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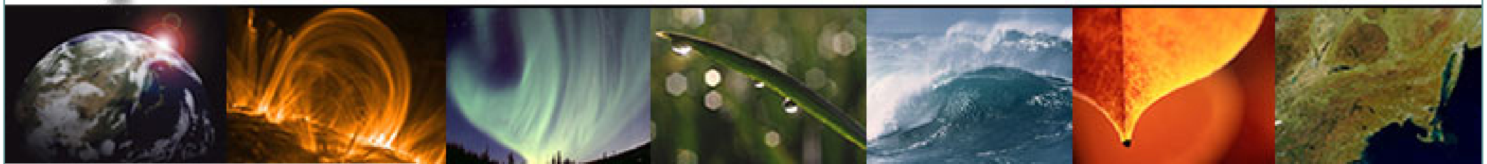

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Spring 2015
In this Issue of *Spheres*…

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EOS Director: Harlan Spence
EOS Dir. of Finance & Admin.: Jo Beth Dudley
Editor: David Sims
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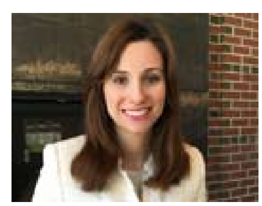
Earth Systems Science

Hello, Goodbye

IT TOOK *SPHERES* nearly two years to finally catch up with Carmody "Carrie" McCalley, who arrived at the Earth Systems Research Center in the fall of 2013 to work with Ruth Varner on trace gas analysis in Sweden and at Sallie's Fen in Barrington, New Hampshire. Read More…

Earth Systems Science

Head in the Clouds



WHEN MUGE KOMURCU looks skyward at passing clouds, she admires their beauty and mercurial nature like any good cloud watcher. But she notes, "When I see a cloud, I think about the small ice particles and cloud droplets inside." Read More…

Space Science

Having a FIELDS Day

WHEN NASA's Magnetospheric Multiscale mission blasted off at 10:45 p.m. EDT on March 12, 2015, a decade's-worth of effort by Space Science Center scientists, engineers, machinists, and students was sent skyward on the first scientific mission dedicated to studying magnetic reconnection—a poorly understood, universal process in which magnetic fields reconfigure themselves and release enormous amounts of energy. Read More…

Around the Hall

News and Notes

• Faculty, Staff, and Student News Read More…
• From the Director: All in a Month's Work Read more…

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Space Science

Lightning Strikes Twice

Joseph Dwyer solved a longstanding mystery about lightning and become the global go-to guy

IT WAS PURE SERENDIPITY that Joe Dwyer became the world expert in the high-energy physics behind lightning strikes, and ironic that he's now landed back in the virtual stomping grounds of his research from days of yore.

Dwyer, who came from the Florida Institute of Technology to the Space Science Center last September as the new Peter T. Paul Chair in Space Sciences, began his career doing space instrumentation work —one of the core strengths and legacies of the SSC. But in 2001, as a young assistant professor at FIT, he abruptly switched gears while applying for a National Science Foundation Faculty Early Career Development (CAREER) grant.

Joe Dwyer in 2003 on the rocket launch tower at the International Center for Lightning Research and Testing at Camp Blanding Florida with an early x-ray instrument.
Photo courtesy of Joseph Dwyer, UNH-EOS.

Funded at the time by NASA for his space physics research, Dwyer was encouraged to find some other line of work for his CAREER proposal, since it was unlikely that the NSF would provide him with five years of funding to continue his NASA research.

“I needed to find something else to do and, meanwhile, there was all this 'boom, boom, boom' going on outside my window. There's a lot of lightning in Florida,” Dwyer recalls. “So I started wondering if maybe I could do something with that.”

He had heard about lightning possibly producing x-rays—something that had been talked about since the 1920s. "People had been trying to see if it was indeed true for over 70 years, but at that time researchers still didn't know the answer,” Dwyer says. “People occasionally reported detecting x-rays from lightning, but nobody had ever confirmed it.”

Joe Dwyer had found his CAREER grant research focus.

“That's where things were back in 2001. Few scientists really believed lightning emitted x-rays but because it was an idea that never quite died I thought, 'Okay, I know how to build x-ray detectors. I'll just set them up outside and perhaps we can settle this once and for all,'" Dwyer says.

