the SPS Observer
Volume LIV, Issue 1
SPRING 2020

PHYSICS AND A CLIMATE IN CRISIS

+ Speaking Out and Getting Motivated
+ Meeting the Challenges of a Warming World
+ Stemming the Tide of Climate Change
+ SEES-ing Young Minds with Science
+ From E&M to Promoting Innovation in Developing Communities

SPS Chapter Report

Submission Deadline: June 15

Importance of Chapter Reports

- Maintain chapter health, success, and growth
- Provide guidance for future SPS members in your chapter
- Determine chapter's strengths and areas of improvement
- Share your chapter's best practices with other SPS chapters
- Receive feedback and recognition from SPS National Office

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- SPS Outstanding Chapter Awards
- Blake Lilly Prize
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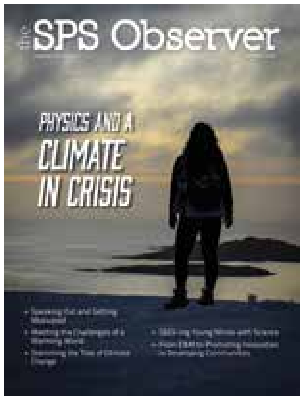
TABLE OF CONTENTS

SPRING 2020 ▪ VOLUME LIV, ISSUE 1

FEATURES

DEPARTMENTS



ON THE COVER
Oceanography grad student Jacquelyn Veatch stands atop a retreating glacier along the Western Antarctic Peninsula. However, the view looks promising as scientists from all disciplines work hard to understand our planet at Palmer Station. Photo courtesy of Jacquelyn Veatch.

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The Society of Rheology

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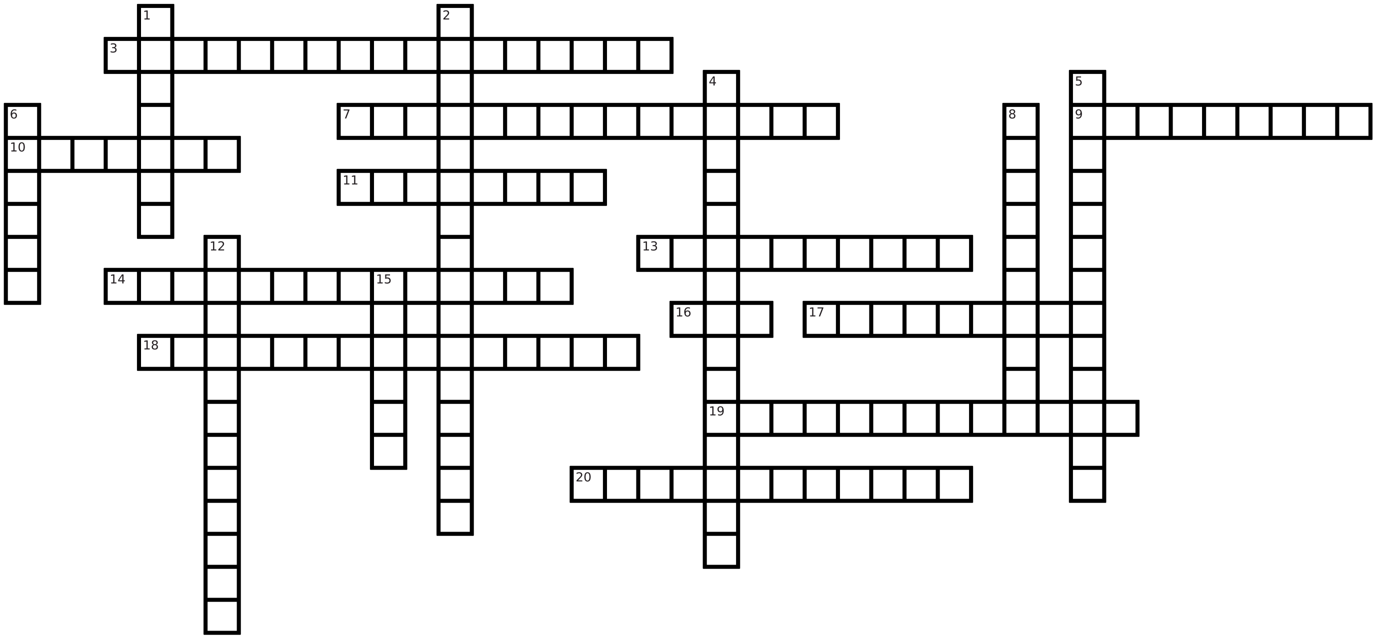
Crossword Puzzle – Climate Crisis

Put your climate science knowledge to the test with this climate-themed crossword puzzle! Can you finish it first?

by Kayla Stephens and Mikayla Cleaver, SPS National Office



ACROSS

3. Determining past climates from studying tree growth characteristics
7. Comes from naturally replenished resources, such as sunlight, wind, waves, and geothermal heat
9. Greenhouse gases released into the air that are produced by numerous activities, including burning fossil fuels, industrial agriculture, and melting permafrost, to name a few
10. Average of weather patterns over a longer period of time
11. These frozen bodies have been losing mass since at least the 1970s
13. Efforts to cut the rate of man-made emissions of greenhouse gas into the atmosphere
14. For the first time brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects, with enhanced support to assist developing countries to do so
16. A family of gases that have contributed to ozone depletion and are also greenhouse gases
17. A substance that contaminates the air, earth, or water
18. The total amount of greenhouse gases produced to directly and indirectly support human activities
19. Relating to or resulting from the influence of human beings
20. A daily record of global atmospheric carbon dioxide concentration

DOWN

1. A greenhouse gas that traps heat in the atmosphere
2. Study of climate change taken on the scale of the entire history of the Earth
4. Land degradation in arid, semi-arid, and dry subhumid areas resulting from various factors, including climatic variations and human activities
5. Permanent removal of trees and shrubbery that can lead to significant levels of carbon dioxide emissions
6. Absorbs around 30% of the CO_2 we pump into the atmosphere
8. Amount of electromagnetic radiation reaching a surface, measured in watts per square meter
12. Occurs naturally and is also caused by human activities such as agriculture, burning of fossil fuels, and industrial processes
15. Fiscal policy that introduces taxes intended to promote ecologically sustainable activities via economic incentives

Submit a picture of your completed crossword puzzle to sps-programs@aip.org for a chance to win. If you are one of the first THREE to complete and submit the puzzle correctly, you will win a prize from SPS National, get a shoutout on our social media, and be mentioned in the next issue of the *SPS Observer*! Best of luck puzzling!

Enacting Change as a Physicist

by Molly McDonough, SPS and Sigma Pi Sigma Executive Committee, Associate Zone Counselor Representative

Over the last 650,000 years, the Earth has weathered seven cycles of glacial advance and retreat. The end of the last cycle, around 11,700 years ago, marks the beginning of human civilization.[1]

With humans ultimately came industrialization and a marked deviation from Earth's past climate cycles. In the past century, the global sea level has risen about 8 inches, surface temperatures have risen by approximately 1.62 °F, and the ice sheets in Antarctica have rapidly shrunk.[1]

As physicists, it is our responsibility to educate ourselves and to communicate the evidence supporting the severity of the climate crisis in the age of false information and climate change denial.

The SPS and ΣΠΣ community expressed concern for the climate crisis at the 2019 Physics Congress, and as a result, the Society of Physics Students National Office voted to release the following SPS and ΣΠΣ Statement on the Climate Crisis:

"The Society of Physics Students and the Sigma Pi Sigma National Council encourage chapters to sponsor, engage in, and pursue outreach events that promote awareness of the scientific basis of human-induced climate change to the general public. Furthermore, chapters are encouraged to champion initiatives that address the climate crisis and to practice environmental sustainability."

It is critical that we call upon ourselves as scientists to advocate for climate change education to our public policymakers, government officials, and college and university administrators. If we don't take steps to educate those around us and make changes in our communities, climate change will be catastrophic to animals, ecosystems, and society. As the primary cause of climate change, humanity must do its part to reduce its ecological impact.

HERE ARE A FEW WAYS YOU CAN MAKE AN IMPACT ON CLIMATE CHANGE:

1. Speak up and vote!
This is the single most significant impact you can have on global climate change. Contact your local government officials (find their information at usa.gov/elected-officials) and encourage Congress to enact new laws that limit carbon emissions and require polluters to pay for the emissions they produce. If your elected officials are unwilling to change their stance on climate change, get out and vote. Voting in local and federal elections is critical to increasing awareness around climate change and getting the right people in office to make change happen. Additionally, the AIP Mather Public Policy Internship hosted by the Society of Physics Students places interns at congressional offices on Capitol Hill and at national laboratories. This program allows physicists like you to engage in science policy and make a difference on a federal level.

2. Use renewable energy.
At home, choose a utility company that generates at least half of its energy from solar or wind power. Review your electric, gas, and water usage to see if you can make reductions. At your college or university, bring up sustainability concerns with your department, student government, or university administration and see if they can provide support for enacting change.

ABOVE: Molly McDonough. Photo courtesy of the SPS National Office.

3. Rethink your commute.
Using public transit can drastically reduce your carbon footprint. Additionally, walking or biking to class is a great alternative to driving a car. Either of these options will reduce fuel consumption and the generation of air pollution and greenhouse gases. If a car is necessary, consider a more fuel-efficient option, such as a hybrid or electric car, or carpool with a friend!

4. Remember that small steps make a big difference.
By working to eliminate personal food waste and consumption of single-use plastics, everyone can contribute to reducing waste. Two major tenets of the recycling process are reduction and reuse of consumables. Reduce your plastic use by opting for reusable or compostable containers and bags, and reuse plastic bags, water bottles, and other containers.

As we continue our fight to save the planet, I encourage you to use the SPS community to support your efforts. The Society of Physics Students offers awards for students to support their outreach efforts, such as the Future Faces of Physics Award and the Marsh W. White Award. Most importantly, within SPS there are thousands of bright, passionate scientists who are ready to work with you to make a lasting difference for our planet. //

To learn more about SPS awards and opportunities, visit spsnational.org/awards.

References

1. climate.nasa.gov/evidence/

Beyond Undergrad Physics:

A Physicist's Path into Climate Science

by Samantha Staskiewicz, SPS Alumni, The Pennsylvania State University

As we enter another election season, I'm fascinated by the way our society has turned climate change into a political controversy. Because there is no controversy. Climate change *is* real.

As a scientist, I've never doubted the validity of climate change, and I personally think it is the biggest challenge facing our generation. In fact, solving the climate crisis should be at the forefront of the national agenda, because we will not be able to address other issues if our planet becomes uninhabitable and our species ceases to exist.

Many will call me dramatic; they'll say that we won't even be alive for the inevitable crumble of humanity, so why should we care? But the truth is, *we* might not be alive for it, but people around the world are already facing the consequences of the climate crisis, and things will only get more dangerous for the next generations.

A common argument for not taking climate change seriously is that our planet has gone through extreme environmental change over the centuries, and today's rising temperatures are no different. But we've only recently started to emit billions of tons of CO_2 from the burning of fossil fuels, which directly links to the planet's increasing temperatures. These emissions disrupt the natural energy balance of Earth's system by trapping heat in the atmosphere. Carbon dioxide is one of the leading gases that contributes to this effect, and over the past 150 years, atmospheric levels of carbon dioxide have increased from 280 parts per million to over 400 parts per million.[1]

Increasing atmospheric temperatures lead to several other types of environmental consequences, including but not limited to changes in precipitation, melting sea ice, sea-level rise, and increased droughts, wildfires, floods, and other types of natural disasters. This eventually leads to the decline of ecosystems as environments become uninhabitable for their traditional animal populations, and this could happen to places inhabited by humans too. Furthermore, an increase in abrupt natural disasters also puts lives at risk. Much damage has already been done, but there are actions that we can take as a society to limit our emissions and the effects we have on our climate.

While any individual can take steps toward decreasing his or her environmental footprint—including carpooling, recycling, and being conservative with the use of environmental resources—as physicists, we have the opportunity to do even more to combat climate change.

ABOVE: Samantha Staskiewicz. Photo courtesy of the SPS National Office.

