MIT

# Science AT MIT

Summer 2022 **Published twice yearly**

# Challenge accepted

## MIT scientists take on climate change

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Summer 2022 | **Published twice yearly**

**Executive Editor:**
Julia C. Keller

**Contributing Writers:**
Leah Campbell, Paige Colley, Crystal Koe, Mark Dwortzan, Raleigh McElvery, Kate Wilverman Wilson, Alice McBride, and Daniel Griffin

**Proofreader + Copyeditors:**
Matthew Christensen, Leah Campbell, and Sarah Costello

**Design:**
Ink Design, inc.

**Cover image:**
Portraits of MIT climate researchers

SCHOOL OF SCIENCE
Massachusetts Institute of Technology

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# Letter from the Dean

My fellow alumni and friends,

This issue of *Science@MIT* is dedicated to highlighting some — but by no means all — of the important researchers working on climate science at MIT. You may have seen last month's announcement about the flagship projects funded through MIT's Climate Grand Challenges.

Beginning on page 4, you can take an in-depth look at two of the five Climate Grand Challenges flagship projects. These research projects are led by science faculty — and not surprisingly, their main departmental affiliation is the Department of Earth, Atmospheric and Planetary Sciences (EAPS). EAPS professors Kerry Emanuel, Raffaele Ferrari, Paul O'Gorman, and Noelle Selin, are all prominent researchers in climate science research and modeling.

The other three Climate Grand Challenges flagship projects (which you can read about on MIT News) may not be led by science-affiliated faculty, but each has representation from science researchers including biology professors Mary Gehring and Jing-Ke Weng; chemistry professors Yogesh Surendranath and Timothy Swager; mathematics professor Alan Edelman; as well as impressive cadre of science faculty and research staff from the MIT's Center for Global Change Science and, of course, EAPS.

Two themes are common among all the flagship projects: science is foundational to progress in combatting climate change; and science alone is not enough. Collaboration, grounded in science, is key to progress.

In launching the MIT Climate Action Plan, President L. Rafael Reif declared that "we must go as far as we can, as fast as we can, with the tools and methods we have now … as well as invest in, invent, and deploy new tools. Current tools alone will not get us to the target."

I espouse this bold action plan of which the Climate Grand Challenge flagships are a part. And while the pace of science can at times feel painstakingly slow and requires significant investment, science without immediately known applications — for the purpose of answering Why? or How? — is, itself, incredibly valuable.

On page 10, you can read about biology graduate student Giselle Valdes, one of our fellowship recipients supported by the Fund for the Future of Science (in turn supported by gifts our friends and alumni). In Professor Peter Reddien's lab, Valdes studies how the dynamics and regulation of gene expression in flatworm stem cells drive their resolution to a specific fate. Reddien, Valdes, and others in the lab group are studying the molecular and cellular mechanisms that control cell regeneration. One can see the long-term value in regrowing cells — even body parts! — but understanding the underlying mechanisms is the primary goal.

Chemistry graduate student, Amanuella Mengiste, our other Future of Science fellowship holder, works in the lab of Associate Professor Matthew Shoulders. One of Mengiste's projects is to better understand a class of proteins known as G protein-coupled receptors (GPCRs). GPCRs are the conduits by which cells detect external stimuli — be they photons, small molecules, or proteins. Mengiste's goal is to create GPCRs that are activated by pharmacologically inert small molecules and capable of activating different signaling pathways in a controlled manner. (You can read more about Mengiste's research in our winter 2020 issue of *Science@MIT*.) Like Valdes, Mengiste has a goal of understanding cellular mechanisms that could — perhaps, someday — lead to a pharmacological intervention or direct therapeutics. Or their research projects might not lead to any known practical applications.

Or, perhaps in 50 years' time, the processes studied now might lead to a life-saving vaccine, as in the story of the development of the RNA vaccines and our subsequent understanding of how to identify the Covid virus. On page 16, you can read about how biology postdoc Digbijay Mahat brought life-saving detection and prevention technologies to his home country of Nepal where, due in part to Mahat's efforts, more than 40 percent of the population is now vaccinated.

The truth is, we don't always know the practical impact of the research done today. As scientists, we know how to ask important questions, and answering them often leads to new questions. I have no doubt that this innate curiosity, coupled with technological advances and ingenuity of our MIT researchers, will lead to life-saving and earth-preserving results.

I hope you'll join me supporting these innately curious scientists — especially our graduate students like Valdes and Mengiste or early-career scientists such as Mahat — who are beginning on their research path with possibilities and questions ahead of them.

With my very best wishes,

Dean Nergis Mavalvala PhD '97

# Looking forward to forecast the risks of a changing climate

## To better inform local policy in the face of weather extremes, MIT scientists seek to shift global climate models away from reliance on historical observations

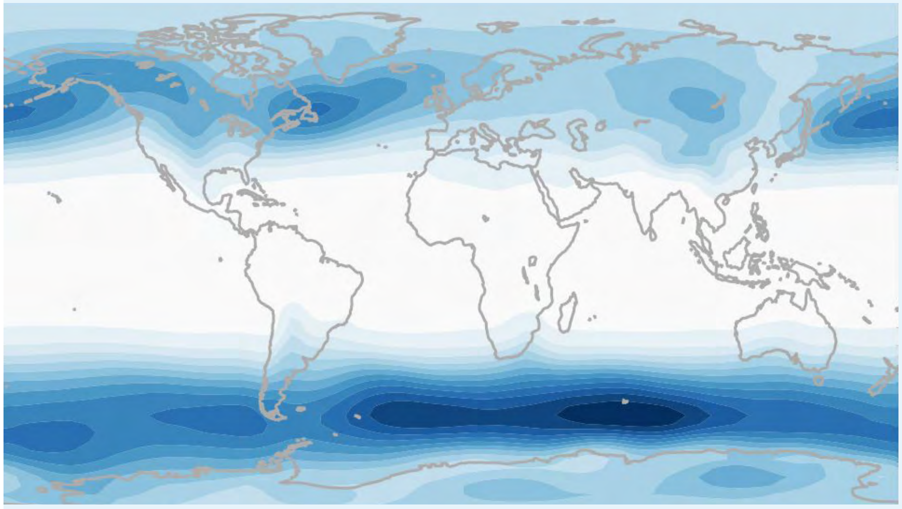
Paige Colley | Department of Earth, Atmospheric and Planetary Sciences

Extreme weather events that were once considered rare have become noticeably less so, from intensifying hurricane activity in the North Atlantic to wildfires generating massive clouds of ozone-damaging smoke. But current climate models are unprepared when it comes to estimating the risk that these increasingly extreme events pose — and without adequate modeling, governments are left unable to take necessary precautions to protect their communities.

Paul O'Gorman

MIT Department of Earth, Atmospheric and Planetary Science (EAPS) professor Paul O'Gorman researches this trend by studying how climate affects the atmosphere and incorporating what he learns into climate models to improve their accuracy. One particular focus for O'Gorman has been changes in extreme precipitation and midlatitude storms that hit areas like New England.

"These extreme events are having a lot of impact, but they're also difficult to model or study," he says. Seeing the pressing need for better climate models that can be used to develop preparedness plans and climate change mitigation strategies, O'Gorman and collaborators Kerry Emanuel, the Cecil and Ida Green Professor of Atmospheric Science in EAPS, and Miho Mazereeuw, associate professor in MIT's Department of Architecture, are leading an interdisciplinary group of scientists, engineers, and designers to tackle this problem with their MIT Climate Grand Challenges flagship project, Preparing for a New World of Weather and Climate Extremes.



In a recent *Geophysical Research Letters* study co-authored by Professor Paul O'Gorman, MIT researchers find that extratropical storm tracks — the blue regions of storminess in the Earth's middle latitudes — would change significantly with solar geoengineering efforts. *Image courtesy of the researchers.*

"We know already from observations and from climate model predictions that weather and climate extremes are changing and will change more," O'Gorman says. "The grand challenge is preparing for those changing extremes."

Their proposal is one of five flagship projects recently announced by the MIT Grand Challenges initiative — an Institute-wide effort catalyzing novel research and engineering innovations to address the climate crisis. Selected from a field of almost 100 submissions, the team will receive additional funding and exposure to help accelerate and scale their project goals. Other MIT collaborators on the proposal include researchers from

A recent *Nature Communications* study led by Professor Kerry Emanuel finds that North Atlantic hurricanes have indeed increased in frequency over the last 150 years, similar to what historical records have shown.
*Photo: MIT News, iStockphoto*

the School of Engineering, the School of Architecture and Planning, the Office of Sustainability, the Center for Global Change Science, and the Institute for Data, Systems, and Society.