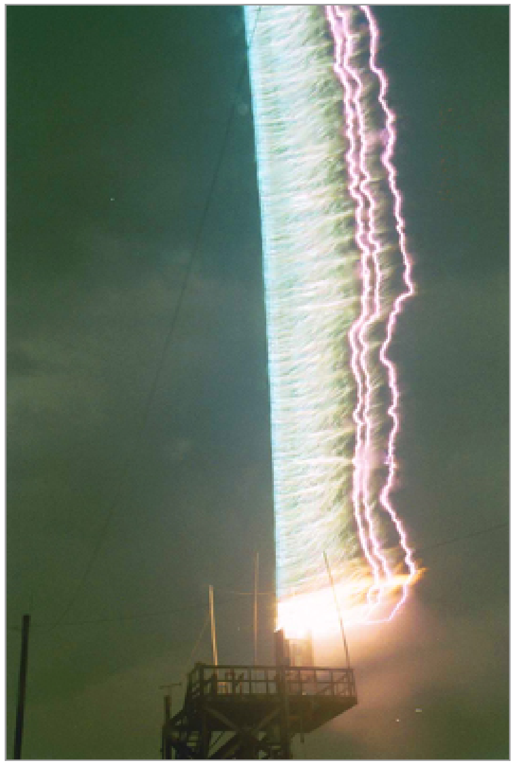
It was a bold stance for a young researcher to take when, admittedly, he didn't know the first thing about his topic of choice.

"Most people with a modest interest in the subject probably knew more about lightning than I did at the time. I figured there must be someone in Florida who knows about lightning and could help."

So he did a web search on "lightning expert in Florida" and came up with a fellow named Martin Uman—a world expert in lightning.

"I sent him an email telling him what I was proposing to do—to see if lightning emitted x-rays—and asked if he might help. To show you how little I knew at the time, I even misspelled lightning in that email," Dwyer says with grin.

"I needed to find something else to do and, meanwhile, there was all this 'boom, boom, boom' going on outside my window."



Rocket-triggered lightning was found to generate x-rays, providing clues to how lightning propagates to the ground. The top of the rocket launch tower is at the bottom of the picture.
Photo courtesy the University of Florida.

"Despite that blunder Martin Uman wrote back anyway and said that we could actually use triggered lightning to study this so you don't have to sit around waiting for years until natural lightning strikes near your instrument. You can make it on demand, or at least give it a place to strike, by setting up by a rocket launcher and launching a rocket tethered to the ground by a copper coil, which can trigger a lightning strike," explains Dwyer. "So I put that in the proposal."

In the meantime, there he was in Florida–the Land of Lightning, he had some start-up money he could use and graduate students who could help, and he'd had experience with x-ray instrumentation years before while at Columbia University as a research scientist. Why await word from the NSF on his CAREER proposal?

Moreover, sensing that his proposal was a long shot at best since he'd never done any research in the field and never published a single lightning research paper, Dwyer and colleagues just dove right in. They built an instrument that could accurately measure x-rays from lightning at the ground, successfully triggered a lightning strike via a tethered rocket and, after pulling the trigger many times, showed once and for all that lightning does indeed emit x-rays.

"Lots and lots of x-rays, and the signals were really big," notes Dwyer. He adds, "Actually, in hindsight, several people probably had measured the x-rays before, but my group did the careful, detailed measurements and repeated the experiment over and over with precision, which you can do with triggered lightning. We published in *Science* and with that it was finally established that lightning emits x-rays."

Meanwhile, Dwyer found out that he had actually won the CAREER award.

"Within a few months of getting the CAREER award I'd done most of the things that I said I'd do in that five-year period," Dwyer says. "So the pressure was off and I was able to take some chances in this same field. It turns out there was a lot of low-hanging fruit on this subject and we were able to make many important discoveries about lightning." All of which made him the go-to guy for lightning.

He adds, "Surprisingly, the field is going through this growth phase right now where a lot of really important lightning discoveries are being made all the time, which for scientists is really exciting."

Ben Franklin aside, lightning remains a deep mystery

It turns out the x-ray mystery that Dwyer helped solve once and for all just scratched the surface of lightning-related mysteries remaining to be probed. In fact, Dwyer notes, "Lightning is an unsolved problem in science, we really don't know how it works at the basic level. In physics we're usually answering 'how' questions, and with respect to lightning these are: 'How does it get started?'—or what's known as the initiation problem; and, 'How does it move?'—or the propagation problem."