When I was an undergraduate physics major, I struggled with deciding what I wanted to do after college. Starting out, I was aware of only the main physics subdisciplines—topics like astrophysics, quantum mechanics, and condensed matter. But the more I learned about all of the doors that physics can open, the more I realized that, despite not being "traditional" physics paths, fields like climate science, environmental science, the geosciences, oceanography, and meteorology have a physics component to them.

About a year into my undergraduate career, I was introduced to a professor in our department who conducted research on cirrus cloud ice crystals, which are some of the first objects that sunlight interacts with when it enters the atmosphere. Understanding the geometry of cirrus cloud ice crystals is essential to improving climate models. The more accurately the model reflects reality, the better our predictions will be. With improved predictions, we as a society can better prepare for the future and design solutions to different climate-related issues. I was really interested in the impact of this professor's research and decided to join his research group for the next three years of college. I am forever grateful for this experience because it led me to work toward a concentration in geophysics, and it got me more interested in atmospheric science.

My entire undergraduate research experience inspired me to pursue a climate-focused graduate degree. I am currently a graduate student in the Department of Meteorology and Atmospheric Science at Penn State University, where I study the atmospheric effects of melting sea ice. It amazes me how much physics I use on a day-to-day basis—and how much my physics degree has prepared me to work on solving problems in atmospheric science.

As physics majors, we have problem-solving skills that qualify us to impact a multitude of areas. I believe that if more physics students got involved in environmental-related fields, we could be one step closer to combating climate change.

I strongly encourage the physics world to branch out further into the field of climate science. This could include conducting climate-related research in physics or a related field, engaging in science policy efforts, or communicating the science that is being done around the world. As scientists, we also have the ability to understand scientific dialogue, and we need more people to communicate scientific results on climate studies to decision makers and the public. If any of these ideas appeals to you, I encourage you to explore career options in climate science and see what you can do to make a difference with your knowledge of physics. //

References:

1. "IPCC, 2014: Summary for Policymakers," in *Climate Change 2014: Mitigation of Climate Change, Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, IPCC, Geneva, Switzerland, eds. O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, et al., Cambridge, United Kingdom: Cambridge University Press, 2014, ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_summary-for-policymakers.pdf.

Fall 2019 Chapter Awards

Congratulations to the following winners of the Fall 2019 Chapter Awards. These awards are made possible in part by generous contributions from Sigma Pi Sigma alumni. For examples of past award-winning projects, visit spsnational.org/awards/chapter-awards.

FUTURE FACES OF PHYSICS

Future Faces of Physics Awards are made to SPS chapters to support projects designed to promote physics across cultures. The goal of the Future Faces of Physics Award is to promote the recruitment and retention of people from groups historically underrepresented in physics.

Abilene Christian University
Physics Roadshow
Elizabeth Jennings (Leader)
Larry Isenhower (Advisor)

Colorado School of Mines
Future Faces of Physics with CSM SPS
Dylan Honors (Leader)
Charles Stone (Advisor)

Ithaca College
Promoting Indigenous Voices in Big Science
Robert Melikyan (Leader)
Preston Countryman (Advisor)

John Carroll University
STEMMED: Science and Service
Kyle Blasinsky (Leader)
Danielle Kara (Advisor)

Marshall University
Astrophysics in the Appalachians: A Perspective on Pulsars by Dr. Natalia Lewandowska
Jacquelyn Sizemore (Leader)
Sean McBride (Advisor)

Universidad de Puerto Rico – Mayagüez
Physics for Everyone
Génesis González (Leader)
Erick Roura (Advisor)

University of the Sciences
Fall in Love with Physics!
Alyssa Petroski (Leader)
Roberto Ramos (Advisor)

ABOVE: Students play with vortex rings during an outreach activity hosted by the Colorado School of Mines. Photo credit: Tara Braden.

SPS CHAPTER RESEARCH

The SPS Chapter Research Award program provides calendar-year grants to support local chapter activities that are deemed imaginative and likely to contribute to the strengthening of the SPS program.

American River College
Polarimetric Measurements of the X-Ray and Gamma-Ray Background Noise in the Stratosphere
Kaylianne Jordan (Leader)
Paulo Afonso (Advisor)

Ithaca College
Rockets vs. Kinematics
Robert Melikyan (Leader)
Preston Countryman (Advisor)

Rhodes College
MMOD Hardware Testing and Communications for the Rhodes College CubeSat Program
Giuliana Hofheins (Leader)
Brent Hoffmeister (Advisor)

South Dakota State University
Partially Lithiophilic Non-Conductive Matrix as Lithium Host for Lithium Metal Battery
Abdullah Al Maruf (Leader)
Robert McTaggart (Advisor)

Suffolk University
Neutron Energy Distribution of an AmBe Source at the MGH Proton Center
Phuc Mach (Leader)
Walter Johnson (Advisor)

Universidad Autonoma de Ciudad Juarez
Construction of a Radio Telescope for the 21-cm Hydrogen Spectral Line
Fernando Terrazas (Leader)
Sergio Flores (Advisor)

TOP: The University of Tennessee, Knoxville SPS chapter successfully securing their rocket after launch. Photo courtesy of the UT Knoxville SPS chapter.

ABOVE: SPS member Bri Treffner, Colorado School of Mines, smashes a cinder block on science teacher Mr. Breiding while he lays on a bed of nails. Photo courtesy of Tara Braden.

MARSH W. WHITE

Marsh W. White Awards are made to SPS chapters to support projects designed to promote interest in physics among students and the general public. The Marsh W. White Award dates back to 1975 and is named in honor of Dr. Marsh W. White for his long years of service to Sigma Pi Sigma and the community.

ABOVE: University of the Sciences SPS president Gopal Goberdhan and SPS member Karla Miletic discuss the physics of the sand pendulum and Newton's cradle with booth visitors. Photo courtesy of the USciences SPS chapter.

Adelphi University
Lab for Kids
Carissa Giuliano (Leader)
Matthew Wright (Advisor)

Augustana College
Spring into Physics!
Emmalee Pentek (Leader)
Cecilia Vogel (Advisor)

Georgia Institute of Technology
Spark, Spin, Freeze!
Matthew Barroso (Leader)
Edwin Greco (Advisor)

Ithaca College
Bots with Buds
Oluwasekemi Odumosu (Leader)
Jerome Fung (Advisor)

Missouri Southern State University
Promoting Physics Outreach with Interactive Demos
Jeremiah Wald (Leader)
Jency Sundararajan (Advisor)

New Jersey Institute of Technology
Stimulating Minds by Simulating Physics
Jonpierre Grajales (Leader)
Andrei Sirenko (Advisor)

Radford University
Electrifying Electronics
Alex Anderson (Leader)
Rhett Herman (Advisor)

Rhodes College
Becoming Best Buddies with Physics: The Amazing Race
Gia Pirro (Leader)
Brent Hoffmeister (Advisor)

State University of New York at Stony Brook
High School Physics Engagement Labs
Max Podgorski (Leader)
Robert McCarthy (Advisor)

Towson University
Science Fridays
Colin Hamill (Leader)
Jeffrey Simpson (Advisor)

University of Central Florida
Improving Outreach through Illuminating Optics
Zainulabedin Khan (Leader)
Costas Efthimiou (Advisor)

The University of Iowa
Children's Book Outreach
Genna Crom (Leader)
Jasper Halekas (Advisor)

The University of Southern Mississippi
Physics for All
Swapnil Bhatta (Leader)
Michael Vera (Advisor)

The University of Texas at Dallas
Comet Rocket Competition 2020
Austen Adams (Leader)
Jason Slinker (Advisor)

University of the Sciences
How Can Physics Power Your Life?
Gopal Goberdhan (Leader)
Roberto Ramos (Advisor)

SIGMA PI SIGMA CHAPTER PROJECT

The Sigma Pi Sigma Chapter Project Award provides funding of up to $500 for chapter inductions and events.

Abilene Christian University
50th Anniversary of ACU Physics – Sigma Pi Sigma Induction
Benjamin Edwards (Leader)
Larry Isenhower (Advisor)

Henderson State University
Zone Wide Sigma Pi Sigma Induction
Joseph Dees (Leader)
Shannon Clardy (Advisor)

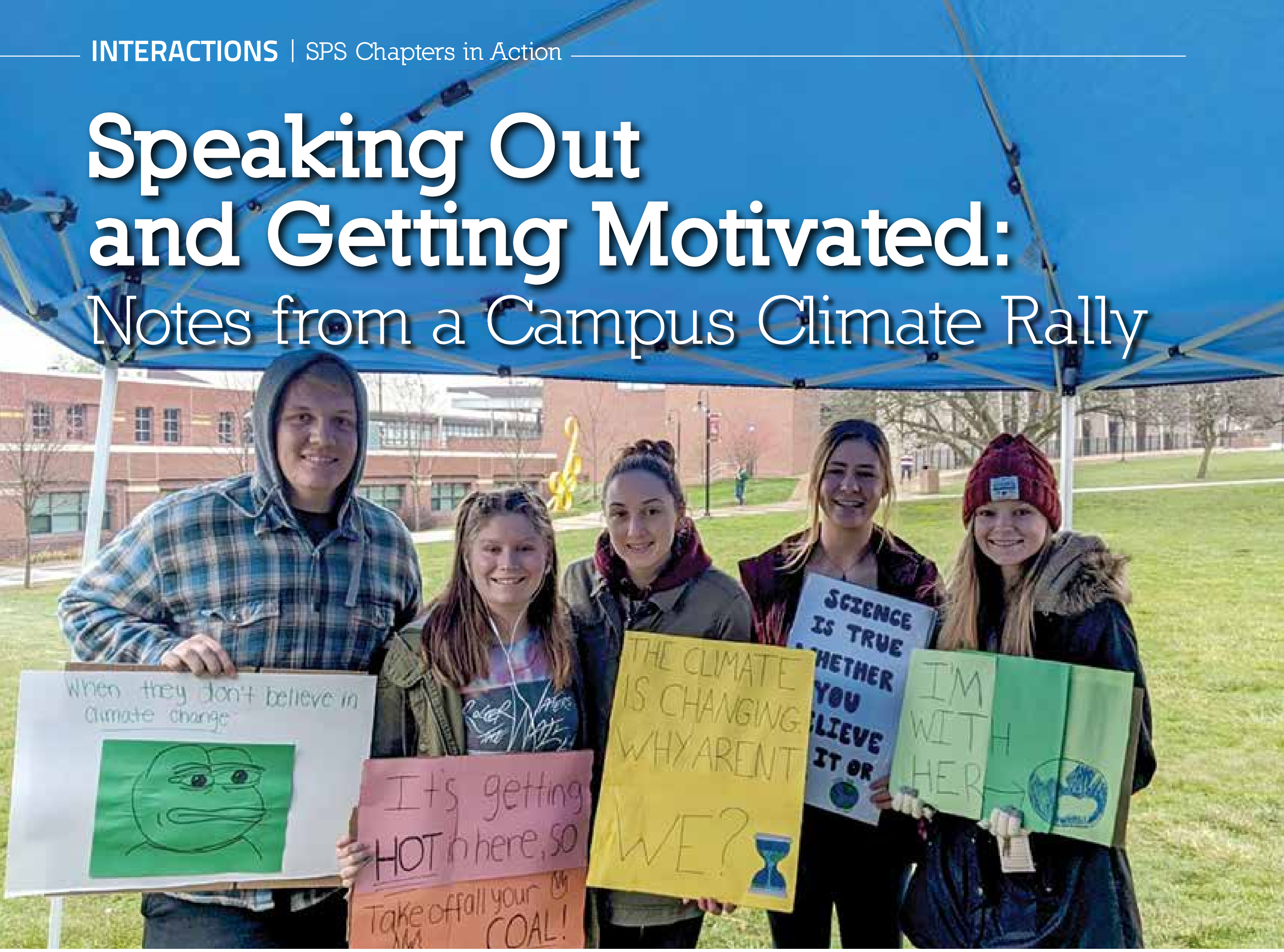
St. John's University
The Engineer's Catapult
Seychelle Khan (Leader)
Charles Fortmann (Advisor)

University of Central Florida
UCF Induction Ceremony
Zainulabedin Khan (Leader)
Costas Efthimiou (Advisor)

University of North Alabama
Sigma Pi Sigma Induction and Alumni Event
Mel Blake (Leader and Advisor)

University of the Sciences
Sigma Pi Sigma: Celebrating the Culture of Scholarship and Service in Physics
Dan Fauni (Leader)
Roberto Ramos (Advisor)

Speaking Out and Getting Motivated:
Notes from a Campus Climate Rally



by Emma Evans, Webmaster, Kutztown University SPS Chapter

Kutztown University's SPS chapter has made it a goal to become more educated on climate change and to spread that knowledge to others. We began by assigning members to research different areas of climate change, after which we felt more prepared to make an impact in the community.

