHANGE AND FOR SOCIAL JUSTICE

For **Crystal Upperman** (Ph.D. '16, marine estuarine environmental sciences), climate change is a fight for people of color and for social justice.

"The same emissions that are changing our climate are the ones that are changing us and impacting the health of children," Upperman explained. "Black people, Hispanics and Asians have higher exposure to air pollution than whites."

She's committed to changing that.

"I've lived in frontline communities all my life," Upperman said. "This mission is essential to me as a person."

As a senior scientist at Aclima, Upperman used the company's next-generation platform to measure air pollution and its impact block by block, advocating for solutions that protect public health and advance environmental justice. She later led a push for climate-friendly and socially responsible strategies as vice president of climate resilience and social performance for AECOM.

Now, as a senior manager at Deloitte, Upperman helps clients develop and implement more climate-friendly policies, particularly in communities highly burdened by pollution.

"We've seen the fallout that results from not being responsive to social justice concerns and climate concerns," Upperman explained. "It's great to be able to show that there are values that are supportive of social justice and also supportive of protection of the environment."

WHY PHYTOPLANKTON COULD BE A GAME-CHANGER FOR THE ENVIRONMENT

Phytoplankton—microscopic algae in water—absorb carbon and emit oxygen like land plants and may be key players in our search for understanding climate change, according to **Beth Weinstein** (B.S. '01, computer science).

While at UMD, Weinstein met with recruiters from NASA's Goddard Space Flight Center at a campus networking event and was interviewed on the spot. She graduated with a job working on NASA's Earth Science Data Systems program, which makes NASA's satellite data free to the public.

After working with Earth Science Data Systems for seven years, Weinstein transitioned to building satellites herself. She now works on the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) satellite mission, which expanded her perspective on climate change solutions.

"Before PACE, I had no idea how much phytoplankton could affect carbon levels in the atmosphere," Weinstein said. "Learning about how our ocean-atmosphere system works and how our aerosol-cloud system works, we can be more creative about how to combat climate change."

Launching in January 2024, the PACE satellite will scan the globe every two days for oceanic and atmospheric changes. It will give scientists in-depth knowledge of how phytoplankton respond to Earth's changing climate and could potentially be used to reduce carbon levels and address climate change.

Photos courtesy of Crystal Upperman and Beth Weinstein

› TACKLING CLIMATE CHANGE FOR FEDERAL CLIENTS

Steve Ambrose's (B.S. '76, physical sciences) interest in the environment was ignited in the 1960s by musicians like John Denver and Jethro Tull, who sang about taking care of our planet, as well as a visit to the World's Fair in New York in 1964. That interest solidified in 1972 after he saw the devastating impact of Hurricane Agnes on much of the East Coast.

At UMD, Ambrose majored in physical sciences to explore his passions in meteorology, geology and astronomy. As chief climate scientist at Science Applications International Corp. (SAIC) and head of the SAIC Climate Enterprise, Ambrose calls his role a "once-in-a-lifetime opportunity to make a difference."

"It gives me the chance to lead SAIC in advancing solutions for climate change, and I'm really committed to establishing SAIC as a leader in climate science," Ambrose said.

After Ambrose graduated, he worked at the National Oceanic and Atmospheric Administration's (NOAA) National Ocean Service analyzing tide data, continuing at NOAA's National Weather Service and the National Environmental Satellite, Data, and Information Service. Across his career, Ambrose has worked to protect the environment and provide knowledge and understanding of weather and climate observations, data and models for more than 40 years.

"The data is clear: Climate change is an increasing threat to society," Ambrose said. "Technology and innovation will help us collect data to understand these changes; analyzing that data will help us understand how we can best be resilient and adapt to climate change."

› COMBATING ENVIRONMENTAL INEQUALITY WORLDWIDE

Born in Bosnia and Herzegovina, **Saliha Dobardzic** (M.S. '00, sustainable development and conservation biology) spent her formative years living in different countries with her family. She learned early on that a healthy environment can be a form of wealth—and that an unhealthy environment can take a disproportionate toll on the most vulnerable.

"Children, the elderly, the disabled and generally discriminated-against groups tend to disproportionately suffer the effects of environmental degradation, such as pollution and loss of nature's services," Dobardzic said.

Dobardzic is working to change that as senior climate change specialist for the Adaptation Fund. The organization finances programs that help vulnerable communities in developing countries adapt to climate change. Since 2010, the Adaptation Fund committed $924 million to over 130 projects spanning more than 100 countries and benefiting over 30 million people.