"And I'd say the initiation problem has to be one of the biggest mysteries in the atmospheric sciences—how you get lightning started inside a thunderstorm. It's hard to know how to even approach the problem."

"Few scientists really believed lightning emitted x-rays but because it was an idea that never quite died I thought, 'perhaps we

can settle this once and for all.'"

How could something so common—lightning discharges occur about four million times per day and lightning strikes cause more deaths and injuries in the U.S. than either hurricanes or tornados—remain so poorly understood?

"It's an overlooked area of research for one thing," says Dwyer. "I think a lot of people assume it's a solved problem. Everyone knows Ben Franklin 'solved' it 250 years ago but he simply showed lightning was an electrical phenomena, which was important but that certainly didn't solve the problem."

Even today, scientists understand the inside of a star halfway across the universe better than how lightning gets started inside a thunderstorm five miles above our heads. And, Dwyer notes, lightning actually *shouldn't* be occurring according to what little is known about the inner workings of thunderstorms.

The rocket launch tower at Camp Blanding Florida
Photo courtesy of Joseph Dwyer, UNH-EOS.

"The gamma rays coming out of thunderstorms are probably a souped-up version of the x-rays we see on the ground from lightning."

"You look at how thunderstorms charge up and the electric fields never seem to be large enough to actually make a spark, and yet we see lightning coming out four million times per day. Then, it can travel hundreds of miles through the clouds, all the way across a state sometimes, but we don't really understand how it does that either."

Perhaps x-ray marks the spot.

Another reason why lightning is an overlooked area of physics is that it's a very tough phenomenon to research. As Dwyer notes, a thunderstorm is a big dangerous place; you can't see inside it with a telescope, it's hard to get into, and if you do fly inside it with an airplane you might not have an airplane coming out. "It can ice up, turbulence can rip it apart, lightning can strike, there's a half dozen ways you can get killed in an airplane in a thunderstorm."

With all that for context, it's clear to see how nailing down the x-ray/lightning connection might open wide a new avenue of exploration as to the how and why of lightning.

The x-ray instrument pictured in the foreground was the first instrument used to record x-rays from rocket-triggered lightning. In 2002, measurements made by this instrument established that lightning emits bright bursts of x-rays, giving researchers a new tool for studying lightning.
Photo courtesy of Joseph Dwyer, UNH-EOS.

Of the x-ray finding Dwyer says, "We finally nailed down something really new and different about lightning and suddenly we've got a clue as to how lightning might get started and how it moves."

Related to the x-rays emitted by lightning is a phenomena known as terrestrial gamma-ray flashes, or TGFs, that can be seen from outer space. These fleeting, monster bursts of gamma rays, originally thought to originate at high altitudes, were finally shown to come out of thunderstorms. So bright are they that they can temporarily blind spacecraft in low-Earth orbit-spacecraft designed to measure gamma rays from all over the universe but that are unable to keep up with the gamma-ray count rates coming from thunderstorms.

"Surprisingly, the field is going through this growth phase right now where a lot of really important lightning discoveries are being made all the time…"

"These gamma rays are emitted from thunderstorms around the time lightning is initiating, so these TGFs are right there in mix and we can use them as another probe into the processes. The gamma rays coming out of thunderstorms are probably a souped-up version of the x-rays we see on the ground from lightning."

But it is only speculation that x-rays and TGFs are important for lightning initiation. If these processes were taken out of the picture would lightning initiation cease?

"We don't know but at the very least it could be an interesting side effect, and in that case it would help us further probe what's going on. So, at a minimum, these processes will provide us with a useful investigative tool, while on the other hand they might prove to be the keys to the kingdom of lightning initiation and propagation."

Lightning and severe weather are two of the most visible products of thunderstorms. However, scientists are discovering that the storms also contain a fascinating variety of strange phenomena, including powerful gamma-ray flashes and puzzling clouds of positrons— the anti-matter version of the electron.
Photo courtesy of @iStock.com/lg0rZh

While actively continuing his triggered lightning research in Florida, back in the world of space instrumentation and mathematical modeling at the SSC, Dwyer is comparing models with data from instruments on the Fermi Gamma-Ray Space Telescope and the Reuven Ramaty High Energy Solar Spectroscopic Imager spacecraft, which have instruments that can measure gamma-rays coming from thunderstorms. He also does pencil and paper theoretical work and runs computer simulations.