## Climate modeling

Fifteen years ago, Kerry Emanuel developed a simple hurricane model. It was based on physics equations, rather than statistics, and could run in real time, making it useful for modeling risk assessment. Emanuel wondered if similar models could be used for long-term risk assessment of other things, such as changes in extreme weather because of climate change.

Kerry Emanuel

"I discovered, somewhat to my surprise and dismay, that almost all extant estimates of long-term weather risks in the United States are based not on physical models, but on historical statistics of the hazards," says Emanuel. "The problem with relying on historical records is that they're too short; while they can help estimate common events, they don't contain enough information to make predictions for more rare events."

Another limitation of climate models which rely heavily on statistics: they have a built-in assumption that the climate is static.

"Historical records rely on the climate at the time they were recorded; they can't say anything about how hurricanes grow in a warmer climate," says Emanuel. The models rely on fixed relationships between events; they assume that hurricane activity will stay the same, even while science is showing that warmer temperatures will most likely push

> **“The problem with relying on historical records is that they’re too short; while they can help estimate common events, they don’t contain enough information to make predictions for more rare events.”**

typical hurricane activity beyond the tropics and into a much wider band of latitudes.

As a flagship project, the goal is to eliminate this reliance on the historical record by emphasizing physical principles (e.g., the laws of thermodynamics and fluid mechanics) in next-generation models. The downside to this is that there are many variables that have to be included. Not only are there planetary-scale systems to consider, such as the global circulation of the atmosphere, but there are also small-scale, extremely localized events, like thunderstorms, that influence predictive outcomes.

Trying to compute all of these at once is costly and time-consuming — and the results often can’t tell you the risk in a specific location. But there is a way to correct for this: “What’s done is to use a global model, and then use a method called downscaling, which tries to infer what would happen on very small scales that aren’t properly resolved by the global model,” explains O’Gorman. The team hopes to improve downscaling techniques so that they can be used to calculate the risk of very rare but impactful weather events.

Global climate models, or general circulation models (GCMs), Emanuel explains, are constructed a bit like a jungle gym. Like the playground bars, the Earth is sectioned in an interconnected three-dimensional framework — only it’s divided 100 to 200 square kilometers at a time. Each node comprises a set of computations for characteristics like wind, rainfall, atmospheric pressure, and temperature within its bounds; the outputs of each node are connected to its neighbor. This framework is useful for creating a big picture idea of Earth’s climate system, but if you tried to zoom in on a specific location — like, say, to see what’s happening in Miami or Mumbai — the connecting nodes are too far apart to make predictions on anything specific to those areas.

Scientists work around this problem by using downscaling. They use the same blueprint of the jungle gym, but within the nodes they weave a mesh of smaller features, incorporating equations for things like topography and vegetation or regional meteorological models to fill in the blanks. By creating a finer mesh over smaller areas they can predict local effects without needing to run the entire global model.

Of course, even this finer-resolution solution has its trade-offs. While we might be able to gain a clearer picture of what’s happening in a specific region by nesting models within models, it can still make for a computing challenge to crunch all that data at once, with the trade-off being expense and time, or predictions that are limited to shorter windows of duration — where GCMs can be run considering decades or centuries, a particularly complex local model may be restricted to predictions on timescales of just a few years at a time.

“I’m afraid that most of the downscaling at present is brute force, but I think there’s room to do it in better ways,” says Emanuel, who sees the problem of finding new and novel methods of achieving this goal as an intellectual challenge. “I hope that through the Grand Challenges project we might be able to get students, postdocs, and others interested in doing this in a very creative way.”

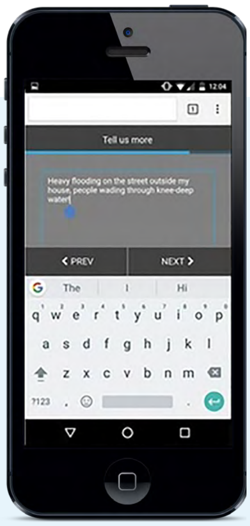
## Adapting to weather extremes for cities and renewable energy

Improving climate modeling is more than a scientific exercise in creativity, however. There’s a very real application for models that can accurately forecast risk in localized regions. One element of the proposal is quantifying the risks extreme weather events pose for renewable energy sources, because increasing reliance on renewable energies will be troublesome if those sources can’t sustain power grids during extreme weather events.


Location


Flood Depth


Photo




Description

Using RiskMap.us from the MIT Urban Risk Lab led by Professor Miho Mazereeuw, residents of areas with extreme weather, such as Broward County, Florida, can use social media to upload flood reports that are aggregated into a publicly available map that tracks flooding.
*Image: MIT Urban Risk Lab*

Another problem is that progress in climate modeling has not kept up with the need for climate mitigation plans, especially in some of the most vulnerable communities around the globe.

"It is critical for stakeholders to have access to this data for their own decision-making process. Every community is composed of a diverse population with diverse needs, and each locality is affected by extreme weather events in unique ways," says Mazereeuw, the director of the MIT Urban Risk Lab.

A key piece of the team's project is building on partnerships the Urban Risk Lab has developed with several cities to test their models once they have a usable product up and running. The cities were selected based on their vulnerability to increasing extreme weather events, such as tropical cyclones in Broward County, Florida, and Toa Baja, Puerto Rico, and extratropical storms in Boston, Massachusetts, and Cape Town, South Africa.

In their proposal, the team outlines a variety of deliverables that the cities can ultimately use in their climate change preparations, with ideas such as online interactive platforms and workshops with stakeholders — such as local governments, developers, nonprofits, and residents — to learn directly what specific tools they need for their local communities. By doing so, they can craft plans addressing different scenarios in their region, involving events such as sea-level rise or heat waves, while also providing information and means of developing adaptation strategies for infrastructure under these conditions that will be the most effective and efficient for them.

"We are acutely aware of the inequity of resources both in mitigating impacts and recovering from disasters. Working with diverse communities through workshops allows us to engage a lot of people, listen, discuss, and collaboratively design solutions," says Mazereeuw.

By the end of five years, the team is hoping that they'll have better risk assessment and preparedness toolkits, not just for the cities that they're partnering with, but for others as well.

"MIT is well-positioned to make progress in this area," says O'Gorman, "and I think it's an important problem where we can make a difference."

Miho Mazereeuw

# JoAnne Stubbe and Stephen Buchwald are giving back

## Two faculty members share their reasons for supporting the Chemistry Department with endowment funds

Crystal Koe | Chemistry

JoAnne Stubbe, Novartis Professor of Chemistry emerita calls herself “just a science nerd”; never mind the National Medal of Science presented to her by President Barack Obama in 2009 for scientific contributions, or the numerous other honors achieved in a career that has spanned several outstanding academic institutions over 45 years.

“I’ve been lucky to be paid to pursue my passion for scientific discovery my whole life,” says Stubbe. She retired in 2017 after 30 years at MIT where she was the first woman to achieve tenure in chemistry.

Stubbe began her career at Williams College, then moved to Yale University Medical School, and then to the University of Wisconsin in biochemistry. She finally received tenure while at Wisconsin after 13 years as an assistant professor, before she was recruited by MIT’s Chemistry Department.

JoAnne Stubbe
*Photo: Justin Knight*

“The journey helped me achieve the self-confidence required to be successful and gave me the freedom to continue to work in the lab and to teach,” says Stubbe.

She considers teaching to be her most important contribution to MIT, but Stubbe says that being here allowed her to advance her research in a way that wouldn’t have been possible elsewhere. Even now, she enjoys looking at the MIT webpage each morning to read about new discoveries. “You just pinch yourself and squeal because something exciting was discovered,” she says. “That’s what MIT is about. You’re surrounded by people who are passionate and love what they’re doing.”

Stubbe recently established an endowment fund to support women graduate students in Chemistry. The CKJJ Stubbe Fund is named for nieces Camille Stubbe (C), who received a degree in chemical engineering at MIT, and Kendra Leith (K), who received a master’s in urban studies and planning and is now associate director for research of D-Lab at MIT; her brother James Stubbe (J), who received a degree in chemistry at MIT; and herself (J).

“I was interested in establishing the endowment because MIT has given me the freedom to be immersed in an environment where there is so much exciting science going on and to pursue my dreams,” says Stubbe. “You are surrounded by outstanding and highly motivated students and colleagues who you can easily convince to collaborate. And I’m grateful for all of that.”

In her early years at MIT, Stubbe received advice about the difference between stocks and bonds, and the importance of finding the right financial advisor, from junior colleague Stephen L. Buchwald, who is now the Camille Dreyfus Professor of Chemistry.