In November 2019, a climate rally was planned on Kutztown's campus in solidarity with worldwide demonstrations ahead of the United Nations Framework Convention on Climate Change. We were excited to jump into the climate change dialogue, armed with both the data supporting climate change and a privileged understanding of this information afforded to us by our physics education.

Prior to the rally, we made signs and discussed climate change research during our SPS meeting. I remember feeling worried that I would be judged by other students on campus and also by the possibility of counterprotesters showing up during the rally.

The day of the climate rally brought pouring rain, but we didn't let that stop us. We stood outside under tents and held our signs while listening to local climate advocacy groups speak on issues about the environment.

ABOVE: Members of the Kutztown SPS chapter attend a climate rally. From left to right: Tyler Fenske (vice president), Emma Evans (webmaster), Lauren Murphy, Caelan Brooks (treasurer), and Emilie Laychock (president). Photo courtesy of the Kutztown SPS chapter.

Not only was it an amazing opportunity to voice our concerns about the climate crisis, but we were also able to meet many inspiring people. During the rally we spoke with advocates from PennEnvironment and other grassroots movements that are trying to stop global warming and climate change. We even made it onto the local news, which allowed us to spread our message to an even greater audience.

Afterward, we felt empowered and motivated to make an impact. This semester our SPS chapter will be holding a climate awareness night with other clubs at the university. We also plan to invite local advocates from PennEnvironment to speak about what we can do to make a difference and bring in experts to give presentations on the science behind climate change. Together we are setting measurable goals and working to make a difference in our local community and on our college campus. //

Jacquelyn Veatch

What she does:

I am a graduate student at Rutgers University, working toward a PhD in physical oceanography. As part of the Rutgers University Center for Ocean Observing Leadership (RUCOOL), I investigate physical mechanisms related to the marine food web in Palmer Deep, Antarctica, and in the Mid-Atlantic. In light of increased climate variability, I study physical features in the ocean that accumulate organisms at the base of the food chain in order to better support maintenance of biological hotspots and understand the coupling of biological and physical processes.

How she got there:

I have a bachelor's degree in biophysics from The George Washington University (GW). From my first research project at GW, in an immunology lab, I was captured by the thrill of scientific discovery. I explored a wide variety of research areas, from urban planning to pathogens, before settling on physical oceanography. My leap to physical oceanography was catalyzed by a few summers spent as a wilderness guide in northern Maine and my determination to combine physics and Earth systems.

As an undergraduate, I met with Dr. Keryn Gedan, a brilliant ecologist and the head of GW's coastal ecology lab, hoping to get involved in her cutting-edge wetland research. I had three years of laboratory experience, four semesters of a biophysics degree, and a boatload of questions about the physical mechanisms of water moving through coastal systems. Dr. Gedan looked at me with amusement and encouragement—she had never worked with a *physics* student before! I convinced her to let me join her lab and dove right in.

This 20-minute meeting launched my career into the world of Earth and climate science. At the time, I didn't know any physicists who were studying the environment. It turns out, however, there are a *lot* of scientists using physics to tackle complex environmental problems and a lot of physics in the ocean!

Best part of her job:

Field research in Palmer Deep, Antarctica. Being in Antarctica felt like being deployed to the front line of climate change. The poles are active agents and sensitive indicators of climate change. Seeing how far a nearby glacier has retreated firsthand made global warming feel much more real and gave my research a sense of urgency. Palmer Deep is the perfect ecological laboratory for observing the marine food web, and the continent is absolutely breathtaking!

More generally, I enjoy the distribution of work. Between observational data, simulated experiments, fieldwork, and office time, I have a variety of work experiences and environments.

TOP: Left to right, Ashley Hann, a graduate student from Oregon State University, the author, and Dr. Matt Oliver from the University of Delaware aboard a Zodiac boat after deploying a glider.

SECOND: The author in front of a nest of Adélie penguins on Torgersen Island.

THIRD: A team installing a high-frequency radar on the Joubin Islands. There are three of these radars installed in a triangle over Palmer Deep. They use backscattering radio waves to map surface currents.

BOTTOM: View near the northernmost tip of the Western Antarctic Peninsula. Photos courtesy of Jacquelyn Veatch.

Most frustrating part about her job:

The weather. Most field operations we conduct are in small boats that require relatively good weather conditions. Sometimes we lose entire days because the wind speed is too high. Alas, this is an unavoidable side effect of fieldwork in remote locations.

How she uses physics:

The movement of water masses through and across the ocean is inherently physical. Currents, waves, eddies, and many other movements are driven by temperature and salinity fluxes that affect the densities of seawater. Tides and the Coriolis effect are driven by lunar and solar movements as well as the rotation of our planet. All of these mechanisms can be derived from physics—an object in motion tends to stay in motion, while an object at rest tends to stay at rest, unless acted upon by an outside force. Water moving from one place to another carries nutrients and a slew of living critters categorized as plankton, meaning "drifters." I use physics to decipher how, where, and why water is moving in order to understand the impact on the marine food web. //

Calculating the Collective Effect:
Stemming the Tide of Climate Change

by Terance Schuh, SPS 2019 Summer Intern, and Brad Conrad, Director of SPS & Sigma Pi Sigma

At this point just about everyone has heard about climate change to some extent. Whether it's through politics, social media, science, or simply at the dinner table, it seems you'd need to be extraterrestrial beings to not have heard of the changing climate on Earth. Truthfully, it is a global, human crisis, and it requires a global and human set of solutions. However, something that we've wondered for a long time is who exactly are the people working on these solutions? What are their educational backgrounds? Where do I go and what should I do if I want to work in the field? What kind of *science* is climate science?

Unfortunately, the answers to those questions are not as cut and dry as some might hope. Climate scientists have wildly diverse backgrounds, and there are many different types of research that fall into the field known as climate science. What we can tell you is that studying physics is one of the best gateways to preparing yourself to study climate change and solve hard-pressing questions society is literally dying to address. If you're reading this article, there is a strong chance you're already passing through that gateway, so you're well on your way to thinking critically about solutions to the climate crisis.

The skills we learn through physics are invaluable for anyone studying how the climate is changing and how we might be able to stem the tide of this crisis. While the problem is inherently interdisciplinary, physics is the backbone of climate science and potential solutions. Consider it this way: Physics is the study of the universe and how natural mechanisms behave. The Earth is a heavenly body with unique, yet predictable characteristics. It orbits the sun, rotates on an axis, and has the capability of absorbing and transmitting thermal radiation. All of these factors contribute to its ability to sustain intelligent life such as us. At the same time, they also drive the weather and climate. The Earth's climate is a natural and complex mechanism that is based on physics principles.

Therefore, as physicists we should desire to study climate behavior and make predictions about how it changes. This includes how it changes both naturally and due to decades of human behavior, such as heavy coal burning, as a stimulus. The climate really is just another branch of physics, and climate change is one big physics problem. We need to present scientifically rigorous solutions to the rest of humanity so we can create a sustainable, inhabited Earth that can thrive for many more eons.

In this puzzler we use a physicist's approach to answer some neat climate-related problems. Interestingly, their answers show you how physics is vital in interdisciplinary studies such as climate change.

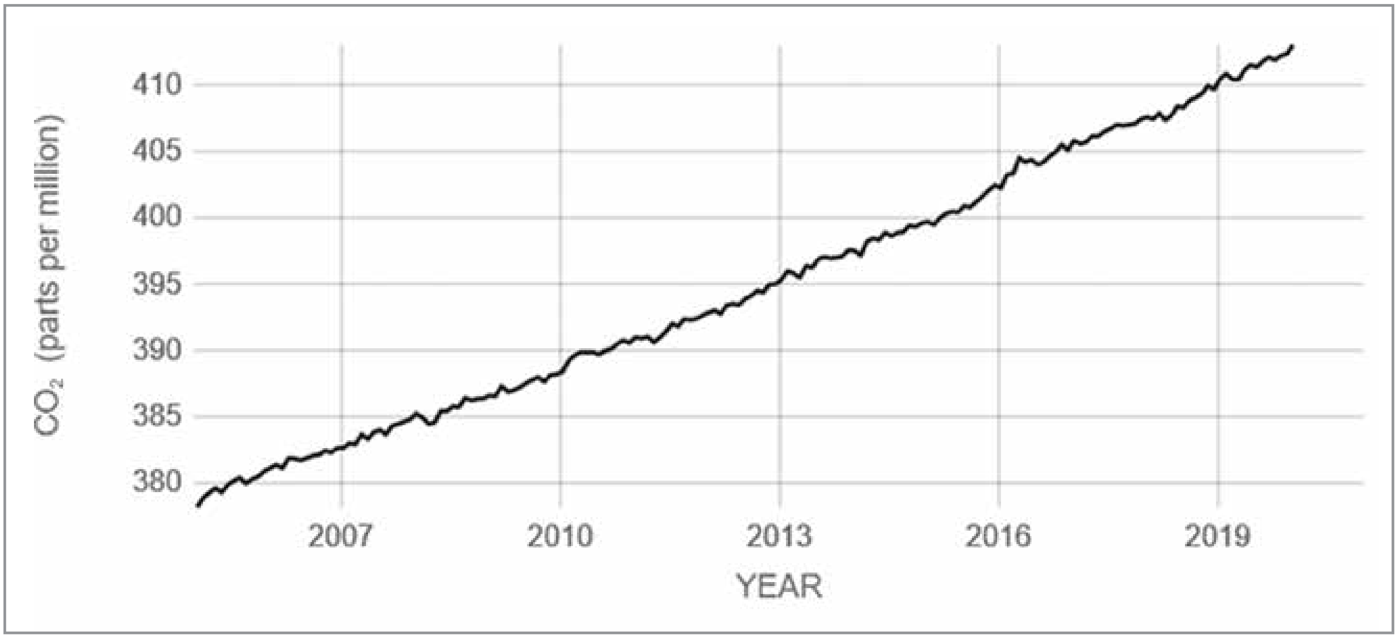


Figure 1. Direct measurement of monthly CO_2 levels. Data source: Monthly measurements (average seasonal cycle removed). Credit: NOAA, source: climate.nasa.gov/vital-signs/carbon-dioxide/.

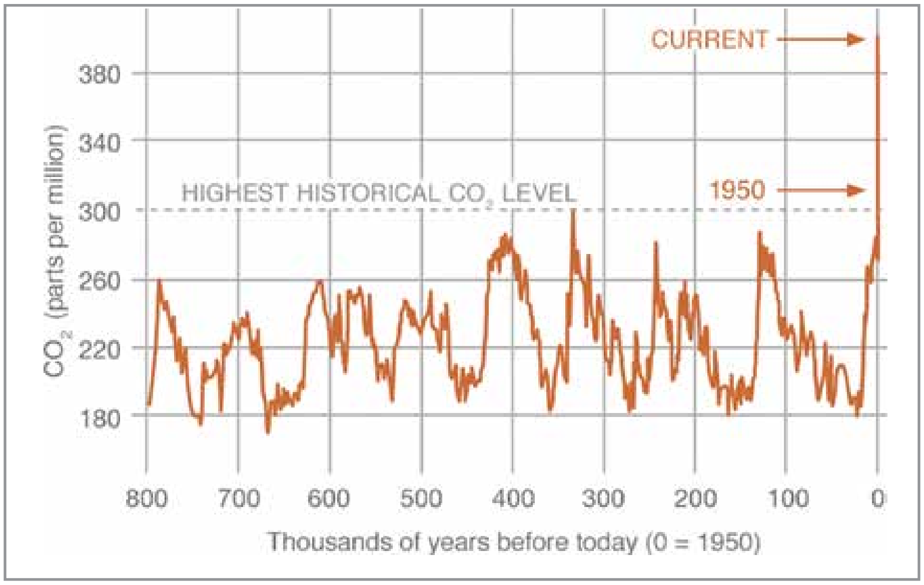


Figure 2. Proxy (indirect) measurements of CO_2 levels. Data source: Reconstruction from ice cores. Credit: NOAA, source: climate.nasa.gov/vital-signs/carbon-dioxide/.