Says Dwyer, "This is a field of research that's still new enough where someone like me can do experimental and theoretical work at the same time, whereas in a more mature field, such as space physics, it would be difficult to do both—you usually have to pick one or the other to be good at it."

by David Sims, Science Writer, Institute for the Study of Earth, Oceans, and Space.

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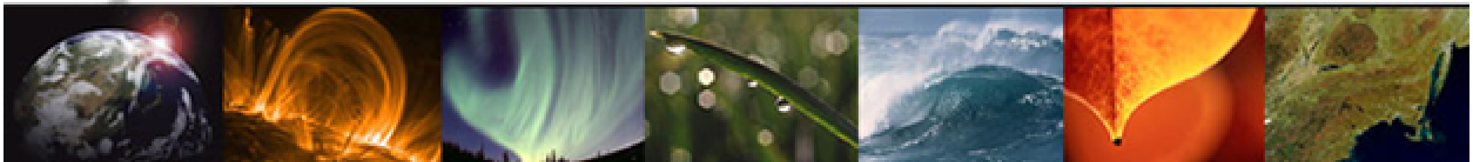

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Space Science

Small is Beautiful

UNH senior Chrystal Moser laid the foundation of her future through baby steps

IN DECEMBER OF 2013, Space Science Center associate professor Marc Lessard stepped on a little donut-shaped bead on his daughter's bedroom floor and had a eureka moment.

“Picking it up I realized it was the exact shape and size we needed to begin building the miniature magnetometer for a small satellite project we were working on,” recalls Lessard. “I gave it to my undergraduate research assistant Chrystal Moser and said, ‘Here, take the finest copper wire you can handle, thread it through the hole, and wind and wrap the bead as tightly and thoroughly as you can.’”

Chrystal Moser in the Space Science Center's Magnetosphere-Ionosphere Research Laboratory with the miniature magnetometer she helped build for an upcoming CubeSat mission. Photo by David Sims, UNH-EOS.

Moser accepted the challenge with gusto.

A sophomore physics major at the time, Moser had only recently linked up with Lessard in an effort to get some hands-on undergraduate research experience—very hands-on it turns out. She had worked in the SSC previously doing programming but found that work not to be a good fit, especially with an eye on her future scientific endeavors.

Says Moser, “I’m not a terribly good programmer and felt I needed to be working in a lab doing real hands-on research. When Marc gave me the little bead and said, essentially, go figure out a way to wrap it with copper wire to make a magnetometer, I jumped at the chance.”

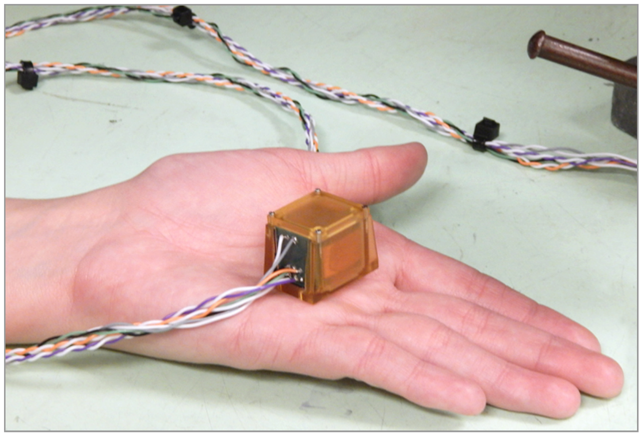
Moser didn’t know the first thing about magnetometers—something Lessard, a rocket scientist, specializes in—had taken no courses in electricity or magnetism but relished being there in Lessard’s Magnetosphere-Ionosphere Research Laboratory getting her hands dirty baby step by baby step.

“I was using copper wire about the size of a human hair and winding it on something as small as that bead took me six hours to make 300 turns by hand,” says Moser. She adds, “I actually liked that—I could think my own thoughts and focus on the challenging physical process. I had to learn as I went along, and that was the most fun—having the creative freedom to problem solve, explore.”