Stephen Buchwald
*Photo: Justin Knight*

Buchwald and his spouse, Susan Haber, both long-time friends of Stubbe at this point, are no strangers to philanthropy. In 2015, for his 60th birthday celebration, they established the Buchwald-Haber Family Fund to support graduate students in organic chemistry.

"I realized that the vast majority of my success is due to the students and postdocs I've had, and it was important to give back," says Buchwald. "I was fortunate enough in 2015 to win a prize which was a lot of money, and that is where I got the idea [for the fund]."

Buchwald is associate head of the Department of Chemistry and recognized as one of the world's most influential chemists. Most recently, he received the 2021 Award for Creativity in Molecular Design and Synthesis from the North Jersey Section of the American Chemical Society and the inaugural Akira Suzuki Award. Buchwald will also be presented with the Paul Karrer Gold Medal, one of the oldest awards in chemistry, in Zurich this summer.

Over 38 years at MIT, Buchwald has often felt frustrated at the high cost of supporting graduate students, whose development and contributions, he says, form a viral part of the academic and scientific ecosystem and lead to practical, real-world change.

"The great universities have had an enormous impact on society, [including a] massive economic impact from ideas and inventions," Buchwald says, citing discoveries made at MIT in the very labs where young researchers are driving progress and pushing boundaries — such as magnetic memory for computers, various strides in biotechnology, and artificial intelligence.

"MIT graduate students and postdocs are brilliant," says Buchwald. "Even if I'm as smart as some of them, which is questionable, I've been able to recruit a very diverse group of people who will think about problems differently, and they've led me into different areas," he says, referencing an almost 10-year collaboration between Professor Bradley Pentelute's group and the Buchwald group.

Buchwald knows that he brings a valuable level of experience and perspective to the department from years of interacting with different people. But, considering the genius he sees in the work of junior colleagues, he thinks that his retirement may come in the next five to 10 years. "Every day when I'm coming in, I think to myself, 'today's going to be the day they figure out they made a mistake in hiring me,'" Buchwald says. "I tell [my students], you know much more than I do about what you're working on, and I just bring in an overview."

Above all, Buchwald takes pride in the way that the department invests in people, noting that many of his colleagues, like himself, started at MIT as early-career researchers. "I think that's a tribute, that we try to grow our own," he says. "I'm exceptionally proud that I've been at MIT my entire career."

Whenever retirement comes, Buchwald's scientific legacy will continue in untold discoveries to be made by future students in organic chemistry; the Buchwald-Haber Family Fund has supported seven graduate students in the laboratories of junior faculty members from investment income alone.

Meanwhile, Stubbe is also still doing research. These days, she works in the lab of a Harvard University collaborator as frequently as five days a week. "It's not work, it's fun," she says. "That's what drives me. I get up in the middle of the night and write down ideas. It's been like that forever. I can't stop thinking about it."

# Giselle Valdes: From aspiring scientist to Future Fund of Science Fellow

## Valdes, biology doctoral student and MIT summer research program alumna, studies the cellular basis of regeneration

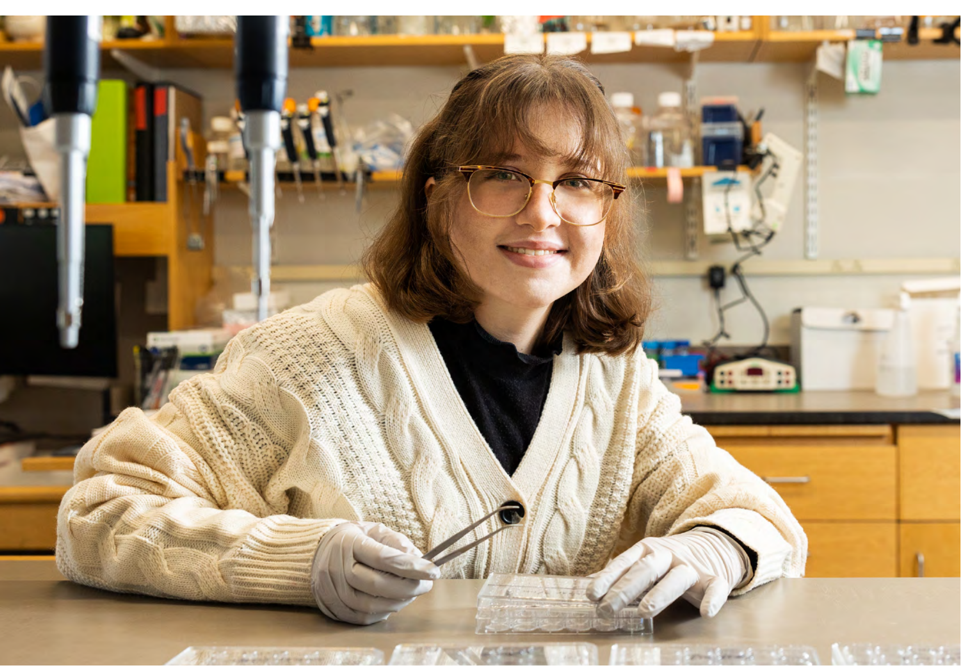
Leah Campbell | School of Science

When Giselle Valdes was in middle school, CRISPR-Cas9, the revolutionary genetic engineering technique, became a reality. As someone who had seen family members struggle with genetic diseases, Valdes was immediately intrigued.

"Could you imagine that, as opposed to only being able to treat the symptoms of certain diseases, you could cure the disease itself?" says Valdes. "I was just blown away by the potential implications of the technology and, ever since then, I was like 'I want to be involved in this.'"

That realization set Valdes on the path to where she is today, a third-year doctoral student in the lab of Peter Reddien, a professor of biology and associate director of the Whitehead Institute. Valdes, along with Amanuella Mengiste, a fellow PhD student in chemistry, are the most recent recipients of the Future Fund of Science Fellowship.

Giselle Valdes
*Photo: Steph Stevens*



As a middle schooler, though, Valdes had no idea what being a scientist even meant. So, she did what any precocious Gen Zer would do: she turned to the internet, googling how to become a scientist and emailing professors at local universities to help her.

"A lot of people told me not to stress too much at the stage I was in," she laughs. Stephen Winkle, an associate professor of chemistry and biochemistry at Florida International University (FIU), was one such scientist who responded to her questions. Winkle became an important mentor for Valdes and, later, her research advisor when she enrolled as a student in FIU's Honors College several years later.

At FIU, though much of her research was in biochemistry, Valdes majored in biomedical engineering. She says that her undergraduate program was oriented toward building medical devices, with more courses in mechanical and electrical engineering than biology. But she sees ways her engineering background has informed her research in biology.

"The computational tools that undergrad afforded me have been invaluable," she explains. "I like the thought process of an engineer, and I think it's helped me think about my project now as a scientist in a unique way."

What convinced Valdes to fully transition into biology, though, was a summer spent at MIT. Leading up to her senior year, she was accepted into the Bernard S. and Sophie G. Gould MIT Summer Research Program in Biology (BSG-MSRP-Bio). She describes that experience as "going to Disney World for the first time" — high praise coming from a Florida native.

"That was my first exposure to high-intensity, high-output science, to an environment where everyone was hyper-focused toward achieving this goal of expanding the human knowledge base," says Valdes.

Valdes, along with Amanuella Mengiste, a fellow PhD student in chemistry, are the most recent recipients of the Future Fund of Science Fellowship.
*Photo: Steph Stevens*

During the internship, she worked in the lab of Eliezer Calo, an assistant professor of biology. The Calo Lab is interested in ribosomes, the small cellular particles that translate RNA into proteins, and how mutations in ribosome development can lead to disorders and cancer. Valdes was interested specifically in the causes and progression of Treacher Collins syndrome, a rare genetic disorder that affects the development of the face and skull.

Calo — a BSG-MSRP-Bio alumnus himself — says that Valdes, with her curiosity, motivation, and enthusiasm did an incredible job that summer.

“I was truly delighted to have Giselle join the lab,” he says. “From the day she started, it was clear that she is a gifted, smart, and highly creative young scientist — intellectually, conceptually, and experimentally.”

According to Valdes, the environment she found in the Calo Lab, and MIT broadly, was as valuable as the research experience itself. She says that everyone was incredibly welcoming and took significant time to train her on molecular biology techniques and methods that were all new to her.

“It was expected and welcome for you to step outside of what you knew and your comfort zone and grow as a scientist,” she says, “and the tools and community were here for you to do that.”

By the end of the summer, Valdes knew that if MIT accepted her into a graduate program, she’d go. Fortunately, she was accepted; the next year, Valdes joined the PhD program in the Department of Biology.

