Earth Guardians

UCI researchers seek solutions to the many effects of climate change
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Viewed from a satellite, the hub of the UCI campus easily stands out from its surroundings, since it looks rather like a huge eye, with the green iris of Aldrich Park staring back at you. It’s an apt vision, since the university has been a watchful eye over this world for most of its history.

UCI’s founding chancellor, Daniel G. Aldrich Jr., a soil chemist, had a steadfast concern for the environment, from picking up stray candy wrappers on campus to seeing that – at a time when many universities were slow to address students’ surging interest in ecology – UCI was devoting several biological science courses to

it. In 1970, Aldrich launched the nation’s first school of social ecology, to study human society as a system as complex and interconnected as nature.

In 1983, UCI atmospheric chemist F. Sherwood Rowland issued his first paper linking chlorofluorocarbons to damage of the Earth’s protective ozone layer. When his subsequent studies amounted to a stunning indicator of mankind’s effect on the ecosystem, some derisive voices likened him to Chicken Little claiming the sky was falling. The Nobel committee felt otherwise, and Rowland’s 1995 Nobel Prize in chemistry (shared with UCI postdoctoral scholar Mario J. Molina) confirmed UCI’s status as a center for climate science.

Fellow atmospheric chemist Ralph Cicerone joined UCI in 1989 to develop the Department of Earth System Science – another national first – bringing researchers from several disciplines together to identify environmental problems and solutions. Later UCI’s chancellor, Cicerone left in 2005 to become president of the National Academy of Sciences.

There are sites on campus now named for all three scientists, but their legacies are far more evident in the numerous faculty across campus – a few of whom are highlighted on the following pages – who continue today to push at the boundaries of our knowledge of the world, the challenges that climate change poses to it, and the possible solutions that might provide for a better tomorrow.

Containing Wildfires With Satellite Data



James Randerson. Photo by Steve Zylius/UCI

“It was an amazing time when I started at UCI in 2003,” says James Randerson, a much honored, published and cited professor of Earth system science. “We had the atmospheric scientist Ralph Cicerone as chancellor. We had the first Earth system science department in the country – and for years, it was the only one. I think UCI led the way for universities realizing the importance of understanding what climate change and sustainability are going to be like in this century.”

Randerson advises the U.S. Department of Energy, is a member of the National Academy of Sciences, and in 2018 became the inaugural Ralph J. & Carol M. Cicerone Chair in Earth System Science.

His lab’s current projects include globally mapping wildfire patterns to understand how climate extremes influence them; using satellite remote sensing to learn how fires are affecting ecosystems; finding ways to gauge the vulnerability of terrestrial ecosystems and their capacity to store carbon as climate changes; and improving climate models to better forecast the biosphere’s future.

“We’re mainly interested in using this information to arrive at solutions,” Randerson says. “One thing we’re working on with NASA is a $200 million constellation of satellites to provide global, around-the-clock data measuring fire outbreaks and how

they’re spreading. This could be invaluable in containing fires before they spread. The damage from wildfires here in the Western states alone runs into tens of billions of dollars annually.”

His team is finding plenty to be concerned about, such as larger and more frequent wildfires in the U.S. West; drought-damaged trees less able to store carbon or survive fires; lightning storms expected to increasingly spark fires across the Arctic tundra, releasing trapped carbon into the atmosphere; and the severity of climate change stunting economic growth and equity around the world.

Emphasizing the hopeful aspects of their work is key, he says. “I’m optimistic that UCI can really contribute to important solutions, but you can easily get overwhelmed by the scope and magnitude of what’s happening on the planet,” Randerson says. “Many students experience what you could call climate fatigue. So I try to frame our discussions to keep a balance between providing optimism for how we can transform things and reminding them how precious the time is that we have to accomplish those things.”

Stalagmites Reveal Ancient Clues



Kathleen Johnson. Photo by Steve Zylius/UCI

Kathleen Johnson, UCI associate professor of Earth system science, studies the history of Earth's atmosphere and climate from a deeply counterintuitive vantage: underground in ancient caves.

Holding a 2-foot speleothem that looks like petrified marble cake, she explains, "This piece of stalagmite spans about 40,000 years of history, reaching back beyond the peak of the last ice age. It's a little like an ice core, but instead of water being frozen, the chemistry of the water has been transferred to the chemistry of these calcite layers that were deposited by the water as it dripped into a cave. The oxygen and carbon composition tells us things about the climate above the cave at the time it formed."