Being given the freedom by Lessard to work largely independently (and independently “taking” a self-designed textbook and online course on the workings of magnetometers), Moser’s first challenge was to simply figure out how to physically manage the task at hand—repeatedly threading a wire .0067 of an inch thick through and around a bead the size of a green pea.

At first she tried using a small vice on a lab workbench but found it difficult to manipulate the wire without it breaking. “So I ended up just taping it to a table so I could rotate it as I did the winding, scoot it around easily when starting a new layer of wiring, flip it over, etcetera.”

“I was using copper wire about the size of a human hair and winding it on something as small as that bead took me six hours to make 300 turns by hand.”



The miniature magnetometer. Photo by David Sims, UNH-EOS.

Once she had mastered the technique, the plastic bead was replaced with a tiny bobbin made of a nickel-chromium alloy known as Inconel that was then wrapped with a nickel-iron alloy material and heat treated. It was on this little high-tech gizmo that Moser carefully wrapped the copper wire to create the mini-magnetometer.

The entire magnetometer, which is comprised of two coils of copper wire aligned in opposite directions, a high-tech plastic “doghouse” sheltering the copper coils and a scant electrical connector board is not much bigger than a sugar cube. Moser designed the doghouse after learning a CAD design software program. She calls the whole unit “adorable.”

Magnetometers, big or small, are designed to perturb the surrounding magnetic field and then measure its behavior, which provides an indirect measurement of the overall background magnetic field.

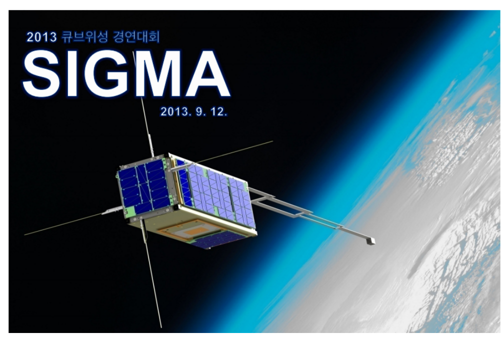
Mini-magnetometer in space

The 2x2x2 centimeter magnetometer Moser helped build will fly on an upcoming South Korean-led nanosatellite mission known as “Scientific cubesat with Instrument for Global Magnetic field and rAdiation”, or SIGMA. Principal investigators for the miniature magnetometer are Lessard and his former Ph.D. student Hyomin Kim, now a research scientist at Virginia Tech.

CubeSats are a new generation of pintsized satellites outfitted with modern, smart-phone-like electronics and tiny scientific instruments to, in effect, boldly go where bigger, more costly and complex satellite missions cannot. CubeSats hitch a ride into space on a rocket dedicated to a larger mission. They are placed into a compartment known as a Poly Picosatellite Orbital Deployer, P-POD for short, and jettisoned from the rocket at the proper orbital height above Earth.

“I had to learn as I went along, and that was the most fun—having the creative freedom to problem solve, explore.”

SIGMA, slated for launch in late 2015, is a proof-of-concept mission and will represent the first CubeSat-borne science-grade miniature “fluxgate” magnetometer flown in space. A fluxgate magnetometer is more tolerant to radiation and more robust than other types of magnetometers, which also tend to be heavy and power-hungry, while the miniaturized version’s small size, low mass and very low power requirements allows it to fly on a 10x10x30 centimeter CubeSat. It is the lowest power fluxgate magnetometer Lessard is aware of.



The SIGMA mission, slated for launch in late 2015, is a proof-of-concept mission and will represent the first CubeSat-borne science-grade miniature "fluxgate" magnetometer flown in space. Image courtesy of Seongwhan Lee, Kyung Hee University.

“This whole effort was motivated by the fact that at the American Geophysical Union meeting a couple of years ago,” Lessard notes, “there was a lot of talk about CubeSats but nobody was talking about flying magnetometers on these missions because they’re big and bulky and suck up a huge amount of power.”

Shortly thereafter, Lessard was part of a successful grant awarded through NASA's Experimental Program to Stimulate Competitive Research, or EPSCoR, Research Infrastructure Development (RID) program that, in part, funded initial research on the development of miniaturized instrumentation for magnetometers to be flown on CubeSats. Astrophysicist Toni Galvin of the SSC is the principal investigator on the EPSCoR grant and also directs the New Hampshire NASA EPSCoR program headquartered at UNH.