“You got the sense that everyone really cared and wanted you to succeed as a scientist,” says Valdes of her initial reaction to the department. “It was a place where I felt that I could grow as a scientist in the ways I wanted to.”

Coming from biomedical engineering, Valdes spent her first year rotating through labs and taking foundational biology courses to help her “make a more rounded decision” about the kind of research she wanted to do. She quickly fell in love with cell and developmental biology and decided to join the Reddien Lab, which focuses on the cellular and molecular processes behind regeneration in various species.

Valdes works on planarians, a type of flatworm that can regenerate its entire body. She focuses, specifically, on stem cell differentiation, trying to understand how stem cells decide what kind of final cell type they’ll evolve into, a critical step in development and regeneration. While she stresses that she’s very much doing basic biology research, she’s almost giddy about its potential applications in the future.

“This might seem almost sci fi, but wouldn’t it be cool to get a mammalian system to fully regenerate organs and body structures?” she exclaims.

Throughout her graduate studies to date, Valdes has remained steadfastly enthusiastic about a career in science. She also remains grateful for the mentors that have helped her get to this point. At MIT, that includes Reddien, Calo, and Mandana Sassanfar, the Biology Department’s director of diversity and science outreach who recruited Valdes to the BSG-MSRP-Bio program. At FIU, it includes Winkle, of course, who first exposed her to what it meant to be a scientist. It also includes the administrators of FIU’s McNair Scholars Program, named for Ronald E. McNair PhD ’77, an accomplished astronaut who received his doctorate in physics from MIT and tragically perished onboard the Challenger space shuttle. The McNair program, Valdes says, provided networking opportunities, such as the one that connected her to Sassanfar, and enabled her to attend conferences and undertake research as an undergraduate.

“These outreach programs and mentorship opportunities were invaluable in getting me to where I am today,” says Valdes.

As for her most recent accomplishment, securing the Future Fund of Science Fellowship, Valdes says she is incredibly grateful for the recognition. She’s also excited for how the fellowship will allow her to take risks in her research and push the bounds of scientific discovery, just as she had hoped to do back in middle school.

“Being a student at MIT has given me the opportunity to take an active role in shaping our understanding of the mechanisms of genetic expression with tools and support I don’t think I would have had otherwise,” she says. “I’m very grateful for the opportunity to be here, and I’m excited to develop as a scientist in this program.”

# Computing our climate future

**To put global climate modeling at the fingertips of local decision-makers, some scientists think it's time to rethink the system from scratch**

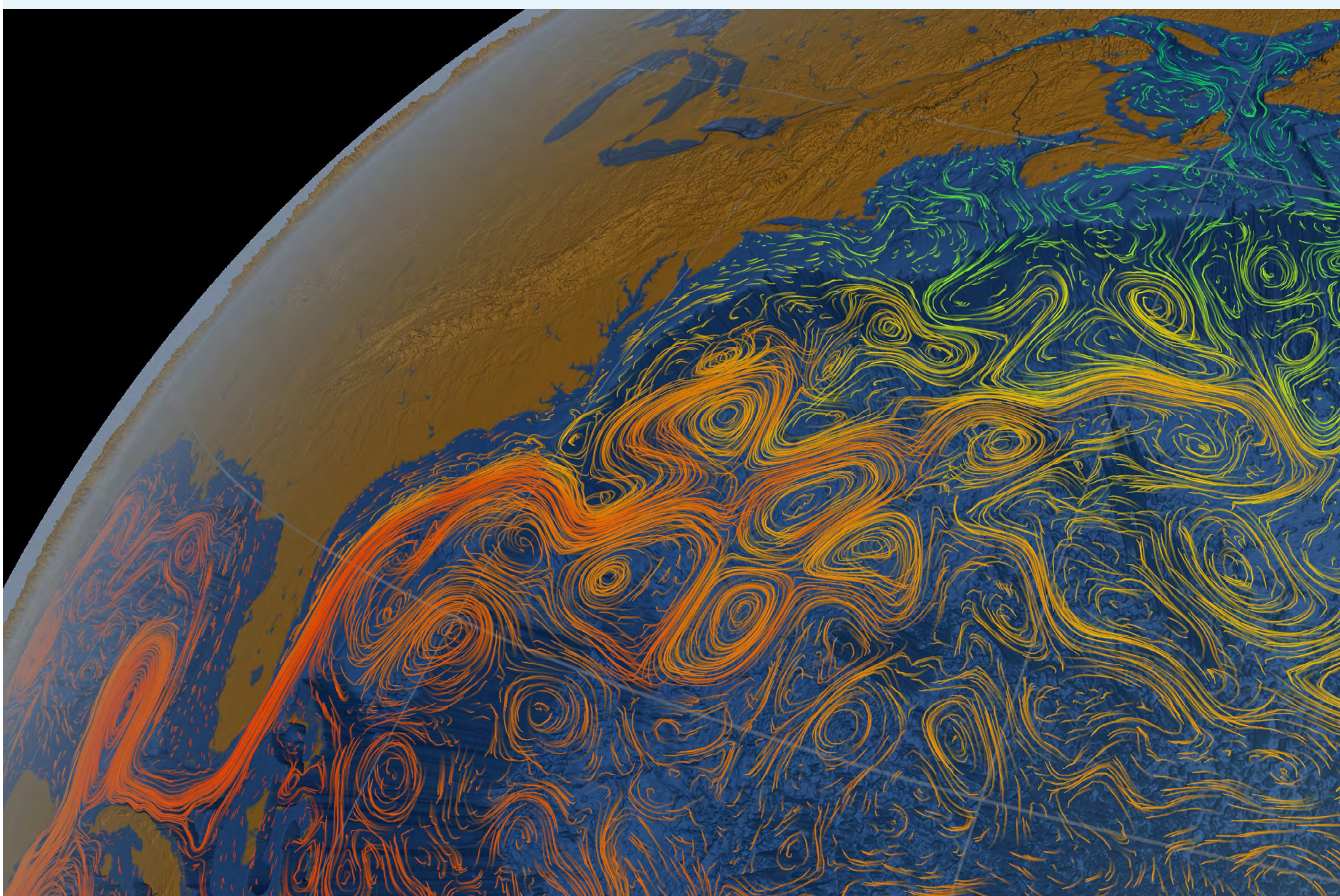
Paige Colley | Earth, Atmospheric and Planetary Sciences

With improvements to computer processing power and an increased understanding of the physical equations governing the Earth's climate, scientists are continually working to refine climate models and improve their predictive power. But the tools they're refining were originally conceived decades ago with only scientists in mind. When it comes to developing tangible climate action plans, these models remain inscrutable to the policymakers, public safety officials, civil engineers, and community organizers who need their predictive insight most.

"What you end up having is a gap between what's typically used in practice, and the real cutting-edge science," says Noelle Selin, a professor in the Institute for Data, Systems, and Society and the Department of Earth, Atmospheric and Planetary Sciences (EAPS), and co-lead with Professor Raffaele Ferrari on the MIT Climate Grand Challenges flagship project, Bringing Computation to the Climate Challenge. "How can we use new computational techniques, new understandings, new ways of thinking about modeling, to really bridge that gap between state-of-the-art scientific advances and modeling, and people who are actually needing to use these models?"

Using this as a driving question, the team won't just be trying to refine current climate models, they're building a new one from the ground up.

This kind of game-changing advancement is exactly what the MIT Climate Grand Challenges is looking for, which is



why the proposal has been named one of the five flagship projects in the ambitious Institute-wide program aimed at tackling the climate crisis. The proposal, which was selected from 100 submissions and was among 27 finalists, will receive additional funding and support to further their goal of reimagining the climate modeling system. It also brings together contributors from across the Institute, including the MIT Schwarzman College of Computing, the School of Engineering, and the Sloan School of Management.