Projects range from establishing water infrastructure in Djibouti to improving agricultural productivity in Tanzania to supporting innovation in water services in peri-urban areas of Chile. Dobardzic's graduate studies in conservation at UMD, as well as subsequent studies in geography, provided a strong foundation for her work.

"Studying in pioneering, interdisciplinary graduate programs at Maryland made me aware of different ways to view problems and, likewise, ways of tackling them," Dobardzic said. "Integrating perspectives from different disciplines is essential when dealing with a complex, multifaceted problem like climate change."

Photos courtesy of Steve Ambrose and Saliha Dobardzic

RESEARCH WITH IMPACT

Our faculty members, students and alumni are climate crusaders. Read on to learn more about how Science Terps are tackling the grand challenge of climate change.

RAY KALTSCHMIDT/BERKELEY NATIONAL LAB

A Perennial Grass Could Mitigate Climate Change in the Midwest

Atmospheric and Oceanic Science Professor **XIN-ZHONG LIANG** found that growing one perennial grass, *Miscanthus x giganteus,* could cut warming in the Midwestern United States by 1 degree Celsius. Miscanthus grows up to 10 feet tall, creating a canopy that has a strong likelihood of significantly lowering regional summer temperatures while increasing humidity, rainfall and overall crop productivity. The grass is water efficient, noninvasive and requires little fertilizer. It's also able to grow on land that has little or no agricultural or industrial value. When pairing a dynamic crop growth model with a regional climate model, Liang found that the miscanthus did more than just cool the land—it also significantly increased summer precipitation by 14-15%.

YURI TIMOFEYEV

SEBASTIAN POCIECHA/UNSPLASH

PATRICK KELLEY/USCG/USGS

Could Burying Dead Wood Alter Earth's Climate Trajectory?

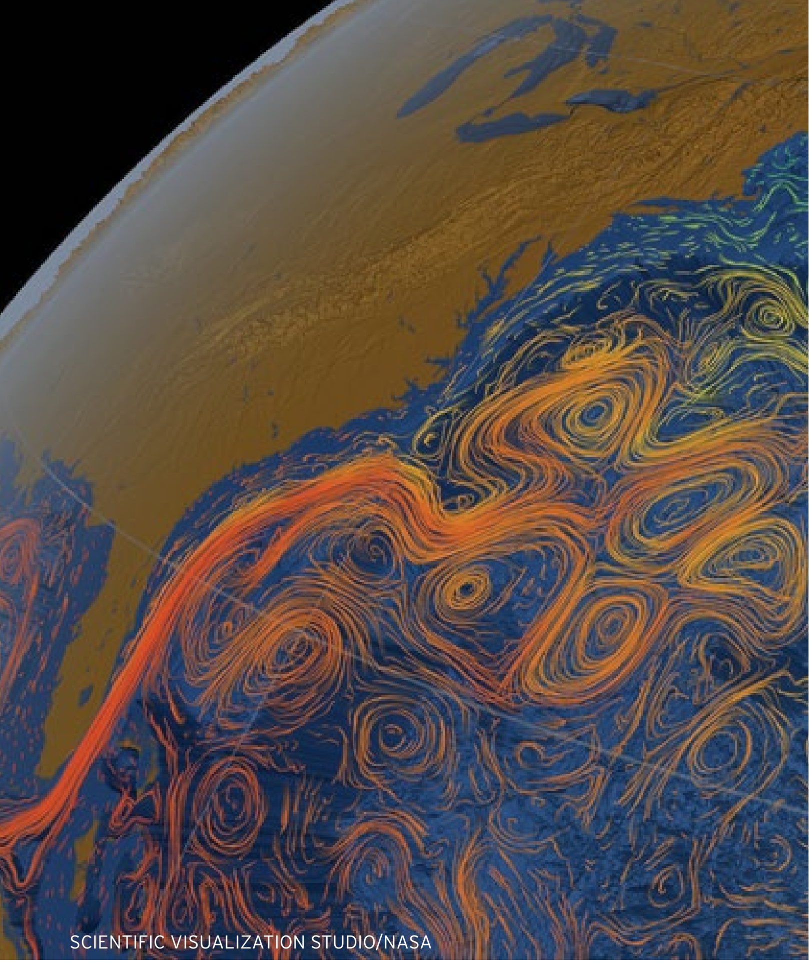
A living tree cleans the air and soaks up carbon dioxide that causes global warming. But when a tree dies, burns or slowly rots, the carbon it gathered from the environment over the course of its life escapes. Atmospheric and Oceanic Science Professor **NING ZENG** realized that dead trees can be used as a simple, effective carbon capture method to buy time while societies develop less destructive ways to live. Zeng's studies and tests have confirmed that to have the desired effect, millions of trees that fall or are cut in cities, forests and farms must be buried deep enough underground that decomposition doesn't set in. Growers could also remove carbon dioxide from the air with fast-growing tree species like poplar, harvest and bury it, then plant anew. Instituting a system of wood dumps around the world could put away a billion metric tons of carbon dioxide annually. Zeng's big idea landed him in the top 60 of the XPrize Carbon Removal challenge.