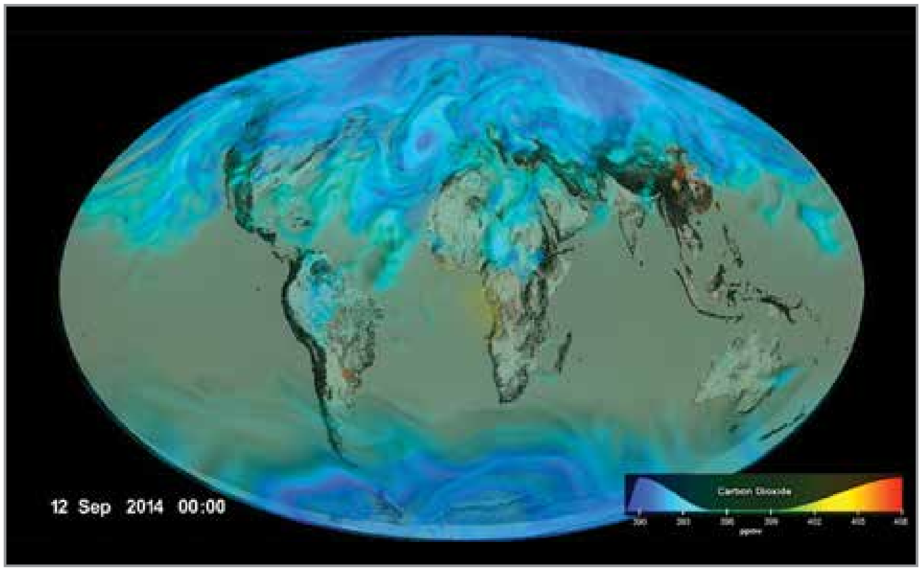


Figure 3. Visualization of CO_2, by Greg Shirah and Horace Mitchell. Released on January 23, 2017, source: svs.gsfc.nasa.gov/12478.

IF WE STOPPED DRIVING CARS, WOULD THAT SOLVE THE CLIMATE CRISIS?

To be more specific, we're asking you to work out what would happen if everyone around the world stopped driving fossil fuel–powered private vehicles. How would it affect the current climate crisis? This question allows for a lot of interpretation, as there are different ways to estimate important quantities.[1–5] Additionally, this is a very personal question—people have connections to their cars. Car culture is a tradition in many countries, and the availability of quick and cheap transportation over long distances is now seen as mandatory for modern life. Driving might not be the largest source of global CO_2 emissions, but often people want to make a direct impact, and auto emissions are one of the most easily observable sources of CO_2 emissions. For the sake of this problem, let's focus specifically on the reduction of CO_2 emissions and ignore other transportation sources.

We'll start with some basic assumptions (that are backed up by recent statistics):

- With a global population of over 7 billion people, we'll estimate there are at least 1 billion working automobiles, globally.
- The average person drives 30 miles a day.
- The average automobile on the road today gets 22 miles per gallon of gas.
- One gallon of gas creates 19.6 lbs of CO_2 emissions.

Right away we see that since 1 gallon of gas creates 19.6 lbs of CO_2 and the average vehicle on the road has a fuel efficiency of 22 miles per gallon, every 22 miles of driving creates 19.6 lbs of CO_2. Since the average person drives 30 miles a day and not 22 miles, we then have to calculate how much CO_2 each person is emitting into the atmosphere solely from driving.

$$(22\text{ Miles})/(19.6\text{ lbs of }CO_2) \cong (30\text{ Miles})/(26.7\text{ lbs of }CO_2)$$

Therefore, each person generates an average of 26.7 lbs worth of CO_2 emissions daily.

Of course, not everyone in the world drives. However, we assumed there are approximately 1 billion cars in the world right now. Even if that assumption is on the lower end of approximations, it is partially balanced by the fact that not every car is driven every day. Since each car produces 26.7 lbs of CO_2 emissions *each day*, 1 billion cars will produce about 3×10^{10} lbs of CO_2 emissions, and that's solely from private vehicles! Putting it in different terms, humans are emitting a staggering 1.3×10^7 tons of CO_2 into the atmosphere *each day* simply from driving private vehicles! It's also important to note that this number does not include the daily emissions from other forms of transportation such as airplanes, trains, and boats, but you can imagine that they would only enhance the issue.

As physicists, we know that numbers mean nothing without a frame of reference, so let's figure out how this number relates to our global daily CO_2 emissions using recent statistics[6-10]:

- Global, *annual* CO_2 emissions = 40×10^9 tons
- Global, *daily* CO_2 emissions = 0.11×10^9 tons

From this, we can calculate what percentage our number corresponds to in the grand scheme of things:

$$(1.3\times10^7 \text{ tons of } CO_2 \text{ per day worldwide from driving})/(1.1\times10^8 \text{ tons of } CO_2 \text{ per day worldwide})\cong12\%$$

This means that cars are contributing ~12% of total CO_2 emissions. The US Environmental Protection Agency (EPA) estimates that all sources of transportation in the United States[6] are responsible for ~30% of the total US emissions. A little more than half of transportation pollution is caused by cars,[11] so our estimate is pretty good. But what does that mean in terms of climate change? First of all, it means that if we all stopped driving cars tomorrow and continued doing so indefinitely, we could reduce the new CO_2 being put in the atmosphere by one-eighth. And while the earth does absorb and process some CO_2 each year,[6] human-made carbon emissions are rising.[7] We can see this from CO_2 concentration measurements as a function of year in Fig. 1 from NASA. Figure 1 shows an increasing CO_2 trend, and when compared with the historical data of the past few hundred years, as seen in Fig. 2, the trend is not just striking but deeply concerning. So although giving up driving personal vehicles would stunt the climate crisis, we need to do more: develop carbon neutral methods of traveling, limit other sources of CO_2, and reduce dependence on carbon-heavy forms of energy. In other words, collectively not driving would significantly slow our annual CO_2 emissions in the short term, but maybe the long-term solution is to remove CO_2 from the atmosphere . . .

WHAT IF EVERYONE ON THE PLANET PLANTED A TREE?

As kids we thought about this question a lot, as we learned that trees "breathe" in CO_2 and breathe out O_2—they are figurative carbon sponges. And we firmly thought that if we could just plant enough trees, we could store enough CO_2 to stop global warming. Some have worked on this before.[12] We can see from Fig. 2 that a level of 300 parts per million CO_2 is the historical average for recent history, and we are currently well above 400 ppm CO_2.[12,13] From that curve we can estimate a rough increase of 2 ppm per year. To absorb just the increase in atmospheric CO_2, we'd need to capture more, ~20 billion tons of CO_2 per year using trees. Figure 3 shows us some data visualizations using the Orbiting Carbon Observatory (OCO-2). Are trees up to the task?

Let's assume we can get each person in the world a tree instantaneously, with no energy or CO_2 cost. Furthermore, let's assume they plant a small seedling and the tree grows to a large size. Let's pick a pine tree, as they tend to have long, straight trunks, and find its volume—some species of pine tree can grow well over 60 feet. Let's consider only the amount of material in the trunk; this neglects the mass of the limbs (and of all the needles they produce), but they are less effective at storing carbon. If we treat the trunk as a cone of 18 m height and a diameter of 1 m, we know from geometry that the volume of wood V_{wood} should be

$$V_{wood}=\pi\cdot \text{radius}^2\cdot \text{height}/3,$$

and plugging in our estimates, we arrive at 5 m³ of wood per tree per person. So if all 7 billion people planted a tree, we'd have (**5 m³ of wood)·(7×10⁹)=3.5×10¹⁰ m³** of wood. If the density of wood is about **750 kg/m³**, we end up with **3.5×10¹⁰ m³ of wood · 750 kg/m³=2.6×10¹³ kg of wood**. While wood is made of elements other than carbon, it's also porous, leaving lots of empty space and water inside. So let's assume that wood is ~1/3 carbon. This gives us about 8.8×10^{12} kg of carbon, or about 1×10^{10} tons of carbon. But this is the total wood after about 30 years of growth! So we are capturing about 3.2×10^8 tons of carbon per year. Thinking back fondly on our chemistry courses, the molecular weight of CO_2 is ~44 g/mol (12 g/mol for carbon, and 2×16 g/mol for oxygen). Consequently, CO_2 is 27% carbon by weight. Assuming that all the tree's carbon comes from CO_2, we are actually removing ~1.2×10^9 tons of CO_2 each year!

Comparing to our estimate of 1.2×10^{10} tons of CO_2 that is currently being added to the atmosphere each year, this won't be enough. But if we planted a tree each year, after 10 years we'd be capturing 1.2×10^{10} tons of CO_2 each year. This means that if everyone planted a tree each year, we could roughly remove the same amount of CO_2 we are adding to the atmosphere and stop the increase in atmospheric CO_2!

Now, the issue is what to do with the wood once it's grown. If we let nature take its course, the trees will eventually die and then rot, thereby releasing the carbon back into the environment. We want to stop the process and capture the carbon indefinitely, so we could cut the trees down, dry them, and stack them in a warehouse. Or we could bury them in such a way that they would not decay. The key is to capture the carbon before it makes its way back into the atmosphere.

From here, we leave the following climate crisis puzzler to the reader: If we have about 420 ppm of CO_2 in the atmosphere and the atmosphere is roughly 5×10^{18} kg, we have about 3.6×10^{12} tons of carbon dioxide in the atmosphere as of 2020. **Based on the figures and statistics provided,[10–13] how many years in a row would all of humanity need to plant two trees to bring the CO_2 levels back to the 300 ppm level? How much area would that take as a percentage of the earth? Could we even store that much carbon/wood, or could we just make new forests? How long if we each planted a tree AND stopped driving cars?**

Challenge questions: If everyone gave up eating meat, how would that impact the climate situation? Can you think of another scenario in which a single behavioral change would address the magnitude of this problem? Did we make a mistake in this puzzler? Let us know any and everything by emailing sps@aip.org. //

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FEATURE

Meeting the Challenges OF A WARMING WORLD

by Korena Di Roma Howley, Contributing Editor

There's no doubt about it—the climate is changing. According to the National Oceanic and Atmospheric Administration (NOAA), 2019 was Earth's second warmest year on record (after 2016), with global temperatures at more than 2º F (1.15º C) above the pre-Industrial average.[1]

At a time when key political leaders and policymakers continue to express skepticism of or deny human-induced warming, scientific organizations have released statements that solidify the growing global consensus that climate change—and the accompanying rise in extreme weather events—is a crisis that must be addressed.

ABOVE: People's Climate March, Washington, DC, April 2017. Photo by Nicole Glass Photography / Shutterstock.com.

In a statement released in 2020 (included in full on p. 18), the Society of Physics Students and the Sigma Pi Sigma National Council urge their chapters to promote public awareness of the science behind human-induced climate change and to practice environmental sustainability. The American Geophysical Union, in a statement updated in 2019, says that "Society must . . . prepare to cope with and adapt to the adverse impacts of climate change. Done strategically, efficiently, and equitably, the needed transformations provide a pathway toward greater prosperity and well-being, while inaction will prove very costly for humans and other life on the planet."[2]

The Executive Committee of the International Association of Physics Students says in a 2019 statement, "As Physics students, we have the right and the responsibility to use what we learn to make sure the public is paying attention to this very pressing issue. Whether by striking, talking to others, holding informative conferences or contacting decision-makers, we, as part of the future of societies everywhere, must be involved in the efforts to tackle climate change."[3]

The features in this issue highlight individual students, professors, and veteran scientists who are directly confronting the important challenges posed by climate change, as well as SPS chapters that are focusing outreach efforts on raising public awareness. Some are changing their academic paths, while others are attending workshops, giving talks, or simply turning the lights out in the lab. All of them prove that physics students and professionals have a role to play—and that they're well prepared to step onto the stage. //

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FEATURE

CLIMATE CHANGE FROM THE GROUND UP:

Contributing to a Global Challenge

by Corey Pahel-Short, Member and Vice President of UNC's SPS Chapter, University of North Carolina at Chapel Hill

I originally pursued physics for a reason many of us do: curiosity. Neutrinos especially interested me because of their "sneaky" nature. I joined a lab searching for neutrinoless double beta decay and thought I had found my niche, but I began having a hard time focusing on my classes and lab research. Climate change consumed my thoughts. What would the pursuit of knowledge amount to if we couldn't stop climate change?