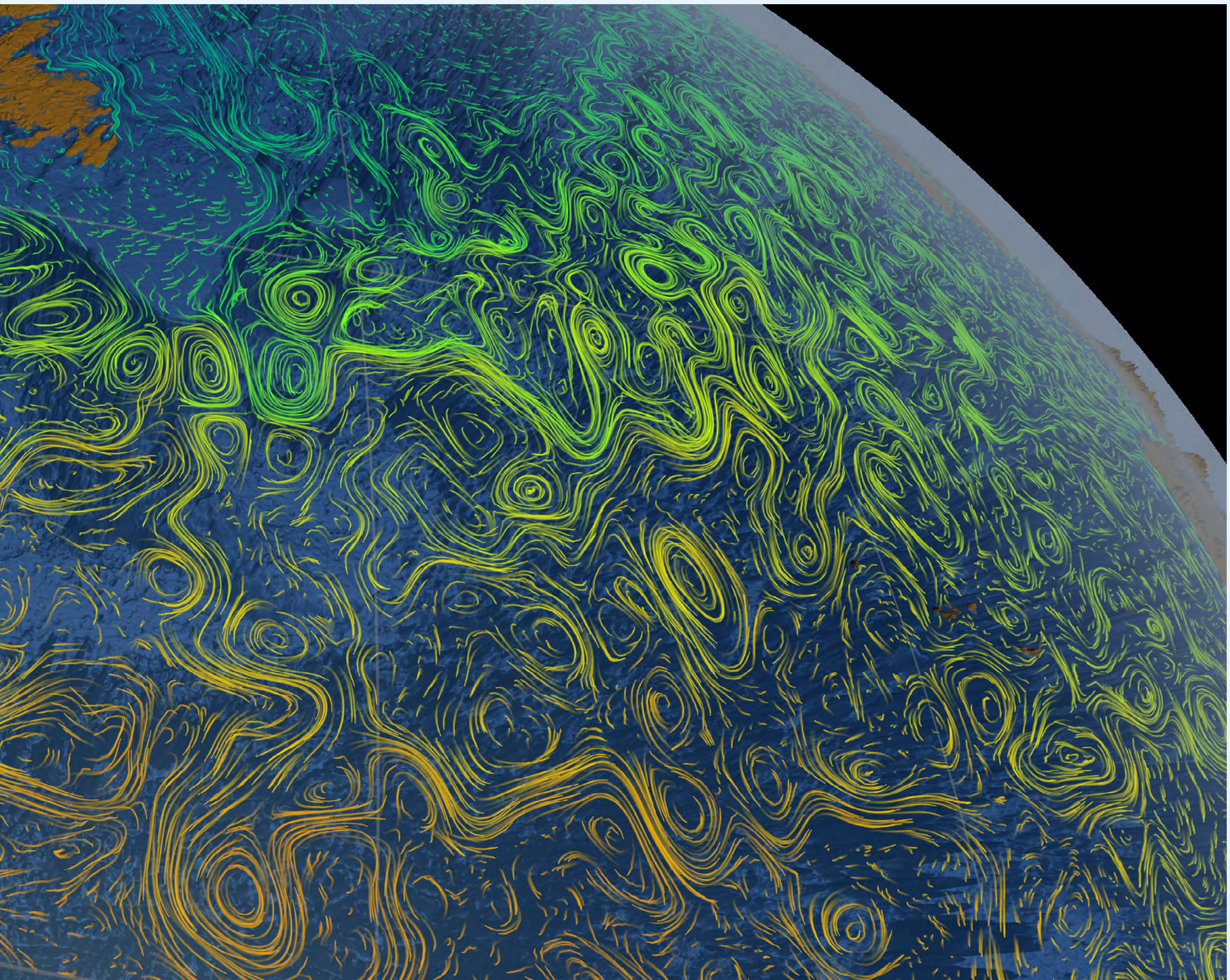
When it comes to pursuing high-impact climate solutions that communities around the world can use, "it's great to do it at MIT," says Ferrari, EAPS Cecil and Ida Green Professor of Oceanography. "You're not going to find many places in the world where you have the cutting-edge climate science, the cutting-edge computer science, and the cutting-edge policy science experts that we need to work together."

## The climate model of the future

The proposal builds on work that Ferrari began three years ago as part of a joint project with Caltech, the Naval Postgraduate School, and NASA's Jet Propulsion Lab. Called the Climate Modeling Alliance (CliMA), the consortium of scientists, engineers, and applied mathematicians is constructing a climate model capable of more accurately projecting future changes in critical variables, such as clouds in the atmosphere and turbulence in the ocean, with uncertainties at least half the size of those in existing models.

To do this, however, requires a new approach. For one thing, current models are too coarse in resolution — at the 100-to-200-kilometer scale — to resolve small-scale processes like cloud cover, rainfall, and sea ice extent. But also, explains Ferrari, part of this limitation in resolution is due to the fundamental architecture of the models themselves. The languages most global climate models are coded in were first created back in the 1960s and '70s, largely by scientists for scientists. Since then, advances in computing driven by the corporate world and computer gaming have given rise to dynamic new computer languages, powerful graphics processing units, and machine learning.

For climate models to take full advantage of these advancements, there's only one option: starting over with a modern, more flexible language. Written in Julia, a part of Julialab's Scientific Machine Learning technology, and spearheaded by Alan Edelman, a professor of applied mathematics in MIT's Department of Mathematics, CliMA will be able to harness far more data than the current models can handle.



The Gulf Stream stretches from the Gulf of Mexico towards Western Europe in a visualization produced using the joint MIT/JPL project, Estimating the Circulation and Climate of the Ocean, Phase II. *Photo: NASA*

“It’s been real fun finally working with people in computer science here at MIT,” Ferrari says. “Before it was impossible, because traditional climate models are in a language their students can’t even read.”

The result is what’s being called the “Earth digital twin,” a climate model that can simulate global conditions on a large scale. This on its own is an impressive feat, but the team wants to take this a step further with their proposal.

“We want to take this large-scale model and create what we call an ‘emulator’ that is only predicting a set of variables of interest, but it’s been trained on the large-scale model,” Ferrari explains. Emulators are not new technology, but what is new is that these emulators, being referred to as the “Earth digital cousins,” will take advantage of machine learning.

“Now we know how to train a model if we have enough data to train them on,” says Ferrari. Machine learning for projects like this has only become possible in recent years as more observational data become available, along with improved computer processing power. The goal is to create smaller, more localized models by training them using the Earth digital twin. Doing so will save time and money, which is key if the digital cousins are going to be usable for stakeholders, like local governments and private-sector developers.

## Adaptable predictions for average stakeholders

When it comes to setting climate-informed policy, stakeholders need to understand the probability of an outcome within their own regions — in the same way that you would prepare for a hike differently if there’s a 10 percent chance of rain versus a 90 percent chance. The smaller Earth digital cousin models will be able to do things the larger model can’t do, like simulate local regions in real time and provide a wider range of probabilistic scenarios.

“Right now, if you wanted to use output from a global climate model, you usually would have to use output

Raffaele Ferrari

Noelle Selin

that’s designed for general use,” says Selin, who is also the director of the MIT Technology and Policy Program. With the project, the team can take end-user needs into account from the very beginning while also incorporating their feedback and suggestions into the models, helping to “democratize the idea of running these climate models,” as she puts it. Doing so means building an interactive interface that eventually will give users the ability to change input values and run the new simulations in real time. The team hopes that, eventually, the Earth digital cousins could run on something as ubiquitous as a smartphone, although developments like that are currently beyond the scope of the project.

The next thing the team will work on is building connections with stakeholders. Through participation of other MIT groups, such as the Joint Program on the Science and Policy of Global Change and the Climate and Sustainability Consortium, they hope to work closely with policymakers, public safety officials, and urban planners to give them predictive tools tailored to their needs that can provide actionable outputs important for planning. Faced with rising sea levels, for example, coastal cities could better visualize the threat and make informed decisions about infrastructure development and disaster preparedness; communities in drought-prone regions could develop long-term civil planning with an emphasis on water conservation and wildfire resistance.

“We want to make the modeling and analysis process faster so people can get more direct and useful feedback for near-term decisions,” she says.

The final piece of the challenge is to incentivize students now so that they can join the project and make a difference. Ferrari has already had luck garnering student interest after co-teaching a class with Edelman and seeing the enthusiasm students have about computer science and climate solutions.

“We’re intending in this project to build a climate model of the future,” says Selin. “So it seems really appropriate that we would also train the builders of that climate model.”

# Growing demand for an energy transition could move the needle, but not far enough

Mark Dwortzan | MIT Joint Program on the Science and Policy of Global Change

Like many of its predecessors, the 2021 United Nations Climate Change Conference (COP26) in Glasgow, Scotland, concluded with bold promises on international climate action aimed at keeping global warming well below 2 degrees Celsius, but few concrete plans to ensure that those promises will be kept. While it's not too late for the Paris Agreement's nearly 200 signatory nations to take concerted action to cap global warming at 2°C — if not 1.5°C — there is simply no guarantee that they will do so. If they fail, how much warming is the Earth likely to see in the 21st century and beyond?

A new study by researchers at the MIT Joint Program on the Science and Policy of Global Change and the Shell Scenarios Team projects that without a globally coordinated mitigation effort to reduce greenhouse gas emissions, the planet's average surface temperature will reach 2.8°C, much higher than the "well below 2°C" level to which the Paris Agreement aspires, but a lot lower than what many widely used business-as-usual scenarios project.