Greenhouse Gases Pose a Continued Threat to Arctic Ozone Layer

A study conducted by Atmospheric and Oceanic Science Professor **ROSS SALAWITCH** calls into question the general assumption that ozone loss would grind to a halt in just a few decades following the 2010 global ban on the production of chlorofluorocarbons and halons. The study shows that unusually low winter temperatures high in the atmosphere over the Arctic are becoming more frequent and more extreme because of climate patterns associated with global warming. These conditions promote the formation of clouds as well as reactions among chemicals pumped into the air decades ago, both of which lead to ozone loss in the polar stratosphere and ultimately to more harmful UV radiation reaching the surface of the Earth.

Loss of Birds and Mammals Spells Doom for Some Plants Amidst Climate Warming

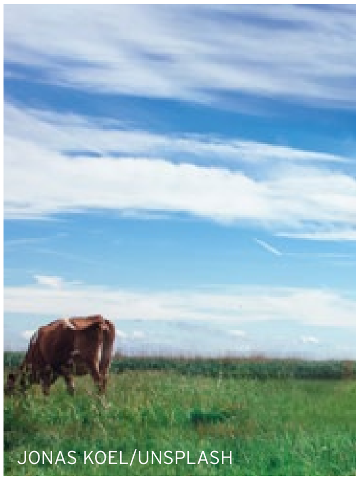
In a study led by National Socio-Environmental Synthesis Center postdoctoral fellow **EVAN FRICKE**, researchers showed that the ability of animal-dispersed plants to adapt to climate change has been reduced by 60% due to the loss of mammals and birds from their ecosystems. Fricke and his co-authors used data from field studies around the world to train a machine-learning model for seed dispersal and then used the trained model to estimate the loss of climate-tracking dispersal caused by animal declines. Results show animal declines can disrupt ecological networks in ways that threaten the climate resilience of entire ecosystems that humans, mammals and birds rely upon for food. These losses were especially severe in temperate regions across North America, Europe, South America and Australia, but restoration and reconnection of natural habitats can counteract some of the declines in seed dispersal.



SCIENTIFIC VISUALIZATION STUDIO/NASA

ANUPMA GUPTA/MICHAEL EVANS

DAVID MLADENOFF



JONAS KOEL/UNSPLASH

Small Events May Have Big Impacts on Atmospheric and Oceanic Circulation

Interactions between the ocean and the atmosphere drive global weather and climate, but what happens on a smaller scale, when winds kick up choppy seas only a few kilometers across? Atmospheric and Oceanic Science Assistant Professor **JACOB WENEGRAT** and his colleagues think these small-scale events may exchange enough heat and energy between the sea surface and air to have big impacts on atmospheric and oceanic circulation. Wenegrat is part of NASA's Sub-Mesoscale Ocean Dynamics Experiment Earth Venture Suborbital mission (S-MODE), which wrapped up the first of three major data collection expeditions. A new aircraft-mounted instrument called a doppler scatterometer took simultaneous measurements of surface currents and winds, which will provide a view of oceanic circulation previously only seen in models. Once the data is analyzed, S-MODE will provide an entirely new view of air-sea interaction.

Study Identifies Causes of Multidecadal Climate Changes

A reconstruction of global average surface temperature change over the past 2,000 years identified the main causes for decade-scale climate changes. The analysis suggests that Earth's current warming rate, caused by human greenhouse gas emissions since 1850, is higher than any warming rate observed previously. The study also found that airborne particles from volcanic eruptions were primarily responsible for several brief episodes of global cooling prior to the Industrial Revolution. The Past Global Changes (PAGES) research team, including Geology Professor **MICHAEL EVANS**, compiled the most comprehensive database of its kind for the study, including nearly 700 sources that record indicators of past temperatures, such as long-lived trees, reef-building corals and ice cores from all of Earth's continents and major ocean basins. The agreement between PAGES's reconstructions and existing simulations suggests that current climate models accurately represent the contributions of various influences on global climate change and are capable of correctly predicting future climate warming.