Studying stalagmites is not a new science, but Johnson is applying novel methods to seek new answers. "One of the main points of paleoclimate research is that looking at the mechanisms under which climate has changed naturally in the past helps us better understand the climate system today and what the implications might be for the future," she says.

Johnson sources materials with the help of recreational cavers, park managers and local community members and has been underground herself in various parts of the world, where, along with the stalagmites, she's encountered bats, roaches, plenty of grime and, once, a Burmese python.

Her recent research centers on the Asian monsoon region, a crucial part of the global climate system, with much of the world's population relying on predictable summer rains. Johnson's studies indicate that a major dry spell over 8,000 years ago may have been precipitated by a shift in oceanic water circulation, which could happen again in the not-too-distant future.

"We're also finding that there's a striking correlation between monsoon strength and changes in the Earth's orbit," she adds. "Learning about these past changes helps us have an eye toward what the future might hold."

Climate Computing

Statistics, computing and machine learning play a significant role in trying to find solutions for climate change. "Computer models can help make predictions about climate events or help us understand the relationship between different components

of the environment," says Veronica Berrocal, UCI associate professor of statistics. She uses computing and statistics to arrive at answers to complex environmental questions. Two recent projects involve tracking the effects wildfires have on public health and using satellites and computer models to gauge changing pollutant levels across California. "Computer models can help fill gaps in information," Berrocal adds. "If you're trying to track air pollution, for instance, and there are areas where there are no monitors, statistical models can extrapolate their levels based on monitoring data from nearby areas and computer model outputs."

Lighter-Than-Air Solutions to Heavy Problems



Jack Brouwer. Photo by Steve Zylius/UCI

If hydrogen power can produce half the energy that Jack Brouwer does when talking about it, it'll be a formidable force for the future. Once he gets going, it's a nonstop flow of ideas.

Brouwer is a UCI professor of mechanical and aerospace engineering and directs the campus-based National Fuel Cell Research Center.

“My research focuses on how we might integrate very high levels of renewable primary energy resources into all applications economywide,” he says. “Even if we’re making the most of sun and wind power, we still need more zero-emission resources, along with ways of storing energy.

“The solutions I focus on are hydrogen electrolyzers and fuel cells. I look at how we might be able to use water plus renewable electricity to make hydrogen, store and distribute it throughout society, and then use it where it makes the most sense.”

Brouwer envisions a near future in which electrical grids run on zero-emission, hydrogen-powered fuel cells and turbine engines and in which hydrogen-based systems power aircraft, cargo ships and long-haul trucks. “Green steel” plants employing hydrogen in a solid oxide electrolysis system would reduce the huge carbon footprint of steel production.

He also foresees the gas as a major means of energy storage, saying: “Hydrogen has advantages over other chemical batteries. For example, airplanes can’t handle the weight or mass of traditional energy storage systems, while hydrogen is the lightest fuel that we know of, which is why we use it in rockets.”

Hydrogen isn’t without its hurdles, one being that it’s highly flammable. Though it’s been safely handled under-industrial uses, Brouwer notes, it will take work to render it suitable for general use.

Selling officials on hydrogen power was also once a hurdle, but he points to the recent bipartisan federal Infrastructure Investment and Jobs Act, which has allocated $9.5 billion to advancing technology for hydrogen production. “That’s more funding than we’ve ever seen,” Brouwer says, “and it really accelerates the timeline for a zero-emissions future.”

Infrastructure and Floods

“I was the kid who always had his arm out the car window, feeling the flow of the wind resistance on my hand. Now I develop computer codes and numerical methods to simulate flooding based on the mechanics of fluid flow,” says Brett Sanders, UCI professor of civil and environmental engineering as well as urban planning and public policy. Though drought is a more immediate concern in California, Sanders cautions that the state is overdue for a historic flood. The last one, in 1862,

inundated much of Southern California. “There’s a massive flood risk, and our infrastructure doesn’t seem up to the task of containing these events,” he says. “With my simulation tools, we’re increasingly able to predict and plan for such events – and in a way where outcomes are more equitable to everyone.” The simulations also help him to imagine flood control plans that could have other benefits. One example Sanders cites is to redesign the Santa Ana River channel to better deal with flooding while also helping the waterway carry much needed sediment to coastal wetlands and sand-starved beaches. He says: “What can we do to best handle a flood but also design it to be of use when it isn’t flooding – to help us have a more sustainable water supply or a healthier ecosystem or a more livable city?”

Linking Environmental and Human Health



Jun Wu. Photo by Steve Zylius/UCI

Not long ago, smog was as much a part of the Southern California landscape as the Hollywood sign it sometimes obscured. Though less visible and greatly diminished, air pollution is still a part of our lives, says Jun Wu, a UCI professor of public health in the Department of Environmental and Occupational Health.