Recognizing the limitations of such scenarios, which generally assume that historical trends in energy technology choices and climate policy inaction will persist for decades to come, the researchers have designed a so-called growing-pressures scenario that accounts for mounting social, technological, business, and political pressures that are driving a transition away from fossil fuel use and toward a low-carbon future. Such pressures have already begun to expand low-carbon technology and policy options, which, in turn, have escalated demand to utilize those options — a trend that's expected to self-reinforce. Under this scenario, an array of future actions and policies cause renewable energy and energy storage costs to decline; fossil fuels to be phased out; electrification to proliferate; and emissions from agriculture and industry to be sharply reduced.

Incorporating these growing pressures in the MIT Joint Program's integrated model of Earth and human systems, the study's co-authors project future energy use, greenhouse gas emissions, and global average surface

Protestors call for a climate recovery plan at the DC Youth Climate Strike 2019 at the U.S. Capitol.
*Photo: Hillel Steinberg*

temperatures in a world that fails to implement coordinated, global climate mitigation policies, and instead pursues piecemeal actions at mostly local and national levels.

"Few, if any, previous studies explore scenarios of how piecemeal climate policies might plausibly unfold into the future and impact global temperature," says MIT Joint Program research scientist Jennifer Morris, the study's lead author. "We offer such a scenario, considering a future in which the increasingly visible impacts of climate change drive growing pressure from voters, shareholders, consumers, and investors, which in turn drives piecemeal action by governments and businesses that steer investments away from fossil fuels and toward low-carbon alternatives."

In the study's central case (representing the midrange climate response to greenhouse gas emissions), fossil fuels persist in the global energy mix through 2060 and then slowly decline toward zero by 2130; global carbon dioxide emissions reach near-zero levels by 2130 (total greenhouse gas emissions decline to near-zero by 2150); and global surface temperatures stabilize at 2.8°C by 2150, 2.5°C lower than a widely used business-as-usual projection. The results appear in the journal *Environmental Economics and Policy Studies*.

Such a transition could bring the global energy system to near-zero emissions, but more aggressive climate action would be needed to keep global temperatures well below 2°C in alignment with the Paris Agreement.

"While we fully support the need to decarbonize as fast as possible, it is critical to assess realistic alternative scenarios of world development," says Joint Program deputy director Sergey Paltsev, a co-author of the study. "We investigate plausible actions that could bring society closer to the long-term goals of the Paris Agreement. To actually meet those goals will require an accelerated transition away from fossil energy through a combination of R&D, technology deployment, infrastructure development, policy incentives, and business practices."

The study was funded by government, foundation, and industrial sponsors of the MIT Joint Program, including Shell International.

# Advocating for vaccine equity

## Postdoc Digbijay Mahat became a cancer researcher to improve health care in Nepal, but the Covid-19 pandemic exposed additional resource disparities

Raleigh McElvery | Biology

When Digbijay Mahat arrived at MIT in 2017 to begin his postdoctoral studies, he had one clear goal: become an expert in cancer research and diagnostics to improve health care in his home country of Nepal. In 2020, when the Covid-19 pandemic laid bare resource disparities around the world, his goal did not waiver. But it did expand to fill a more immediate need — help Nepal find the best way to navigate widespread Covid testing requirements and vaccine rollouts.

Mahat was born in the western region of Nepal, where his family has owned a large swath of land for generations. Before Mahat was born, his grandfather passed away unexpectedly, and, as the eldest son, Mahat's 21-year-old father assumed responsibility for his five siblings, giving up the opportunity to pursue his own education. Perhaps because of this, he made it his mission to give Mahat the education he never received.

While his father wished him all the success and prestige of a medical career, Mahat had other plans. Toward the end of high school, he became captivated by song writing, and even secretly used his school tuition money one semester to record an album. "It was a disastrous flop," he now recalls with a smile.

When the Covid-19 pandemic laid bare discrepancies in resource equity, postdoc Digbijay Mahat worked to help Nepal navigate widespread Covid-19 testing requirements and vaccine rollouts.
*Photo: Raleigh McElvery*


A glimpse of Covid-19 vaccine administration at Karnali Province, Nepal. As of January 2022, 40 percent of Nepal's total population are now fully vaccinated against Covid-19, according to the World Health Organization.
*Photo: World Health Organization*

Although his foray into music provides comic relief today, at the time, Mahat was dismayed to be back on the medical track. He was able to at least convince his father to let him go to the United States for college. He ended up at Towson University in Maryland, living with his aunt and uncle and delivering pizzas to support his family back in Nepal.

As a molecular biology, biochemistry, and bioinformatics major, he took every research opportunity he could get and became enthralled by breast cancer research. Shortly thereafter, his mother was diagnosed with the same disease, which strengthened his conviction to learn as much as he could in the U.S. and return to Nepal to help patients there.

"The state of cancer diagnostics is very poor in Nepal," Mahat explains. Patient biopsies must be sent to other countries like India — a costly practice at the mercy of politics and travel restrictions. "The least we can do is become self-sufficient and provide these vital molecular diagnostics tools to our own people," he says.

Mahat went on to earn his PhD in molecular biology and genetics from Cornell University. When the opportunity to pursue postdoctoral studies with MIT professor Susan Lindquist fell through (Lindquist tragically passed from cancer in 2016), Mahat scrambled to find another position, building up the courage to send a formal research proposal to MIT professor, Koch Institute member, and Nobel Laureate , Phil Sharp. A few days later, he joined Sharp's lab.

"From the beginning, the things that struck me about Phil were his humility, his attention to experimental detail, and his inexplicable reservoir of insight," Mahat says. "If I could carry even just some of that same humility with me for the rest of my life, I would be a good human being."

In 2018, Mahat and Sharp filed a patent with the potential to revolutionize disease diagnostics. Widely available, single-cell sequencing technologies reveal the subset of RNAs inside a cell that build proteins. But Mahat and his colleagues found a way to take a snapshot of all the RNA inside a single cell that is being transcribed from DNA, including RNAs that will never become proteins. Because many ailments arise from mutations in the noncoding DNA that gives rise to this noncoding RNA, the researchers hope their method will help expose the function of noncoding variants in diseases like diabetes, autoimmune disorders, neurological diseases, and cancer.

Mahat was still immersed in this research in early 2020 when the Covid-19 pandemic escalated. As case numbers soared around the world, it became clear to him that the wealth of testing resources available on MIT's campus — and throughout the U.S. generally — dwarfed the means available to his family back in Nepal. Polymerase chain reaction (PCR) testing remains the most popular and accurate means to detect the virus. While PCR machines are quite common in molecular biology labs across the U.S., according to Mahat, the entire country of Nepal owned just a few at the start of the pandemic.

"Digbijay was focused intensely on developing our novel single-cell technology when he became aware of Nepal's challenges to control the Covid-19 pandemic," Sharp recalls. "While continuing his research in the lab, he spent several months contacting leaders in pharmaceutical companies in the U.S. and leaders in public health in Nepal to help arrange access to vaccines and rapid tests."

Mahat was already in contact with the Nepali Ministry of Health and Population regarding the state of the country's cancer diagnostics, and so the government called on him to advise their Covid testing efforts. Given the high cost and limited availability of PCR machines and reagents, Mahat began discussions with an MIT-spinoff biotechnology company, Sherlock Biosciences, in order to bring alternative testing technology to Nepal. These Covid tests, which were developed at the Broad Institute of MIT and Harvard, use the CRISPR-Cas9 system — rather than PCR — to detect the SARS-CoV2 virus that causes Covid-19, making them cheaper and more readily available. Sherlock Biosciences ultimately donated $100,000-worth of testing kits, supplemented by an additional $100,000 grant from the Open Philanthropy Project to help purchase the equipment necessary to implement the tests. In December of 2020, Mahat and his wife Rupa Shah flew to Nepal to set up a testing center using these new resources.

Although this required Mahat to briefly pause his MIT research, Sharp was supportive of these extracurricular pursuits. "We are very proud of his effective work benefiting the people of Nepal," Sharp says.

In addition, Mahat has connected the Nepali government to Johnson & Johnson, secured additional PCR reagents with the help of Thermo Fisher Scientific, and used leftover funds in the Open Philanthropy Project grant to send several thousand additional PCR kits to Nepal at the height of the Omicron wave. Mahat, Sharp, and colleagues also actively encouraged MIT president Rafael Reif to join university leadership in urging the Biden administration to donate vaccines to low-income countries.