I took drastic measures as a second-semester junior—I completely changed my career path to incorporate environmental science into my degree. I wanted to use my physics background to help the world mitigate and adapt to climate change. Parting ways with my lab, I started environmental work from, quite literally, the ground up.

Serendipitously, I met my current boss, Sally Hoyt, through gardening, where I learned more about stormwater controls. Hoyt, a stormwater engineer for UNC, was one of the main people who contributed to bringing UNC's underground, piped stream back to the surface. The restored stream and the native plants surrounding it help filter out pollutants from stormwater and provide habitat for animals and pollinators. I currently intern for UNC's stormwater engineers. Physics provided me with the analytical and technical skills to tackle an internship in a new field. This work primarily involves controlling the substances released into our water systems and implementing infrastructure that slows stormwater. As the effects of climate change continue to materialize, extreme weather events such as flooding will become more commonplace. Our infrastructure will need to adapt.

FINDING A CLIMATE-FOCUSED NICHE

Inspired to mitigate the effects of climate change, I worked on a team consulting for the Town of Chapel Hill in the fall of 2019. After conducting energy and greenhouse gas inventories, we made recommendations to the town council on how to reduce Chapel Hill's energy consumption. I specifically focused on the town's transportation-related energy consumption. The calculations required making a number of assumptions due to a lack of available data. Physics prepared me well for this; the spherical cow can be applied to many fields!

I have found my niche and am currently seeking job opportunities in environmental consulting as I prepare for graduation. Environmental consulting involves helping clients comply with environmental regulations. There's a mix of analysis, which I love, and implementing change. I'm most excited to work for clients that are choosing to be leaders in sustainability by anticipating future regulations.

This isn't to say that every physics major who's concerned about the climate should completely change their career path. While this is how I have made peace with climate change, no path is more valid than another. Volunteering and social activism provide avenues for people who want to both pursue a greater understanding of our universe in physics and address climate change.

HOW SPS CHAPTERS CAN DO THEIR PART

SPS chapters can also take steps toward sustainability. For example, our chapter has contributed to our university's composting initiative by buying a composting bin for the physics lounge. The bin has a lid that prevents smells from permeating the room. We maintain a stock of compostable plates and

ABOVE: The UNC physics lounge composting bin. Photo courtesy of Corey Pahel-Short.

ABOVE: A UNC SPS chapter member engages young scientists during a community outreach event. Photo courtesy of Johnny Andrews, UNC-Chapel Hill.

utensils for general use and for use at SPS meetings and have recycling bins in the physics lounge with signage noting what can and cannot be recycled. This is meant to prevent "wish-cycling," or the recycling of items that people hope are recyclable but often are not.

When we have food at our meetings, we provide vegan/vegetarian options to support those reducing consumption of animal products for environmental reasons. Our SPS chapter also carpools and turns off the lights and AC in the physics lounge when no one is in the room. My advice is to lead by example and gently remind people who frequent the room. One physics professor is known to ride a bike through our physics building while turning off the lights in empty rooms and closing windows to conserve energy.

I also commend our department for creating a physics track with a focus on energy. Required classes for this track include topics such as renewable electric power systems and decarbonizing fuels. Physics majors with this track have gone on to pursue materials science PhDs and jobs in energy production (e.g., solar and geothermal).

Finally, physicists can develop their communication skills through community outreach. Scientists must be able to approachably explain their research to the public in order to convey its importance. SPS chapters can work on these skills by participating in community outreach events. For example, our chapter volunteers at UNC's Science Expo, where research and community groups create demonstrations aimed at engaging children with science. We pair students with physics research groups to both enable undergraduates to learn about research opportunities and to encourage people to explain physics clearly.

I've volunteered with my lab's booth in the past and know that explaining neutrinos to elementary school kids requires some creativity. We demonstrated neutrino oscillations with a ball that changes color when tossed, and the ball kept the kids entertained.

Bridging the gaps in communication between scientists and the public helps to quell distrust in science and lead the way toward better understanding of climate change. //

FEATURE

SPS Makes a Statement on THE CLIMATE CRISIS

by Aaila Ali, SPS Associate Zone Councilor, Zone 11, DePaul University; Tamara Young, SPS Zone Councilor, Zone 15, University of Utah; and Brad Conrad, Director, SPS & Sigma Pi Sigma

On January 25, 2020, the National Council of the Society of Physics Students (SPS) and Sigma Pi Sigma, the physics honor society, approved the following statement for general dissemination. This statement was approved by leadership on February 22, 2020, and is the society's first statement about human-induced climate change and how we, as a community, can and should act:

> "The Society of Physics Students and the Sigma Pi Sigma National Council encourage chapters to sponsor, engage in, and pursue outreach events that promote awareness of the scientific basis of human-induced climate change to the general public. Furthermore, chapters are encouraged to champion initiatives that address the climate crisis and to practice environmental sustainability."

As physicists, we don't often see the impact of our work within our own lifetimes. This doesn't discourage us from trying to contribute but rather inspires us to try to leave a lasting impact in the physics community. This understanding has guided us as we've pushed the boundaries of physics and astronomy to where they are today. Similarly, we may not experience the worst impacts of the climate crisis ourselves, but this does not mean that the actions we take today won't impact the lives of future generations. We have a responsibility to acknowledge the impacts of our actions and to try to mitigate our negative contribution to this crisis.

We live on a literal spinning rock, in the middle of a vacuum, millions of miles from the sun. Our atmosphere provides us with a layer of protection that enables life as we know it, yet is only ~16 km thick. That's much less than 1% of the radius of the Earth! Figure 1 gives an overwhelming sense of that precariousness. Our actions *here, today,* in our *daily lives* will affect everything we and our communities experience moving forward. To have a real, lasting impact on what the future looks like, we need to move together through action and deed.

We at SPS encourage you to not just educate the general public about why we need to address the climate crisis but to conduct the activities of your chapter and your department in environmentally sustainable ways. The committee uses the word *crisis* intentionally and encourages chapters not just to act but to share ways to protect our precarious planet along with the broader community. Carl Sagan suggested to NASA that *Voyager 1*, as it was leaving the solar system, take the image shown in figure 2 to highlight how fragile and connected we truly are. Everyone you've ever known, everything you've ever touched, and (probably) every place you'll ever go is in that single pale, blue pixel. We need to protect it, and fiercely, because it can't protect itself, yet it protects us.

As chairs of the SPS National Council Governance Committee, we believe it is important to release a statement acknowledging the man-made climate crisis and champion initiatives to help alleviate it. We encourage students to think about the impact their own actions have on the environment, as well as the actions and events planned by their SPS chapters.

Tamara shares her own experience with climate change in Utah:

My first recognition of the impact of climate change was in the 1990s. I was a relatively new teacher, teaching science in the middle grades. I remember that one of the end-of-level test questions for my integrated 8th-grade science class was on the impact of climate change. It was a question intended to check whether students could use data and critical thinking skills. I don't remember the details of the question, but I remember my response to it: I'm going to lose my garden.

I have lived in the Western United States for most of my life, and I have seen years of flooding and years of drought. The flood years are bad; the drought years are worse. One of the impacts of climate change is that local conditions are going to become more extreme. I already live in a desert. A couple of degrees temperature increase will change my home from a place where I can have a garden to a place where I cannot.

The water for my home comes from snowmelt. It is a precarious existence. Not only are you dependent on the amount of snow that falls each winter but also on the temperature of the ground when the snow falls. If it falls on warm ground, it melts and doesn't contribute to the snowpack. Late spring blizzards help only if the ground is still frozen. The delay in the start of the ski season affects the local outdoor recreation industry; it also affects whether or not I can grow tomatoes.

Aaila's personal experience with climate change involves the lovely Chicago winters:

When I was a young child and would dress up for Halloween, my mother would insist that I wear a large coat over my costume. By Halloween, there was already snow on the ground in Chicago. This is something I remember because it was always very upsetting not to be able to show off the Halloween costume I had worked hard to create. But still, winter was always my favorite season because of the natural beauty outside as well as winter traditions in the city.

This past year, it had not even snowed by Christmas. A few years ago it snowed randomly in the middle of April. We joke in the city that within a week you may cycle through all four seasons, but we also understand that recent changes in our climate are not normal. In Chicago, the impacts of climate change for now may simply manifest as snowless winters; elsewhere these changes result in hurricanes and floods and droughts, severely impacting the lives of people who live there.

Since recognizing the impact of climate change in my own community, I have come to appreciate how much my mother valued recycling at home. Our recycling bin was always much larger than the garbage can. In high school, I began to carry my own coffee mug around and looked into ways to compost organic waste. These are minor changes I introduced into my lifestyle to reduce my impact on the environment.

In the face of this climate crisis you might ask, Why are we talking about tomatoes and Chicago winters? Because it is personal. The climate crisis is personal. It affects each of us in a personal way. We could talk about other things that affect more people, that are more detrimental, that are more significant on a global scale. But we don't change ourselves and our lives because of global problems. We change ourselves and our lives for personal reasons. These are the things that we are losing in the face of this climate crisis. What changes can we make to ameliorate the climate crisis?

We encourage every SPS chapter and member to think about these things. What do you value? What changes can you make? //

Figure 1 (TOP): Sunset on the Indian Ocean as seen by astronauts aboard the International Space Station. The image presents an edge-on, or limb view, of Earth's atmosphere as seen from orbit. Earth's curvature is visible along the horizon line, or limb, that extends across the image from center left to lower right. Above the darkened surface of Earth, a brilliant sequence of colors roughly denotes several layers of the atmosphere.

Figure 2 (ABOVE): This image of Earth is one of 60 frames taken by the *Voyager 1* spacecraft on February 14, 1990, from a distance of more than 6 billion kilometers (4 billion miles) and about 32 degrees above the ecliptic plane. In the image the Earth is a mere point of light, a crescent only 0.12 pixel in size. Our planet was caught in the center of one of the scattered light rays resulting from taking the image so close to the Sun. This image is part of *Voyager 1's* final photographic assignment, which captured family portraits of the Sun and planets. Photos courtesy of NASA.

Share what your chapter is doing with us and the community at sps@aip.org and on social media with the hashtag #SPSclimatechange.

FEATURE

CHANGING CLIMATE
and Changing Lifestyles

by Martin Berger, Gabe McDowell, and Tristen White, 2019 Physics Congress Reporters and SPS Members, Juniata College

The room was filled with round tables, each containing blank sheets of paper and several markers. We sat down at a table and introduced ourselves to our soon-to-be partners. With the opening remarks of the workshop, we looked at each other and immediately knew what the paper was for: solving Fermi problems.

The workshop was part of the Sigma Pi Sigma Physics Congress (PhysCon) held in Providence, Rhode Island, last November. During PhysCon we had the chance to engage in several events centered around the idea of how physics can be beneficial and affect the quality of human life. One of the commonalities we noticed among these experiences was a focus on climate change and how we as physicists can help mitigate the impacts. The goal of this particular workshop was to apply "physics thinking" to get to the heart of our connection to climate change.

The workshop leaders, University of Maryland professor Ellen Williams and University of Wisconsin – River Falls professor Earl Blodgett, explained that many climate change–related questions seem too broad or wide-ranging to solve easily, but with logic and sensible assumptions it's possible to arrive at a reasonable answer. For instance: How much carbon dioxide is produced by cars every year worldwide? How much money could a household save by switching to windows that trap more heat inside?