“We still see a lot of adverse health effects,” she says. “Concentrations of fine particulate matter have even risen due to wildfires. And while outdoor pollution temporarily dropped during the COVID shutdown, we published a paper showing that indoor pollution increased, because with everyone staying indoors, there were more combustion byproducts from cooking, more chemicals from cleaning products and so on.”

Wu and her department colleagues and students track such data, particularly in underserved communities, to present stakeholders such as health officials and civic leaders with information and potential solutions.

“I look at environmental exposures of people to various agents, such as air pollution, noise, heat, wildfires, etc. and also at the health impact of those exposures,” she says.

For example, Wu is collaborating with Alana LeBrón, a UCI assistant professor of public health in the Department of Health, Society and Behavior, on a study of lead contamination in Santa Ana and its effects on children’s health and academic performance. In addition, she’s helping communities tackle concerns about air pollution and wildfire impacts, including industrial and firework emissions in Santa Ana.

Wu’s work isn’t all about dealing with problems: “I’m very excited to be exploring the beneficial effects that parks and other green spaces can have on better health outcomes for people – how they can help relieve stress, improve concentration and encourage physical activity. Trees can also absorb certain chemicals from the atmosphere, while a tree canopy provides shade. Unfortunately, the vulnerable communities that have more pollution are also the communities that have less green space, so the goal is finding ways to address that.”

Plankton Building Blocks



Adam Martiny. Photo by Steve Zylius/UCI

The smallest ocean microorganisms have been and continue to be building blocks of life on this planet, and they may come in especially handy in our future, according to Adam Martiny, UCI professor of Earth system science as well as ecology and evolutionary biology.

As an indicator of plankton's ubiquity, he notes that scientists nine decades ago were puzzled to find that the deep ocean had a chemical makeup very similar to that of plankton on the surface. It didn't take long to determine that the phenomenon was the result of billions of years of plankton living, dying and sinking. Martiny adds, "Everything that lives in the ocean either eats a microbe or eats something that's eaten a microbe. They form the base of the food chain."

And there's this: Phytoplankton, a type of plankton that converts sunlight into energy through photosynthesis, absorb CO2 – as do trees and plants on land.

"As the CO2 in our atmosphere keeps rising and things get hotter, we likely can't reduce our emissions fast enough to avoid some pretty dire conditions," Martiny says. "So we also need to remove some of the CO2 we already have in the atmosphere. We don't have the space to plant enough trees for that, whereas if you look from here to Hawaii, there's a lot of water there. If we could stimulate

phytoplankton growth with nutrients all the way out to Hawaii, it would potentially make a dent in the large amounts of CO2 we have in the atmosphere."

If such a plan sounds risky, that's because it is.

Martiny says: "Are we willing to change the entire ocean in order to take CO2 out of the atmosphere? With any solution we look at, we really need to understand the consequences, because if we roll them out, we're going to change part of the planet, and we better make sure that we get it right. But if we don't try, we might be looking at a few thousand years of a very hot planet.

"There's still a lot that we have to learn," he adds. "Understanding these pathways is going to lead to important engineering principles for carbon removal in the future, and UCI is gearing up to be an important part of all that."

Tracking El Niño

The El Niño weather phenomenon exerts its influence over much of the world and can bring droughts, floods and other extreme conditions, making it crucial that climate scientists understand its cycles. Complicating that, "the El Niño of the 21st century is not the El Niño we knew in the 20th century," says UCI Earth system science professor Jin-Yi Yu, whose expertise is in climate dynamics, particularly atmosphere-ocean interactions. He was a pioneer in the discovery that El Niño often shifts to a second point of origin – in the mid-Pacific, not just near the Peruvian coastline – affecting its patterns, frequency and intensity. Much of Yu's research is done within complex computer weather models from the National Center for Atmospheric Research, to which he adds updated records of sea surface temperature cycles, wind data and other variables. "El Niño affects everything from crops in California to hurricanes in the Atlantic to fisheries in India, and we need to keep advancing our understanding," Yu says. "If, for example, we ever want to do something to mitigate or reduce some effects of global warming with geoengineering, it's essential to understand everything we can about El Niño."

The Law of the Land – and the Sea and Air



Alejandro Camacho. Photo by Steve Zylius/UCI

“Climate change is the central challenge of our time, and, obviously, that makes it a moral imperative to try to think through how we address it,” says UCI Chancellor’s Professor of law Alejandro Camacho. “It’s also a personal concern: I care about my children and their children and how the planet can adjust, and that doesn’t happen without responsive policymaking.”