These days, Mahat is nothing short of a local celebrity in Nepal. Despite his current drive for ensuring vaccine equity, his ultimate goal is still to bring cancer treatment resources to the country. He not only envisions setting up his own research center there, but also hopes to inspire young people to pursue careers in research. "Before me, no one in my entire village had pursued a scientific career, so if I could motivate even a few young kids to follow that path, it would be a win for me," he says.

But Mahat adds, he's not ready to leave MIT just yet. "I feel privileged and honored to be part of this compassionate community," he says. "I'm also proud — proud that we've been able to come together in this time of need."

Digbijay Mahat (right) and his wife Rupa Shah wait at the presidential palace for an audience with the president of Nepal, Bidya Devi Bhandari.
*Photo: courtesy of Digbijay Mahat and Rupa Shah*

# Using elegant math to understand complex systems of the brain

## Martin Luther King Jr. Scholar Lawrence Udeigwe bridges disciplines to translate vision into elegant math and neuroscience theory

Leah Campbell | School of Science

It's a tale familiar to many first-generation students. Neither of Lawrence Udeigwe's parents had more than a sixth-grade education, and yet they were willing to sacrifice everything to educate their children.

"My dad," Udeigwe says, "would tell us, 'I'm ready to sell everything for you guys to go to school.'"

Udeigwe recounts that in Nigeria at the time, achieving the sort of success and stability his parents hoped for meant studying something practical and working for the government. So, he moved to the United States, enrolled at Duquesne University in Pittsburgh, and majored in computer science.

"But then I discovered math," he says, and his dream of a programming job with the government back in Nigeria was replaced by something new.

Udeigwe has gone on to have a successful career as a professor of mathematics at Manhattan College in New York City, bridging disciplinary gaps between computation, pure math, and neuroscience. This year, Udeigwe is at MIT as a Martin Luther King (MLK) Visiting Professor and Scholar in the Department of Brain and Cognitive Sciences. He's one of nine professors, in research areas ranging from art to engineering, selected for outstanding contributions in their fields to increase the presence of underrepresented scholars of color at MIT.

Lawrence Udeigwe stands with James DiCarlo, the Peter de Florez Professor of Neuroscience and Udeigwe's MIT host during his tenure as an MLK Visiting Professor.
*Photo: Steph Stevenson*

The journey to MIT for Udeigwe began in graduate school at the University of Delaware. Though the program was called applied math, he was technically studying pure math until, as he explains with a laugh, he discovered that he was, in fact, interested in applied math, specifically in its applications in biology.

Like his discovery of math as an undergraduate, Udeigwe's discovery of mathematical biology pushed him to shift gears. He moved back to Pennsylvania to the University of Pittsburgh to continue his PhD where he got his first taste of mathematical neuroscience. From there, he became a professor at Manhattan College, a liberal arts college in the Bronx. He says that it's been a wonderful position for improving his teaching skills and getting to work closely with students, but he's often had to put his research on the back burner.

Despite the heavy course load, though, he's remained intellectually engaged with the neuroscience community, attending conferences and watching lectures online. One such presentation, from MIT's Center for Brain, Mind, and Machines, was by MIT's James DiCarlo, the Peter de Florez Professor of Neuroscience and, at the time, head of the Department of Brain and Cognitive Sciences.

Udeigwe was immediately drawn to DiCarlo's research using advanced computer models to understand the complex systems in the brain that underlie vision. A cold email and several meetings later, DiCarlo and Udeigwe had applied for the MLK Scholars Program to get Udeigwe to MIT.

"I love Jim's lab, the collegial nature of it," Udeigwe says. "We're all colleagues, trying to build something, trying to push forward our little part of the enterprise of science."

One of the core aspects of that enterprise for Udeigwe has been to bridge what DiCarlo describes as a tension in neuroscience. On the one side are those classically trained in math and physics who want to create models to describe neural activity using elegant equations that are easy to understand (at least for anyone who thinks in terms of simple differential equations). On the other side are those like DiCarlo who rely on simulation and brute computational force to create models that can scale up to describe the entire complex system of vision but are, as DiCarlo describes them, "opaque to humans."

Both Udeigwe and DiCarlo hope that by working together they can find something in between.

"He's a mathematician. I'm more of an engineer and experimentalist," says DiCarlo. Both, he explains, have a lot to learn from each other as to how the other side approaches fundamental questions in neuroscience. They're also the perfect combination to jointly teach students to better understand the advantages — and

**“I’m a mathematician. I like the pithiness of math equations ... But not all nice equations lead to things we can build so I have to be open to different methodologies.”**

potential shortfalls — of applying mathematical theories to complex systems like the brain.

The class they’ve designed, a seminar for graduate students and advanced undergraduates, starts with a basic discussion establishing definitions and clarifying differences between theories, models, hypotheses, and frameworks. From there, they plan to look at “theories that have worked,” as Udeigwe describes it, figuring out where those theories came from, what they can accomplish, and where they’ve fallen short.

“Students will explore the pros and cons of these two toolboxes,” says DiCarlo. “Are they going to go more to the classic, elegant differential equations toolbox? Are they going to go to the more modern, artificial network simulation toolbox? Or are they going to find bridges between those two approaches, as Lawrence is trying to do?”

To that end, Udeigwe has been working with Tiago Marques, a postdoc in the lab, on a project to improve models of what’s called the ventral stream. The ventral stream is the series of brain processing steps that translates images into patterns of increasingly complex neural activity so that the image striking the eye becomes an object recognized by the brain. The first processing step, called the V1, is the part of the path that’s best understood. Of particular interest is a property of the V1 area called surround suppression.

Scientists understand that each neuron in the V1 is activated in response to one small region of an image. Standard computer models of visual processing are designed to capture that fact. Surround suppression, though, means that the strength of each neuron is modified (usually suppressed, as the name suggests) by the addition of features in the image outside of that neuron’s primary region — features that stimulate neighboring neurons. While such surround phenomena are empirically well understood, they’re not explicitly incorporated into existing models of the ventral stream.

Udeigwe’s goal is to change that by incorporating surround suppression into contemporary models derived from machine learning, with the hope that that will improve object recognition to be more humanlike. In turn, those computer models — grounded in elegant mathematics — can be used to better understand object recognition in people.

DiCarlo says that Udeigwe’s work is an ambitious step in trying to link mathematical models at the single-neuron scale to the workings of the entire ventral processing stream. For Udeigwe, it’s an also opportunity to bring together MIT and Manhattan College. Two of his students, Andrew Cirincione and Artiom Bic, are working on the research with Udeigwe and Marques and have visited MIT several times.

Udeigwe is already strategizing ways to foster his relationship with MIT beyond the period of the fellowship. He hopes to continue teaching the course developed with DiCarlo, extending it around theory in science broadly, and to leverage the relationships he’s building this year for future collaborations. He also wants to further his research around the intersections of math and vision with bite-sized projects that his Manhattan College students, such as Cirincione and Bic, can undertake.

Udeigwe has also been developing a research initiative for veterans and reservists at MIT. The idea was motivated both by his own long-standing interest in military service as a means to give back to the country and his experiences with student veterans at Manhattan College. Udeigwe hopes to foster opportunities for students to develop and undertake research projects around national security issues, informed by what he describes as the unique perspective and problem-solving skills they’ve gained through military service.

As to whether his time at MIT has converted him to DiCarlo’s more simulation-based approach to neuroscience, Udeigwe laughs that he remains “agnostic.”

“I’m a mathematician. I like the pithiness of math equations. It’s elegant, it’s portable to other fields. It’s easy to convey to students,” he explains. “But, at the same time, not all nice equations lead to things we can build ... so I have to be open to different methodologies.”

# New book celebrates trailblazing MIT physicist Mildred Dresselhaus

## “Carbon Queen” explores how the Institute Professor transformed our understanding of the physical world and made science and engineering more accessible to all

Kate Silverman Wilson | MIT Press

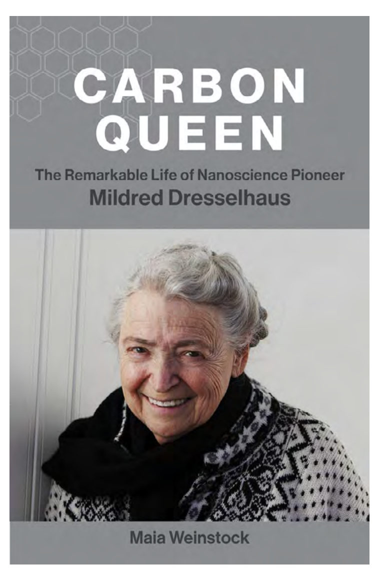
As a girl in New York City in the 1940s, Mildred “Millie” Dresselhaus was taught that there were only three career options open to women: secretary, nurse, or teacher. But sneaking into museums, purchasing three-cent copies of *National Geographic*, and devouring books on the history of science ignited in Dresselhaus a passion for inquiry.