Each table received one such Fermi problem, named after the physicist Enrico Fermi who often engaged students and colleagues with questions like, How many piano tuners are there in the city of Chicago? We were expected to work together to make reasonable assumptions in pursuit of an answer. Imagine the scene as tables of newly

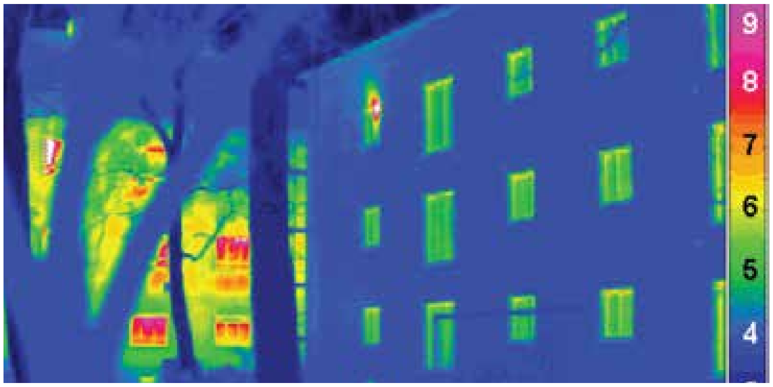
ABOVE: Students prepare pasta using a passive cooking model in a PhysCon workshop led by Carla Ramsdell. Photo credit: Society of Physics Students National Office.

acquainted physics students discussed the logistics of how many cars are owned and driven in the world!

> **"We have understood the effect of $C0_2$ on the world for well over 100 years."**
>
> **-Ellen Williams, University of Maryland professor and former director of the Advanced Research Projects Agency – Energy, during her 2019 Physics Congress plenary.**

Amid this chaos was a deeper point. Despite the complexity of climate change and how we must sometimes rely on approximations in our quest for understanding, the questions forced us to confront, as humans, our habits and how they affect the Earth. Thinking through how many people drive a car every day and how far, and then considering gas mileage, really started to put the human contribution to climate change into perspective. "It was an absolutely groovy exercise that really gives us insight into the scope of the everyday," said Nicholas Stubblefield, a workshop participant from Boston College. If one person decided to change their routine, the impact would be minute. But what if many people shared this mentality?

We saw this topic from another angle during a PhysCon tour of the Naval Submarine Base New London in Groton, CT, the world's first submarine base at just over 150 years old. The Naval Submarine School is one of the largest parts of the base, home



TOP: Workshop co-leader and plenary speaker Ellen Williams poses with PhysCon attendees from Adelphi University. Photo credit: Society of Physics Students National Office.

ABOVE: This thermal image contrasts the heat loss of an energy-efficient building (foreground) with a traditional building. Photo credit: Passive House Institute, PHI.

> **“The science is not confusing and it’s certainly not poorly understood.”**
>
> **-Ellen Williams on climate change and the effect of CO_2 on the Earth (2019 Physics Congress plenary).**

to around 1,200 sailors studying to become submariners. The base has many tools to help students prepare for life on a submarine, including piloting simulations, rooms where students practice making repairs in a flooded submarine, and a 40-foot-deep pool where they practice escaping from a flooded submarine. Along with these skills, the sailors also learn how to live efficiently—on a submarine there is not much extra space for food and waste! On the tour, we also learned that the Navy has been moving submarines from diesel to nuclear power. This enables them to stay at sea longer and reduces their emissions. While this is only a small step, it is heartening to see these changes being made.

We have taken the knowledge from our PhysCon experience and started implementing changes in our physics department. For example, we recently reinstalled a monitor on our building that tracks weather, wind speed, and temperature in real time. We are thinking about how to use this information to track environmental patterns.

There are many opportunities for action before us, and if we all implement changes, no matter how small, the impact will add up. We encourage you to challenge yourself or your chapter to invent something or change something about your lifestyle that benefits you, those around you, and our Earth. You may be surprised with the creative solutions you find. Hopefully, instead of solving Fermi problems related to how much more carbon dioxide is released into the atmosphere each year, someday we’ll be able to address problems related to how much progress we’ve made. //

Breaking the **Boundaries of Physics and Food**

by Thomas Lampanaro, Susanna Phillips, Cynthia Tibberts, and Elijah Velazquez, PhysCon Reporters and SPS Members, Roberts Wesleyan College

For many, physics seems like an impossibly complicated science, a standalone subject that doesn’t interact with other fields. We attended PhysCon 2019 with the expectation that we would learn about this “complicated stuff.” Although we did learn about some very interesting scientific developments, we also discovered that physics reaches into almost every part of our daily lives.

Take a subject that interests us all: food! Food production constitutes a surprisingly high portion of our carbon emissions—nearly a cubic meter of CO_2 is produced for each meal cooked. In the PhysCon workshop Cooking as a Context for Physics and Politics, Appalachian State University professor Carla Ramsdell explained some simple changes we can implement while cooking to reduce our environmental impact. One thermodynamically motivated change is to use cast-iron pans, since the heat stays concentrated near the center, where most of the cooking happens. She also encouraged us to use only as much water as we need to do a job. Most people boil a box of pasta in five cups of water when two will do the trick. Heating the extra water wastes energy.

Not only did Ramsdell describe the importance of considering energy while cooking, but she also helped us connect the two fields directly. Before the workshop started, she had us each count out 60 strands of uncooked pasta noodles, then showed us how to boil them in our PhysCon thermoses. By the end of the workshop, we had each made an easy, environmentally friendly pasta dish that tasted great! //

FEATURE

TEACHING CHANGE:

The Importance of Climate Communication

by Olivia Cooper, SPS member, Smith College

ABOVE: Smith SPS members and senior physics majors at CUWiP 2020 (left to right: Olivia Cooper, Michaela Guzzetti, Simona Miller). Photo courtesy of Tina Guzzetti.

Show, don't tell. I was reminded of the value of this approach by Professor Nathanael Fortune, who teaches physics at Smith College and gives public talks on climate change to legislators and community members.

"Showing" is especially important, he says, for communicating often misunderstood issues like climate change. For example, he noticed that many people were having trouble understanding the mechanisms of climate change and fully grasping the time scale of that change. Wondering how scientists could explain it better, he searched for a good analogy. Eventually, he stumbled on the bathtub.

DROWNING THE PLANET

We know that if the water is left running in a plugged bathtub, it will overflow. Now imagine that the tub's drain is clogged, so that the tub empties slowly while water flows in quickly. In this scenario, the equilibrium level will rise and eventually the tub will still overflow.

Now imagine the bathtub is Earth, the water is CO_2 and other greenhouse gas emissions, and the water level is the average global temperature. Energy, in the form of radiation, comes into the Earth's atmosphere from sunlight and is partially reflected back into space in the form of blackbody radiation. In changing the atmosphere, cloud cover, or amount of ice on the surface, we change the amount of energy that is reflected back. This essentially "clogs the drain," a process often augmented by positive feedback loops. For example, global warming melts the permafrost, which releases more greenhouse gases into the atmosphere, which leads to more global warming.

ABOVE: Professor Nathanael Fortune. Photo courtesy of Smith College.

Even as we're clogging the drain, we're drowning the Earth, filling up our planetary bathtub with CO_2 twice as fast as nature is taking it back out. This is tipping the scale and driving the global temperature higher and higher.

Fortune uses this analogy to show how even leveling off our emissions will not solve the problem—we actually have to reduce the rate at which they're emitted. We have to turn the water way down.

At his public talks and in his courses, Fortune has found illustrations like the bathtub analogy to be effective science communication tools. Visuals and analogies that relate to everyday human experiences make science concepts, especially those as complex and misunderstood as climate change, easier to grasp. Furthermore, this method of teaching helps audience members to evaluate the veracity of the information themselves, rather than just trusting a talking head. They may even be empowered to explain it to their peers in their own words.

A CONCENTRATION FOR THE MODERN ERA

As an astronomy and physics major at Smith, I use similar communication tools to explain my particular field of science. Still, as I look beyond the atmosphere at distant galaxies, I take care not to neglect my stewardship of the Earth. So when my astronomy advisor, Professor James Lowenthal, told me about the Climate Change Concentration at Smith—a program for which Fortune is also an advisor—I realized it would be the perfect way to continue engaging with climate change while pursuing a career in astronomy.

Established in 2014, Smith's Climate Change Concentration program allows students to become more engaged with and informed about climate change through a deliberate selection of courses and experiences. As climate change is inherently interdisciplinary and relevant to every field, the concentration brings together students across majors—from astronomy to government to studio art—and is designed to stitch together the skills each student needs to address climate change in whatever field they pursue after graduating from Smith.

Within the concentration, I focus on climate communication and education. This focus has shaped my coursework and practical experiences. Last summer, I published research I conducted on climate literacy in undergraduate climate change courses that informed a climate education program in my home state of California. I had the opportunity to bring together a range of passions—including a sense of belonging in California, scientific research, climate education, and science writing—to do productive work for both myself and the fight against climate change.

More recently, I put my climate communication skills to the test by running an outreach project on the health impacts of climate change at a hospital in my rural Northern California hometown, which braces for the worsening impacts of wildfires each year. Equipped with the background in climate science and communication techniques I developed at Smith, I spoke with medical professionals who have known me since I was half my size about emergency preparedness, environmental awareness, and sustainable practices in the face of catastrophic wildfires. These experiences were rewarding with respect to my future career as a researcher, as well as to my personal journey communicating climate change.

PUTTING CLIMATE CHANGE ON THE SYLLABUS

My curriculum within the concentration is self-designed and has included classes related to climate change in English, psychology, astronomy, and other departments. This interdisciplinarity is something both Fortune and I would love to see more of in higher education curricula.

While I value the classes I took that specifically focused on climate change, we need to do a better job of integrating climate change into core courses. For Fortune, that means not only designing an introductory-level physics class called Energy, the Environment, and Climate Change but also dedicating a week of Introductory Physics II (focused on electricity and magnetism) to the absorption and emission of electromagnetic waves spanning wavelengths, using the example of global warming and the greenhouse gas effect to teach the Stefan–Boltzmann relationship.

Putting climate change on the syllabus shouldn't be limited to physics classes. Economics courses could cover how industrial capitalism and neoliberalism affect carbon emissions. Literature classes could discuss how climate change has transformed the genre of environmental literature since the Industrial Revolution. Climate change touches every field, and its study is inherently interdisciplinary.

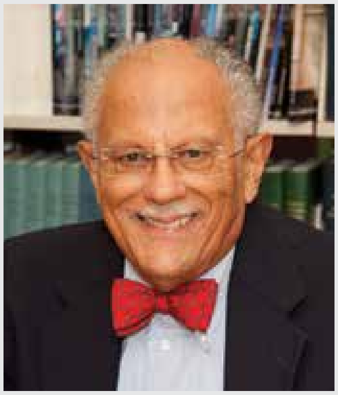
To dispel misconceptions, raise awareness, and mobilize change, we need to incorporate this interdisciplinary mindset while teaching climate change, in addition to using imagery like Fortune's bathtub analogy. In presentations, conversations, and especially in introductory or gateway classes, educators and scientists have the opportunity and responsibility to integrate climate change into their curricula, from physics to film studies to sociology and beyond. By teaching climate change, we can contribute to a better understanding of this global issue and advocate for science, exploration, and curiosity, practicing stewardship for climate change awareness and action. //

SPECIAL FEATURE

Interview with Warren Washington, a Pioneer of Climate Modeling

by Korena Di Roma Howley, Contributing Editor

In the 1960s, when Warren Washington was among those developing the first atmospheric computer models, he and his colleagues were interested in discovering how they could simulate the observed climate system and verify that they had the right physics for the current climate. More than 50 years later, during a period of increasing global temperatures, the field Washington helped pioneer has taken on new relevance, helping scientists to not only understand our present climate but also to predict what may be in store for the planet.



ABOVE: Warren Washington. Photo courtesy of NCAR.

Washington, now 83, was the second African American to earn a PhD in the atmospheric sciences. He would go on to publish extensively, advise US presidents, chair the National Science Board, lead the American Meteorological Society, and receive the National Medal of Science from President Obama. In 2019, he was awarded the Tyler Prize for Environmental Achievement, known as "the Nobel Prize for the environment."

In 2018, after 54 years, Washington retired as a senior scientist with the National Center for Atmospheric Research (NCAR), where he remains a distinguished scholar. He continues to mentor students, give lectures, and review reports for the National Academies of Sciences, Engineering, and Medicine.