It is Lessard’s hope that, eventually, UNH will be able to build these miniature magnetometers for widespread use on space science missions.

“We hope to prove the technology of our magnetometer on this mission, and once we do, it opens the way for a possible future mission to the moon to measure magnetic anomalies using a CubeSat launched from a lunar orbiter. So this is a big thing as it may provide the opportunity for us to send one of our miniature fluxgate magnetometers to the moon.”

"For Chrystal, this has been a phenomenal ride I think. She came in and caught the wave and has

been surfing like crazy ever since."

“Yeah, I get so excited about the lunar possibility, and so does Marc,” Moser says adding, “And I’m so excited, too, because this hasn’t been achieved before for this size magnetometer with its low power consumption and level of accuracy.”

Moser, of course, will be long gone from Lessard’s lab when that happens but she does plan to go to graduate school to study space science instrumentation. And while UNH with its long, proud history of building space instruments and flying on missions would be one of her first choices, she thinks it best to mix things up a bit and begin her graduate career at a different institution.

Doing what?

“Rovers or, and I know it’s a long shot, interplanetary space travel/human space flight,” Moser says. “I would like to be involved in building hardware and getting teams together. It’s so much fun being here at UNH and meeting so many different people with different interests. One of my roommates is in computer science, another is an electrical engineer and we’ll talk about same stuff I do but they having a completely different perspective on things, and that’s the best.”

Says Lessard, “For Chrystal, this has been a phenomenal ride I think. She came in and caught the wave and has been surfing like crazy ever since.”

by David Sims, Science Writer, Institute for the Study of Earth, Oceans, and Space.

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Ocean Science

Moving Target

The Northeast Consortium begins a new phase of projects under shifting fisheries priorities with a first-time focus on the impact of recreational fishing

IN SEPTEMBER OF 2014, with $800,000 in fresh research funds from the New England Fishery Management Council (NEFMC) to administer, the Northeast Consortium put out a region-wide request for proposals to its constituency of commercial fishermen, scientists, and other stakeholders in the Gulf of Maine and Georges Bank.

While a broad range of projects was considered, priority was given to specific proposals that aim to demonstrate how to access closed areas and increase catch of haddock without impacting cod, yellowtail flounder, and windowpane flounder, as well as to studies that develop gear-engineering solutions to minimize bycatch of flatfish.

The call was answered with 18 proposals submitted from nine different institutions and entities and totaled a whopping $2.5 million in projected costs.

Fishing crew attaching an underwater camera to a bycatch reduction device to record fish behavior.
Photo courtesy of Northeast Consortium.

"It was great getting such a response but we didn't have anything like that amount, and so we had some difficult decisions to make," notes Chris Glass, director of the Northeast Consortium.

Glass and his review committee eventually whittled it down to four projects running the gamut from the survivability of haddock in recreational fisheries to new trawl gear design and avoidance strategies.

Soon thereafter, the NEFMC unexpectedly released another $200,000 in funding for the consortium to administer, which required an additional request for proposals to be sent out and resulted in roughly doubling the number of funded projects.

"More funds were provided because they realized there were some additional priorities they wanted to address that the original request for proposals did not cover," Glass says. "One thing they're concerned about in particular is getting more information about the spawning of groundfish—especially cod—not only *where* spawning is occurring but information about spawning activity that might allow us to eventually protect these areas better."

With the supplemental funds, Glass will now fund a total of seven or eight new projects that will help propel the crucial research forward.

The work of the Northeast Consortium has become the standard model for bringing commercial "fishers"—the gender-neutral term used in the industry—and scientists together in an effort to improve fisheries. But in recent years, a significant reduction in funds for supporting the research needed to identify strategies and solutions for the sustainability of fishery resources in the region has hampered further progress.

The consortium was created in 1999 to encourage and fund effective, equal partnerships among commercial fishers, scientists, and other stakeholders to engage in collaborative research and monitoring projects in the Gulf of Maine and Georges Bank. At the time, this approach was highly creative, innovative, and risky; New England fisheries stocks were heavily overfished, restrictions were being imposed and economic hardship was on the rise. In such a climate, commercial fishers were extremely reluctant to team up with scientists.