In “Carbon Queen: The Remarkable Life of Nanoscience Pioneer Mildred Dresselhaus,” science writer Maia Weinstock, who is also the deputy editorial director in the MIT News Office, describes how, with curiosity and drive, Dresselhaus defied expectations and forged a career as a pioneering scientist and engineer. Dresselhaus made highly influential discoveries about the properties of carbon and other materials and helped reshape our world in countless ways — from electronics to aviation to medicine to energy. She was also a trailblazer for women in STEM and a beloved educator, mentor, and colleague.

“Millie was nothing less than a hero to many, in her home country and around the world,” Weinstock writes in “Carbon Queen.” “The story of her life provides insights into the workings of an ever-expanding mind, the ongoing evolution of societal attitudes toward women and people of color in science and engineering, and the unique power of kindness.”

Her path wasn’t easy. Dresselhaus’ Bronx childhood was impoverished. Her graduate advisor felt educating women was a waste of time. But Dresselhaus persisted, finding mentors in Nobel Prize-winning physicists Rosalyn Yalow and Enrico Fermi. Eventually, Dresselhaus became one of the first female professors at MIT, where she would spend nearly six decades. Weinstock explores the basics of Dresselhaus’ work in carbon nanoscience, describing how she identified key properties of carbon forms, including graphite, buckyballs, nanotubes, and graphene, leading to applications that range from lighter, stronger aircraft to more energy efficient and flexible electronics.

Mildred “Millie” Dresselhaus




*Book cover courtesy of MIT Press*

Maia Weinstock
*Photo: Cidgy Bossuet*

# Climate science on display

**Museum exhibits can be a unique way to communicate science concepts and information, especially as concerns climate change; recently, MIT faculty have served as sounding boards for curators at the Museum of Science, Boston, a close neighbor of the MIT campus**

## Advancing public understanding of sea-level rise

Paige Colley | Earth, Atmospheric and Planetary Sciences

Professor Emerita Paola Malanotte-Rizzoli in the Department of Earth, Atmospheric and Planetary Sciences was asked to consult on the Museum of Science's newly opened exhibit, "Resilient Venice: Adapting to Climate Change."

The exhibit focuses on Malanotte-Rizzoli's hometown, a city known for flooding. Built on a group of islands in the Venetian Lagoon, Venice has always experienced flooding, but climate change has brought unprecedented tide levels, causing billions of dollars in damage.

Brent Minchew

One of the plans Venice has implemented to address the flooding is the MOSE system — short for Modulo Sperimentale Elettromeccanico, or the Experimental Electromechanical Module. The MOSE is a system of flood barriers designed to protect the city from extremely high tides. Construction began in 2003, and its first successful operation happened on Oct. 3, 2020, when it prevented a tide 53 inches above normal from flooding the city.

Professor Emerita Paola Malanotte-Rizzoli inspects the displays created by Iconem, a startup whose mission is digital preservation of endangered World Heritage Sites. The firm took detailed 3D scans and images of Venice to put together the displays and video.
*Photo: Paige Colley*

The barriers are made of a series of gates, each 66 to 98 feet in length and 66 feet wide, which sit in chambers built into the sea floor when not in use to allow boats and wildlife to travel between the ocean and lagoon. The gates are filled with water to keep them submerged; when activated, air is pumped into them, pushing out the water and allowing them to rise. The entire process takes 30 minutes to complete, and half that time to return to the sea floor.

The MOSE system is only one of many plans taken to mitigate the rising water levels in Venice and to protect the lagoon and the surrounding area, and this is an important point for Malanotte-Rizzoli, who worked on the project from 1995 to 2013.

"It is not the MOSE or," she emphasizes. "It is the MOSE and." Other complementary plans have been implemented to reduce harm to both economic sectors, such as shipping and tourism, as well as the wildlife that live in the lagoons.

## "Arctic Adventure: Exploring with Technology"

Alice McBride | Earth, Atmospheric and Planetary Sciences

In centuries past, it took exceptional effort — and a hefty dose of luck — for polar explorers to survive an expedition across the tundra, glaciers, and icy waters of the Arctic Circle. Since then, modern technology has revolutionized our ability to access and explore these remote and often harsh areas — making polar research safer and bringing in scientific data that even the most curious and intrepid early explorers could never have dreamed of.

Now, by touring the "Arctic Adventure: Exploring with Technology" exhibit, visitors to the Museum of Science can step into the shoes of modern-day polar researchers and discover firsthand the remarkable ways technology helps us learn about these critical regions of the world.

The new permanent exhibit revolves around interactive displays and an immersive design — bringing to life the unique land- and seascapes of the far north through sight, sound, and touch. The experience ranges from discovering the extremes of seasonal sunlight patterns, to hearing the calls of wild animals and feeling the frigid Arctic temperatures of an ice wall you can reach out and touch.

"The overarching goal is to emphasize the beauty and the fragility of the polar environments," says Brent Minchew, the Cecil and Ida Green Career Development Professor in MIT's Department of Earth, Atmospheric and Planetary Sciences. Minchew, a geophysicist who specializes in glaciers and their role in Earth's climate system, provided input and advice to the museum throughout the exhibit's two-year development.

"What's happening in the poles is critically important for a variety of reasons," says Minchew. "They're bellwethers for what's happening in the rest of the climate system. Glaciers shrinking and polar bears losing their habitat and these sorts of things are powerful indicators of what is going on in the world as the climate changes."

Families explore the Museum of Science's "Arctic Adventure" exhibit.
*Photo: Nicolaus Czarnecki/ Museum of Science*

# Challenges behind us

Daniel Griffin | Biology

Dyann Wirth PhD '78

Every year, MIT challenges its alumni and friends to support its educational programs and research enterprise by giving during a 24-hour window. This year, friends and alumni of the School of Science stepped up to the challenge and set a new participation record during the 24-Hour Day of Giving Challenge on March 10.

This year's Challenge raised nearly $1.6 million to support the work of students, faculty, and staff across the Institute. Support provided to the School of Science went to a diverse list of priorities including student fellowships, innovation in research and teaching, and the school's flagship initiative around healthy aging of the brain.

## Reigning champion

Dyann Wirth PhD '78 once again served as the school's 24-Hour Challenger with an ambitious goal: if 175 donors contributed to a fund within the School of Science, that would unlock Dyann's first gift of $50,000; if an additional 175 supporters joined the Challenge, she'd double her gift. Those numbers were easily surpassed with the groundswell of support for the Aging Brain Initiative.

An expert in the molecular biology of infectious diseases, Wirth knows firsthand the importance of funding to enable an active research program in the life sciences.

"An investment in educating the next generation of scientists is crucial to ensuring our health and well-being in the future," says Wirth, who is the current chair of the World Health Organization's Malaria Policy Advisory Committee. She is also a member of the Broad Institute of MIT and Harvard and the Richard Pearson Strong Professor of Infectious Diseases at the Harvard University T. H. Chan School of Public Health.

In total, more than 450 alumni, students, parents, faculty, staff, friends, and others from all over the world supported the School of Science with individual donations.

SCHOOL OF SCIENCE
Massachusetts Institute of Technology
77 Massachusetts Avenue, Building 6-131, Cambridge, MA 02139-4307



## Smoke from bushfires blankets the southeast coastline of Australia during the wildfires in 2020

The Australian wildfires in 2019 and 2020 were historic for how far and fast they spread, and for how long and powerfully they burned. All told, the devastating Black Summer fires blazed across more than 43 million acres of land, and killed or displaced nearly 3 billion animals. The fires also injected over 1 million tons of smoke particles into the atmosphere, reaching up to 35 kilometers above Earth's surface.

Now, atmospheric chemists at MIT have found that the smoke from those fires set off chemical reactions in the stratosphere that contributed to the destruction of ozone, which shields the Earth from incoming ultraviolet radiation. The team's study, in the *Proceedings of the National Academy of Sciences*, is the first to establish a chemical link between wildfire smoke and ozone depletion.

"The Australian fires look like the biggest event so far, but as the world continues to warm, there is every reason to think these fires will become more frequent and more intense," says lead author Susan Solomon, the Lee and Geraldine Martin Professor of Environmental Studies at MIT.

The study's co-authors include Kane Stone, a research scientist in MIT's Department of Earth, Atmospheric, and Planetary Sciences, along with collaborators at multiple institutions including the University of Saskatchewan, Jinan University, the National Center for Atmospheric Research, and the University of Colorado at Boulder.

*Photo: NASA*