As far back as 2006, while teaching law at the University of Notre Dame, he was challenging legal processes, goals and institutions that were too rigid to take the “change” part of climate change into account. Camacho says: “An example of maladaptive management would be a policy that is never revisited or adjusted. More effective governance involves systematically learning from new information and changing circumstances and adjusting policies accordingly. Climate change is a global example of the need for that.”

It’s a theme Camacho explored, with co-author Robert Glicksman, in the 2019 book Reorganizing Government: A Functional and Dimensional Framework. It suggests the need to rethink and adjust not only public processes and goals but also institutions over time, with the intent of making them more responsive, equitable and effective.

When he joined UCI Law 13 years ago, it was coming full circle for Camacho. Before receiving a J.D. from Harvard University and an LL.M. from Georgetown University, he earned bachelor's degrees at UCI in criminology, law and society as well as political science.

"I took environmental law and environment protection courses here. I found the issues to be incredibly difficult and complex but also incredibly important to me," Camacho says. "It made me decide that environmental law was my calling. It's where theory turns into action."

Along with teaching an environmental law practicum, he's active in a range of related activities. Among them, Camacho is the founder and director of UCI's Center for Land, Environment and Natural Resources, where, he says, "the core initiative is what we call workshop roundtables, which bring together experts on a particular environmental topic to advance dialogue and knowledge – and, hopefully, advance policy. We bring together experts from academia, the public sector, nonprofit organizations and sometimes industry. And it's not just having a conversation; it's designed to lead to a document that can be used to help advance policy on these matters."

When Events Collide

It can be difficult enough to track or predict a single climate event. Amir Aghakouchak, UCI professor of civil and environmental engineering as well as Earth system science, specializes in researching what happens when two or more combine. He has refined the use of remote sensing devices such as satellites and radar to track such events and has shared his "toolbox" for other scientists to use. "Interacting hazards are happening with greater frequency," Aghakouchak says. "What happens when drought and heat waves combine? When terrestrial flooding coincides with ocean flooding? How will these things react differently if the planet's temperature goes up a degree? Three degrees? There is so much to take into account – from the effect on vegetation and soil microbes' ability to absorb carbon to the societal and social justice dimensions of these events."

Scaling Up the Future



Julianne DeAngelo. Photo by Steve Zylius/UCI

A half-century ago, the famed Yankees catcher and malapropism master Yogi Berra declared, “The future ain’t what it used to be.” That observation has taken on a grim significance in the ensuing decades’ cascade of floods, droughts, fires and other climate events that suggest the future belongs not so much to the human imagination as it does to the carbon dioxide we’ve released into the atmosphere.

Meet Solutions That Scale, an interdisciplinary research group launched in January 2021 by the School of Physical Sciences. Its mission statement posits a future that’s not just survivable but flourishing.

To get there, STS is engaging scientists and other experts from across the UCI spectrum to work with business leaders, government officials and civic leaders to develop and test solutions to pressing environmental problems – and then develop ways to upscale those solutions to be applied on a global level.

One ambitious project is aimed at finding alternatives to the fossil fuels that power the freight industry. The effort is led by Earth system science Ph.D. student Julianne DeAngelo – one of STS’s initial cohort of fellowship students – with assistance from UCI professors Steven Davis, Jack Brouwer and others. DeAngelo is exploring hydrogen, biofuels and additional alternative power sources to arrive at “the most

cost-effective way to get the freight industry to net-zero” carbon emissions.

As part of its public outreach, STS conducts a seminar series, with one recent example being a webinar in which 2022 Andrew Carnegie Fellow Michael Méndez, UCI assistant professor of urban planning and public policy, discussed “Extreme Wildfire Impacts to Undocumented Latina/o and Indigenous Migrants.”

For solutions to be implemented, STS executive board member Richard Matthew, professor of urban planning and public policy, says, “it’s crucial that we have business leaders, policymakers and community leaders in the room. We need business leaders to bring their managerial and investment skills to bear on issues so they can be realized. We need the policymakers with the know-how to develop regulations.

“What we’re saying is let’s work together and find solutions that make sense from an economic perspective, from a community justice perspective and an ecological perspective. Let’s try those solutions out here. Then – just as California has always been a source of ingenuity and innovation for the planet – our solutions can be scaled up across the globe to help other areas addressing similar issues.”