"…the population is at the very minimum level in order for the stock to be able to sustain any fishery at all… the stock is… almost reduced to zero."

But today, through the consortium's work, collaborative partnerships between scientists and fishers are firmly established and represent the most effective way to gather the information required to help rebuild our fishery resources. Moreover, the Northeast Consortium "template" is being replicated elsewhere around the globe and has helped encourage partnerships between fishermen and those who regulate them for the very first time.

However, Glass points out, despite the consortium's broad successes and the improvement of some fisheries, other stocks continue to be in decline. "So both the initial and supplemental funding represents very forward-thinking on the part of NEFMC," Glass says.

Cod crash

After the September 2014 request for proposals went out, more recent fisheries stock assessments clearly showed big changes in certain species that the NEFMC wanted to address immediately.

For cod, for example, the stock assessment revealed that the population of this once super-abundant, signature Gulf of Maine/Georges Bank fish had been reduced to three percent of the level needed to sustain the species.

Scientists investigating new net designs to reduce unintended catch of cod.
Photo courtesy of Northeast Consortium.

Says Glass, "What that means is the population is at the very minimum level in order for the stock to be able to sustain any fishery at all—it's three to four percent of where it should be, which means the stock is, if you believe the assessment, almost reduced to zero."

"…people are desperately trying to figure out alternate strategies that will allow them to fish for other species that are rebuilt or in better condition."

Thus, emergency action was required and led to the NEFMC releasing the additional $200,000 in research funds. It also led to the closure of all cod fishing "so people are desperately trying to figure out alternate strategies that will allow them to fish for other species that are rebuilt or better in condition," says Glass.

An additional and largely unexplored aspect of concern over cod, haddock, and other species is the impact recreational fishing has on the stocks of these fish.

Instrumentation being readied for deployment during fishing trials.
Photo courtesy of Northeast Consortium.

"The impact of recreational fishing has tended to fly under the radar but we know it's huge," notes Glass, "the amount of fish being caught recreationally probably exceeds what is caught by the commercial industry but a lot of fish are released. We don't know what portion survives or dies, we don't really understand the mortality that's being imposed on stocks by recreational fisheries, so it's really critical to understand just how much impact this is having."

Recreational fishing involves large party or "head boats" that can carry 20 anglers each with an allowed catch. If a section of the sea is dotted with a large number of these boats on any given

"The impact of recreational fishing has tended to fly under the radar but we know it's huge."

day, the numbers of fish being caught, and released, quickly adds up.

"It's big business in this part of the world," Glass says.

Two of the selected consortium projects are looking at fish that are being released from recreational fishing boats, and both are tag, release, and recapture studies.

"One uses conventional tagging and will release thousands of tagged fish that, when recaptured, will provide an estimate of survivability," says Glass adding, "and the other is planning to use acoustic telemetry where they'll be able to follow fish in real time after release from recreational boats."

Additionally, in a technique pioneered by the Northeast Consortium, each of these projects will be putting scientists and observers on the boats. Recreational fishing traditionally has been a self-reported enterprise, which is of course given to all sorts of inaccuracies for a variety of reasons.

Says Glass, "By getting people out there and monitoring exactly what's going on and studying this scientifically, we should be getting a much more realistic figure of the mortality."

by David Sims, Science Writer, Institute for the Study of Earth, Oceans, and Space.

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Earth Systems Science

Hello, Goodbye

Postdoctoral researcher Carmody McCalley heads to a tenure-track position at the Rochester Institute of Technology

IT TOOK *SPHERE*S nearly two years to finally catch up with Carmody "Carrie" McCalley, who arrived at the Earth Systems Research Center in the fall of 2013 to work with Ruth Varner on trace gas analysis in Sweden and at Sallie's Fen in Barrington, New Hampshire.

Now, she's heading for greener, tenured pastures at the Rochester Institute of Technology near her old stomping grounds at Cornell University where she earned her doctorate.

An automated chamber system used to measure methane emissions from Methanoflorens stordalenmirensis, the previously unknown species of microbe that McCalley and colleagues discovered in Stordalen Mire, Sweden.
Photo by Carrie McCalley, UNH-EOS.