For this issue focusing on climate change, I spoke with Washington about his remarkable career and the future of his field. The interview has been edited for space and clarity.

When did you first realize that you were interested in science?

Well, I think very young . . . I was anxious to learn how things worked, and I always enjoyed cars and airplanes and so forth. My mother took me to the library, and that was really important for me. I got a library card, and I was checking out books about various scientists. One of the things that impressed me was that a lot of the scientists—both African American and Caucasian—came from backgrounds that were about the same as mine, so I felt that I could get into science too. And that's what I did.

What made you pursue a career in meteorology in particular?

I switched my major [at what's now Oregon State University] from physics to meteorology because I thought it was a very interesting application of physics. My thesis adviser received a call from some people at Stanford Research Institute who were looking for a mathematician and physics major to help them on a project to build a computer model of the atmosphere, and I took that job for the summer of 1959. I was really impressed that this was a project that used my skills—it had mathematics, it had physics, and I thought it was neat to build a model that simulated how the atmosphere worked.

After working at Stanford Research Institute, I asked them if there was a place I could go to get a PhD in computer modeling of the atmosphere and the climate . . . It turned out that [of those institutions], one of them I couldn't go to because it was segregated. That was Florida State University. It had a good meteorology program, but they weren't admitting African American students. I think I was accepted at most of the other schools, and I ended up going to Penn State.

How has climate change research and modeling evolved since you began your career in the 1960s?

Our group here at NCAR was one of the few places that started using models to explore climate change. [At that time] scientists like myself were interested in whether we could simulate the observed climate system . . . [and] build a model to verify that we had the right physics for the present climate. It wasn't until a few years later that we turned our models into an investigating tool for the causes of climate change [in order to] understand how you go from when we started burning fossil fuels to the present. We tried to simulate the warming that was taking place, and we had to take into account the concentrations of carbon dioxide and other greenhouse gases. The models that we have presently have a lot of detailed physics; for example, how clouds form, how they maintain themselves, how they change the energy balance, surface temperatures, warming of the oceans—[all of that] came a little bit later.

While activists like Greta Thunberg are making headlines and it's a topic that's top of mind, the rate of practical action on climate change isn't very encouraging. How optimistic or not do you feel about our society's capacity for real change?

Polls are showing that 70 percent of the public in the US agree that climate change is happening. Given that, Congress is very much in favor of doing something about it, so when the president tries to cut the budget of climate change research, it's always been restored by Congress, which considers it a serious problem. Unfortunately, the president has taken us out of the Paris Agreement, and we're one of the few countries that isn't trying to set targets and come up with schemes to cut back on the use of fossil fuels. What's encouraging is that the young people we interact with who understand something about how climate change works are helping to influence elections. But there's a lot more that could be done.

Do you have any advice on how to communicate with climate change skeptics or deniers?

Depends on the person, of course. Basically, if I encounter a skeptic, I try to sit down and chat about what their understanding is . . . I try to find out why they're skeptical. I've heard things like, "The satellites prove that the atmosphere is cooling, not warming." Well, it turns out that some of the instruments that are on satellites were drifting a little bit, were drifting out of orbit, which is not unusual. When corrected, it shows a warming trend . . . Every indicator shows that warming is taking place and that we're melting the sea ice and melting glaciers . . . and the sea level is rising. All these things are consistent with climate change.

What is your advice for physics students who want to have a career in meteorology and make an impact on climate change?

My advice to young people is that they can come into the field in a number of different ways. We have people contributing to improving the mathematical techniques for solving [certain] equations, and they're usually people who have strong applied mathematics skills and computing skills. We also need to have people who understand how modern computers are configured so that we can put these models onto computers and more quickly solve the equations. So there are many different fields that can contribute, including physics, of course. //

For more about the life of Warren Washington, read his autobiography, *Odyssey in Climate Modeling, Global Warming, and Advising Five Presidents* (Createspace, 3rd ed., 2012).

Beer from the Stratosphere:
A Payload with a Tasty Payoff

by Zachary Hill, SPS Chapter President, Dr. Justin Oelgoetz, Faculty Advisor, Bryan Gaither, Lab Manager, and Ivy MacDaniel, SPS Member, Austin Peay State University

When the High-Altitude Balloon Project was born at Austin Peay State University in Clarksville, Tennessee, several years ago, our group's intent was to explore the Earth's upper atmosphere. With our most recent launch, we also contributed to a local brewery's creation of a special batch of ale—the appropriately named Stratospheric Black.

This particular project involved developing a wireless communication network that can be used to sync data across payloads during flight. On January 8, 2020, we launched both a proof-of-concept technical payload (demonstrating wireless communication between payload packages) and hops provided by Strawberry Alley Ale Works—a restaurant and brewery a few blocks from campus.

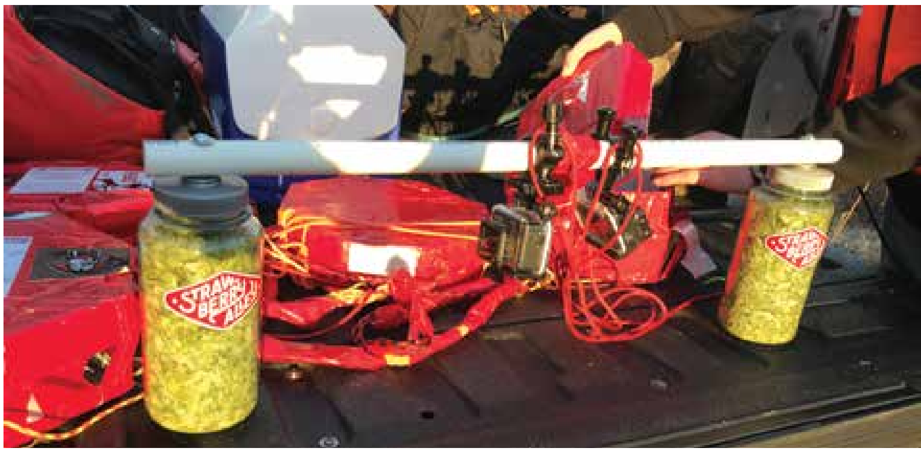
Bryan Gaither, the laboratory manager for APSU's Department of Physics, Engineering, and Astronomy, dreamed up the idea for this collaboration.

"We [at APSU] are always looking for opportunities to do exciting events with and for our local community," he says. "One of my favorite local restaurants and breweries is Strawberry Alley Ale Works, located in historic downtown Clarksville, about a mile from campus. We have already partnered with them to host our monthly Science on Tap, where we have different faculty members present current and relevant scientific topics while enjoying lovely libations."

Ivy MacDaniel, an APSU physics major and member of our local SPS chapter, became involved with the balloon project because she "was mainly focused on weather research and . . . wanted a little hands-on [experience] in a very similar project." She started out just chasing the balloon but has "started monitoring projections, winds, and weather forecasts about a week [out] . . . [helping to] make plans for the launch, which includes calling airports if necessary." For this launch, Ivy did the projections for the path the balloon would take and told us that it looked to be going very close to the Nashville airport. As a result, we had to call up the airport and let them know when we were planning to launch and how close it would be.

LAUNCHING THE PAYLOAD AND RECOVERY

The January payload consisted of three major parts: the wireless communication network, the hops, and the tracking equipment. The wireless communication network included two payload boxes—one with a radio module and all the



TOP: The Austin Peay High-Altitude Balloon group and staff from Strawberry Alley Ale Works. Photo used with permission from the APSU PR department.

MIDDLE: The communication network with sensors (left) and a data-recording device (right). Photo courtesy of Zachary Hill.

ABOVE: All the payload boxes, with the hops displayed in front. Photo courtesy of Zachary Hill.

sensors (pressure, acceleration, temperature) and one with a radio module and an Arduino to receive and record the data from the sensors.

We filled the balloon and attached the payload using our standard procedure,[1] launching the balloon at around 8:30 a.m. The balloon and payload were tracked using an iridium-based system developed for the Eclipse Ballooning Project, led by the Montana Space Grant Consortium.[2] The balloon remained aloft for about two hours, reaching an altitude of over 95,000 feet (video from that altitude is available).[3] After the balloon popped, the payload began its descent and came to rest in a tree outside of Carthage, Tennessee, about 80 miles away.

"As we hiked out to the final GPS coordinates, deep into the woods on the side of a mountain, I started to get a sinking feeling in my stomach and just knew that I was about to spend a painful amount of time in a tree to recover this special payload," Gaither says. "It turns out that the payload parachuted to the top of a tree, approximately 70 feet off the ground. I unpacked my gear, shot a line into the tree with my modified crossbow, secured the climbing rope, and began to ascend the tree. We were fighting daylight hard and my hands were cramping. I got all the way up to as high as my gear would let me go, and then I pulled up this 16-foot pole saw, and for an hour and a half I worked at it."

After freeing the balloon from the tree, we returned with the payload. The technical part of the payload, the wireless communication system, worked mostly as designed. It did turn off prematurely, a failure we are still investigating. Perhaps most importantly to Gaither, we returned the hops to Strawberry Alley Ale Works.

"I can't wait to sample their new Stratospheric Black IPA," he says. The keg-tapping party is scheduled for March 31.

We are looking forward to more launches and collaborations, including an upcoming flight coordinated with an area middle school. There's not likely to be any beer-related payloads on that flight, but it's sure to be a great time anyway. //

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1. Megan McCracken et al., "High Altitude Ballooning Using Amateur Equipment: A Primer," in *Celebrating the 2017 Great American Eclipse: Lessons Learned from the Path of Totality*, eds. Sanlyn R. Buxner, Linda Shore, and Joseph B. Jensen, ASP Conference Series Vol. 516 (San Francisco, CA: Astronomical Society of the Pacific, 2019), 491, www.aspbooks.org/a/volumes/article_details/?paper_id=38799.

2. Angela C. Des Jardins et al., "Eclipse Ballooning Project Live Streaming Activity: Overview, Outcomes, and Lessons Learned," in *Celebrating the 2017 Great American Eclipse: Lessons Learned from the Path of Totality*, eds. Sanlyn R. Buxner, Linda Shore, and Joseph B. Jensen, ASP Conference Series Vol. 516 (San Francisco, CA: Astronomical Society of the Pacific, 2019), 353, www.aspbooks.org/a/volumes/article_details/?paper_id=38794.

3. Footage of the hops when the balloon popped at the peak of the flight can be seen at www.youtube.com/watch?v=2vtkFKufT64/.

TOP: The balloon team gets ready to release the balloon from the launch site.

ABOVE: A view of the hops at peak altitude. Photos courtesy of Zachary Hill.

SEES-ing Young Minds with Science

by Alisha Wiedmeier, SPS Member, St. Catherine University

This past January, my research team and I attended the winter meeting of the American Association of Physics Teachers (AAPT) in Orlando, Florida. We are undergraduate students at St. Catherine University, a small, private institution in Saint Paul, Minnesota. We value outreach, especially as we are an all-women institution, so when the opportunity arose to volunteer at an AAPT-SPS outreach event during the meeting, we were excited to help.

Students Exploring Engineering and Science (SEES) is a free outreach event that targets elementary and middle school students from underserved communities near the location of the AAPT Winter Meeting each year. The event is led by SPS staff, students, and faculty members.

When my team arrived, we saw the work that other volunteers had already completed in preparation for the event. It was truly amazing to see the variety of physics-loving people that were coming together to teach a younger audience. Even more astonishing were the types of activities that these students would be engaging in—upper-level experiments presented in a manner that helped everyone feel like a physicist for the day!

As the participating students entered, their excitement was obvious. Brad Conrad, the director of SPS, sat them down and introduced the SPS undergraduate volunteers. Each volunteer talked about their personal physics journey and how they became interested in science. This created a unique atmosphere, highlighting how scientific disciplines overlap.

After introductions, the students rotated between four stations: circuits, light diffraction, motors, and collisions. I love to teach people about circuits, so I was happy to work at that station. The unit included creating different circuits, in series and parallel, and incorporated cool attachments—fans, sirens, and light bulbs. The students were passionate about the hands-on activities and loved making connections and working as a team. To build their scientific confidence, I encouraged them to shout out answers, even if they were wrong. Even students that came into the activity with insecurities about circuits, or science in general, were laughing and having fun by the end of the rotation.