Rays of Hope



Steven Davis. Photo by Steve Zylius/UCI

“Have you seen how the latest U.N. Intergovernmental Panel on Climate Change report is structured?” asks Steven Davis, UCI professor of Earth system science and civil and environmental engineering, who wrote a chapter in a previous IPCC report. “The first part covers the fundamental realities of how the climate is changing. The second assesses what the impacts will be on humans, our infrastructure and so on, while the third part asks, ‘What can we do about it?’ I’ve spent the bulk of my career squarely in that third part, looking for solutions to mitigate the problems with greenhouse gas emissions and other climate issues.”

Davis took a winding path to Earth system science, first earning B.A.s in political science and philosophy, then a J.D. “But I found I wasn’t loving law,” he recalls. “My wife was studying physical oceanography, and it looked like a lot more fun. I always enjoyed environmental science, so I went back to grad school and earned a Ph.D. [at Stanford University] in geological and environmental sciences. Four years later, in 2012, I joined the great group of colleagues here in Earth system science, and it’s felt like home ever since.”

The aforementioned IPCC report does not lack for grim climate assessments, and newspapers have almost daily accounts of record droughts, fires, heat waves and

other environmental crises.

“I see a lot of despair out there, but I’m actually feeling more optimistic about climate problems because we’ve made a lot of progress in terms of the attractiveness of the solutions,” Davis says. “Renewable energy technologies like solar and wind, batteries and electric vehicles have all plummeted in cost – to the point where people are going to start preferring them not because they necessarily even care about the climate, but because they’re the most attractive, best performing and, in some cases, cheapest options out there.

“It once cost thousands of dollars to get a watt of solar power; now it’s more like 30 cents,” he continues. “And new tech is coming along all the time, such as perovskite solar panels. I think we’re really on the brink of what will be a drastic decrease in our energy system CO2 emissions.”

Davis envisions a similar turning point with businesses recognizing greater economic opportunities in building the infrastructure needed to address climate change in the coming decades. “This is just the start, and there are still a lot of things to wrangle with, like getting the CO2 out of concrete and steel production,” he says. “I see all this as puzzles to be solved, and that’s something people are good at.”

Bridging Environmental Humanities

When it comes to tackling issues of the environment, the humanities have a lot to bring to the table: critical analysis, cultural attunement, storytelling, historical context, and a deep understanding of human beliefs and motivations. So in April, UCI’s School of Humanities launched the Environmental Humanities Research Center to give scholars from the school’s various disciplines – such as history, philosophy and ethnic studies – a chance to share each other’s work and create new dialogues concerning climate change and sustainability. “Colleagues across the school have for years been doing vibrant research and teaching involving issues of ecological and climatological crisis without necessarily communicating with each other,” says center director James Nisbet, chair of UCI’s art history department. “The center is a way to join forces. We also will reach across the schools to share different perspectives on climate change.” Another branch of the center’s mission is to conduct community outreach, he says, “where the public will see the center and UCI as a home for interaction and environmental conversations.”

The Effects of Human Populations



Richard Matthew. Photo by Steve Zylius/UCI

There are scarcely any aspects of human society today that are not touched by climate change. In such a time, it’s only natural that social ecology and the science disciplines across Aldrich Park would become increasingly interconnected.

“The initial thinking behind social ecology was informed by forest ecology, biology and other nature sciences,” says Richard Matthew, associate dean of research and international programs in UCI’s School of Social Ecology, as well as a professor of urban planning and public policy and political science. “The perception of social ecology that imbued its founding is now broadly accepted: Human society is as complex a world as nature is, with feedback mechanisms, nonlinear relationships and emerging properties. Social ecology borrows ideas from nature to understand social relations and social dynamics and, now more than ever, is looking at how these social and natural systems interact.”

He and his team are generally working on several projects at any time, some in tandem with other UCI faculty, different universities, conservation organizations and the United Nations. One major effort deals with issues of climate-driven migration.

“It looks like roughly 1.2 billion people on the planet are vulnerable to being displaced by climate change in the next several decades,” Matthew says. “Migration is often viewed in negative terms, but movement has historically been the single most common way humans deal with environmental stress.

“Most migrants are already vulnerable populations, and they’d be leaving behind what little they have. How can we help them decide their best options? Are there things we can do to help them stay where they are? If they move, can we help them arrive at destinations where they’re an economic benefit to the community? Can we help them avoid conflict zones? Those are questions where we’re looking for solutions.”

He doesn’t harbor any illusions about the years ahead, saying: “There are going to be famines, displacements and suffering, but there are also grounds for optimism and hope. Humankind is remarkably adaptive and innovative even under conditions of tremendous adversity.”

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