Katherine Calvin Leads NASA's Climate Science Initiatives

In January 2022, alum **KATHERINE CALVIN** (B.S. '03, mathematics; B.S. '03, computer science) was named NASA chief scientist and senior climate advisor. Calvin is tasked with advancing NASA's entire science portfolio—and climate science in particular—in the years to come. NASA's climate research spans the agency and includes observations, models, applied science and technology development. As senior climate advisor, Calvin helps connect climate research within NASA and communicate that research externally to other agencies, international partners and the public. As chief scientist, her job is to communicate and advance NASA science more broadly. Calvin says her experience in the Gemstone program at UMD, which required her to work in interdisciplinary teams and learn to communicate with students from a variety of majors to research real-world problems, was one of her most important learning experiences.

BILL INGALLS/NASA

NIKE

Modeling Historical Biomass Could Be Key to Buffering Climate Change

When trees store carbon from the atmosphere, they help Earth maintain a carbon balance—a crucial component to a steady climate. Changes in woody biomass magnitude over millennia are poorly understood, however, leading to uncertainties about long-term carbon sink. Earth System Science Interdisciplinary Center postdoctoral associate **ANN RAIHO** led the development of a model that estimates above-ground woody biomass based on a time-series of fossil pollen assemblages in sediments. The team used the model to statistically reconstruct changes in woody biomass across a 600,000-plus kilometer area in the Upper Midwest of the U.S. over the last 10,000 years. The study found that carbon storage in the region was driven by the population of high biomass tree species such as the American Beech. Once established, high biomass forests were sustained regionally for millennia—but took under two centuries to destroy by industrial-era logging and agriculture. These findings could shift ongoing debates about how landscapes can be managed to maximize carbon storage.

Alum Helps Create Better, Greener Materials for Nike Shoes

KELLEY BAEK (B.S. '05, biological sciences; MBA '11), director of sustainable footwear materials at Nike, plays a central role in the company's efforts to achieve carbon neutrality and eliminate its landfill waste. She manages scientific and engineering efforts to create greener materials for shoe parts, such as plastic bag-derived uppers and soles incorporating chunks of recycled foam. One of her initiatives was the development of Flyleather, a durable performance material that looks, feels and smells like the real thing. Flyleather is made by combining at least 50% recycled leather scrap—traditionally destined for landfills—with synthetic materials using a purpose-built, water-based manufacturing process. The result is an abrasion-resistant shoe that is 40% lighter than its full-grain leather counterparts and has a lower impact on the environment.

Sniffing Out Methane to Pinpoint Sources of Pollution

Although it's 200 times less prevalent than carbon dioxide, methane gas has exponentially more global warming power. A recent study found that quickly cutting methane emissions could slow climate change by 30%, but figuring out where those emissions come from is a challenge. The new Panorama Lab, led by Geology Professor **JAMES FARQUHAR**, will be used to identify both the sources of and the natural processes that remove methane at the atmospheric, regional and hyper-local levels. The lab enables UMD researchers to get a more precise look than ever before at different types, or isotopes, of methane. Traditional mass spectrometers categorize methane isotopes by molecular weight. The Panorama Lab's mass spectrometer is enhanced with a 3.2 ton electromagnetic component that helps segregate atoms of different masses more effectively, detecting the minute variations that indicate if a molecule of methane started out in a wetland or seeped from a landfill.

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Climate Finance & Risk Management Program

As climate change increasingly affects business decisions, leaders must learn to respond to the unexpected. Risk managers, financial analysts and executives must anticipate how weather events and rising sea levels may impact financial growth, supply chains and taxes. To address this educational need, the University of Maryland combined its world-class expertise in climate science, finance and public policy to prepare its partners to plan for and respond to the opportunities and risks of a changing climate.

Photo by Casey Root/USGS

Supported by experts in the College of Computer, Mathematical, and Natural Sciences and the Robert H. Smith School of Business, UMD's executive education program provides business leaders the skills required to understand the latest scientific thinking and models related to climate change, assess climate models, translate climate model outputs into meaningful economic scenarios, and review potential industry and regulatory developments on climate change.

**Learn more:
climatefinance.umd.edu**