When all of the rotations were complete, we reconvened as a large group for lunch. It was powerful to see people of all ages engaging with so much joy, inspired by a shared physics experience. I loved that these students got the chance to learn and embrace this awesome scientific world, thanks to SPS and AAPT. When I first introduced myself at this event, I took a moment to really look at the group of fourth and fifth graders. For the first time in my life, I realized that outreach is about so much more than me. By investing in these future scientists, we invest in the future of science. //

TOP: Students solve a bank robbery mystery using conservation of momentum.

MIDDLE: SPS volunteers assist students in getting motors to run using a battery, a coil, and a magnet.

ABOVE: SPS participants learn about electrical circuits. Photos courtesy of AAPT.

Climate Stories:

Shifting the Narrative of Climate Change Conversations

by Kendra Redmond, Editor

Many people don't accept that we're in the midst of a climate crisis. As a physicist, that can be frustrating. We see evidence as the foundation of knowledge and progress, so it's not surprising that our natural reaction to unconvinced friends or family members is to provide more detailed data, different data, or the same data again, just at a higher volume. But this piling on of evidence often doesn't work. What then?

THE POWER OF STORYTELLING

"We know from research that information alone is not enough to move people to change their behavior," says Jothsna Harris, senior community engagement manager of the nonprofit Climate Generation. "Storytelling is a way to move from the head to heart."

Climate Generation, founded by the polar explorer Will Steger, aims to empower individuals and their communities to engage in solutions to climate change. A key element of their approach is helping people uncover, articulate, and share personal climate stories—stories that draw in listeners and transform climate change from a distant, complex problem into an issue intricately intertwined with our lives.

"Data, trends, and graphs are only part of the picture," says Harris. The rest of that picture, the most compelling part of that picture, is the story of how the climate connects us. It's Malini's story of how a severe weather event cut off the power to her father's ventilator. It's Logan's story of how a non-native species of fruit fly destroys the raspberry crop in his yard every year.

Facts have a place in climate stories, but that place is usually *after* listening, learning, and sharing your personal experience. The story establishes commonality, explains Harris, and lays the foundation for a natural transition to the big picture—the increasing number of severe weather events, the disruptive impact of changing weather patterns on farming and food supplies, and the energy cost of new production. After establishing trust and rapport, facts like these are more likely to be received by the listener.

UNCOVERING YOUR CLIMATE STORY

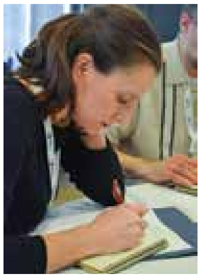
"Most people think they don't have a climate story, but they do," says Harris. The impacts of climate change affect all of us, but it might require some thoughtful brainstorming to arrive at the story you want to share. To help with this, Climate Generation has a series of prompts on their website and a collection of personal stories submitted by others. You might work on this individually or as part of a chapter event or workshop.

Physicists often separate evidence from anecdotes, emotions, and values, but a climate story is the place to pull them all together. Effective climate stories are heartfelt and vulnerable. They weave together personal experiences and climate change, drawing in readers with sensory descriptions and emotion. Putting together this kind of a story might feel a little unnatural at first, but climate change is an emotional issue. Even though you probably learned about climate change intellectually, coming to terms with it can incite feelings of loss, despair, anger, hope, and resolve. This emotional aspect of climate change "is often not acknowledged but most universally resonates with people," says Harris.

SHARING YOUR CLIMATE STORY

Once you've drafted your climate story, share it with close friends or chapter members. Solicit feedback and spend some time refining your story. The more you share your story, the more empowered you'll be to talk about the climate crisis in a way that's authentic and impactful.

When you're comfortable with your story, consider sharing it broadly. Harris encourages people to send their climate stories to local newspapers and radio stations, share them with policymakers along with specific asks, read them at community outreach events, and employ them in everyday conversation with family and friends. As the 11th Doctor says in season seven, episode seven of *Doctor Who*, "The soul's made of stories, not atoms." //



ABOVE LEFT: Jothsna Harris leads a storytelling workshop at a recent Climate Reality Leadership Training. Photo courtesy of Climate Generation.

LEFT: A Talk Climate Institute attendee works on her story. Photo courtesy of Climate Generation.

LEARN MORE AND GET STARTED!
For prompts, tips, and examples of climate stories, visit climategen.org.

TALK CLIMATE!

For a more in-depth climate story experience, consider attending one of Climate Generation's upcoming Talk Climate Institutes. The Talk Climate Institute is a two-day intensive workshop in which participants learn new ways to talk about climate change through interactive sessions, personal reflection, storytelling, art, and more. The next Talk Climate Institute is planned for September 2020 in St. Paul, Minnesota, and will be open to the public—keep an eye on **climategen.org** for details. If you're interested in hosting a Talk Climate Institute on your campus or in your community, reach out to Climate Generation at info@climategen.org.

From E&M to Promoting Innovation in Developing Communities

by Megan Yamoah, SPS member, Massachusetts Institute of Technology (MIT)

In just a couple months, I will be graduating with a bachelor's degree in physics and electrical engineering from MIT. Next year, I will be pursuing an MPhil in Economics at the University of Oxford on a Rhodes Scholarship. Still, at heart, I am a physicist.

For as long as I can remember, I've loved physics. My first passion was particle physics and the search for the Higgs boson at the Large Hadron Collider. Eventually, my interests moved to quantum materials and, finally, quantum computing.

To me, physics has always been a way of looking at the world, of studying not necessarily *what* to think about the world but *how* to think about it—about the way each constituent part functions. That our physical reality can be described so fundamentally by equations on a page continues to astound me.

Studying physics at MIT has been a markedly formative experience. I still remember the shock of my first physics class, Electricity and Magnetism, which suddenly forced me to use tools in vector calculus in ways I had never done before. Then came quantum mechanics and statistical mechanics. Those classes taught me, beyond the practicalities of different areas of physics, how to solve problems. They gave me the tools and the willpower to put my mind to questions and find answers. They taught me that I can solve problems on my own—even very complex problems.

Even more impactful than the classes was the community of insightful peers and wonderful friends in the physics department. With the goal of improving life in the department, I became president of the MIT chapter of the Society of Physics Students and a board member of our Undergraduate Women in Physics group. That opened up an opportunity to work with department leadership on a physics department Statement of Values, the first of its kind for an MIT department.

The Statement of Values aims to outline the values of the department, emphasizing an inclusive, supportive community. The statement was drafted over a span of three years through a series of meetings with department leadership, staff, and fellow students. Through this experience, I learned how to communicate across differences in perspective, as well as to express my concerns and understand the concerns of others.

Studying physics also opened up a variety of opportunities to put my knowledge into practice through research projects. Beginning in my freshman year, I dived into research under Professor William Oliver, investigating various aspects of superconducting qubits and finally focusing on the role of two-dimensional materials in new qubit designs. I also had the opportunity to work with Professor Vladan Vuletic at MIT on atomic physics and Professor Benjamin Huard at ENS de Lyon in France on quantum information.

ABOVE: Yamoah (standing) and a fellow researcher adjust controls on instruments connected to the dilution refrigerator in which they conduct experiments on qubit devices. Photo courtesy of Nathan Fiske.

BELOW: Megan Yamoah. Photo courtesy of Ian MacLellan.

Research allowed me to tackle questions in physics firsthand. But it also led to a new question: What if more students from around the world had the same opportunities to study physics and engineering in groundbreaking areas? I realized, then, that my true passion is combining science and engineering with action that has broad, cross-cultural impact. I want to take an interdisciplinary approach—combining economics, development studies, and engineering—to drive research and innovation in developing communities.

As I look forward to my new path, I know that I'll rely on the technical skills I gained through physics classes and research to study economics, innovation, and institutions. Looking back, I realize that not only does physics teach you how to think, but it also opens up pathways for applying your technical skills to whatever passion you choose to pursue. //

ABOUT THE AUTHOR

Megan Yamoah is a senior at the Massachusetts Institute of Technology (MIT) majoring in physics and electrical engineering. Her research expertise is in the application of novel materials in quantum computing, for which she has received the Barry Goldwater Award. During her time at MIT, she served on the Executive Board of MIT Undergraduate Women in Physics and as the president of the MIT Society of Physics Students. The daughter of immigrants, she is passionate about designing innovation initiatives to drive economic growth in emerging markets. Next, she will pursue an MPhil in Economics at the University of Oxford as a Rhodes Scholar to forward her interests related to how innovation can positively affect emerging economies. She hopes to combine technological innovation, developmental economics, and cultural understanding to drive growth in cities around the world.

Starry Nights at Sacramento State's Zone 18 Meeting

by Mayia Vranas, Associate Zone Councilor, SPS National Council, University of California, Berkeley

We sat in the center of the room, eyes gazing upward at the starry night sky. We watched, impressed, as Dr. Barniol Duran guided us through the cosmos, showing us constellations visible in different parts of the world, nearby stars, and the relative sizes of bodies in our own solar system. The show brought us back to childhood moments in planetariums or hours spent gazing at the real night sky. It concluded with a movie about the astronomers of ancient Egypt, who had the brilliant cosmos in full view, free of today's light pollution.

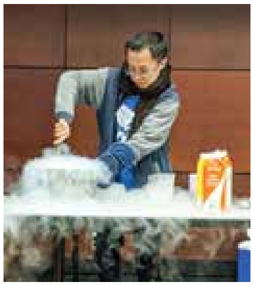
Sacramento State University's planetarium is a brilliant tool for undergraduate courses and local outreach, and the show was just one of the many events that Sacramento State had planned for us at Zone 18's annual zone meeting. Zone 18 comprises SPS chapters in California, Nevada, Hawaii, and several international chapters. This year's meeting, though intimate, brought many Northern California chapters together and included a variety of exciting events.

The meeting began on a Friday with a tour of the California State Capitol building. We met Shahid Hussain, Sacramento State's SPS chapter president, at the steps of the building and were guided through the state's lawmaking process. With the upcoming elections this year, we were reminded of the impact that policymakers have on our resources as physicists. The tour was followed by the show at Sacramento State's new planetarium and a game night in their electronics lab and study room. We played Super Smash Bros., parsed through their extensive physics book collection, and bonded with each other.

The second day of the meeting was packed with events, including a tour of their beautiful campus, several talks, and a small poster session, during which we communicated about the types of research we were conducting at our different schools. We also heard from two wonderful speakers. Dr. Mikkel Jensen spoke about his fascinating work in the field of biophysics at Sacramento State, studying proteins and filaments and the use of optical trapping in his research. Later, Dr. Jeff Parker gave a talk about his work as a plasma physicist at Lawrence Livermore National Lab and provided an overview of the advancements in work on nuclear fusion in recent years. This is a topic relevant to all young physicists as we evaluate how our work may impact the global climate crisis.

Interspersed throughout the meeting were various demonstrations from our zone councilor Don Williams, who traveled from Fresno State University in a van loaded with physics outreach tools. He showed us physics demonstrations of varying levels of complexity and taught us how to teach and execute these demos with different age groups. We watched a superconducting magnet spin, launched a Ping-Pong ball through aluminum cans with the force of the atmosphere, and enjoyed some delicious liquid nitrogen ice cream.

The meeting concluded with a talk from Mikayla Cleaver, the SPS programs coordinator, and a discussion about imposter syndrome. Cleaver spoke about the resources that SPS National has to offer and had us mark our calendars for the 2021 Physics Congress. Finally, we ended the day with my talk about the research and data on imposter syndrome and a heart-to-heart about our own experiences as undergraduates. After an exciting and eventful meeting, the students returned home excited about connecting with other SPS chapters and full of ideas for events of their own. //



TOP LEFT: A student helps make liquid nitrogen ice cream.

TOP RIGHT: Students gaze up at the planetarium show on the first day of the Zone 18 meeting.

MIDDLE: Students rest by the planetarium after the campus tour.

ABOVE LEFT: Dr. Mikkel Jensen speaks to students about his work in biophysics.

ABOVE RIGHT: Two students participate in a demonstration with zone councilor Don Williams on torque. Photos courtesy of Shahid Hussain.

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