On the upside, McCalley, Varner, and others in the ESRC have forged lasting research partnerships that will allow for a variety of collaborative projects well into the future.

"Ruth and I are already plotting," McCalley says of future joint research opportunities.

Notes Varner, "I am looking forward to continuing our collaboration on current projects as well as those in the future. And we're already talking about recruiting students from RIT to do research with us here at the ESRC.

The two scientists first crossed paths back in 2010 when McCalley—then a University of Arizona postdoctoral researcher—was studying links between microbes and methane emissions in the peatlands of the Abisko Scientific Research Station in Abisko, Sweden. Varner was also at Abisko doing formative work for the Northern Ecosystems Research for Undergraduates program that she directs.

The NERU work focuses on the impacts of climate change on permafrost and lake environments in the Stordalen mire complex some 124 miles north of the Arctic Circle. Now in its fourth year, the program has thus far provided 30 undergraduates from colleges around the nation with the opportunity to travel abroad, and cut their teeth on state-of-the-art climate change field research. In addition to collaborative fieldwork with Varner at Abisko, McCalley continues to serve as a mentor to undergraduates during summer season field research.

"I believe Carrie's strong research portfolio as well as her experience working with undergraduates in the NERU program helped prepare her for the RIT position. She came to UNH to continue her research but also to find opportunities to mentor and teach and Carrie has been a critical part of my REU program working closely with me, Mike Palace, and our colleagues

“Ironically, I started researching desert environments in upstate New York and then later moved to the desert to study the Arctic.”

in the department of Earth sciences.

McCalley herself did undergraduate research in Arctic climes when she was at Middlebury College in 2002.

“That’s where I got interested in the Arctic work, and when I finished my Ph.D. at Cornell I went back to that,” McCalley says. She adds, “It was a system that always interested me. I actually went to our Abisko site to work as a technician before going to graduate school. I never thought I’d go back again.”

McCalley's journey back to the Stordalen mire was a bit circuitous: at Cornell her Ph.D. work concentrated on desert ecosystems; she then moved to a postdoc position at the University of Arizona and focused her research on Arctic peatland environments.

Carrie McCalley at a Norwegian fiord near the Stordalen Mire research site in Abisko, Sweden.
Photo by Peggy Hock-McCalley.

“Ironically, I started researching desert environments in upstate New York and then later moved to the desert to study the Arctic,” McCalley says. “At Cornell, I studied in the Mojave Desert, flying to Nevada for a couple of weeks at a time to do the work. My Ph.D. advisor had just started a project at the Nevada Test Site where they tested and now dismantle nuclear bombs. Our study site was safe but it was quite restricted as to where we could go.”

“The atmosphere is changing, the climate is changing, and all that impacts how ecosystems work.”

Upon completion of her dissertation she then switched it up again—this time moving to the Arizona desert where she again set her sights on Arctic ecosystems.

The microbe-climate change connection

McCalley’s specialty is trace gas flux measurements and isotope measurements. For her Ph.D. work she measured nitrogen gas fluxes in desert ecosystems.

For their most recent work, McCalley and Varner (whose current research focus is the measurement of trace gas emissions from agricultural and wetland ecosystems) joined forces on two specific grants—a Department of Energy-funded project that starts at the microbial level and scales up to the ecosystem level, and a National Science Foundation macrosystems grant that starts with ecosystems and goes up to the global scale.

“What unites that work with the Arctic and Sallie’s Fen research is measuring gas fluxes and thinking about how those fluxes are changing in response to climate change,” McCalley notes.

Climate change, she adds, is the motivating reason for asking the questions about the biosphere/atmosphere feedbacks that are at the heart of the field measurements.

“The atmosphere is changing, the climate is changing, and all that impacts how ecosystems work. And I’m particularly interested in how that affects how ecosystems function in ways that change the production of chemically important gases—greenhouse gases or other reactive gases.”

“We expected groups of microbes would matter so it was surprising and interesting to find that a single species played such big a role.”

The key greenhouse gas here is methane, which is also the focus of Varner’s work in Sweden. The emission of methane from peatlands as the landscape warms and thaws under climate change is of concern to scientists because, while it is less abundant than carbon dioxide, it is many times more potent as a greenhouse gas and there is the potential for substantial amounts of it to be released under the right conditions. Current research is aimed at getting a more accurate handle on what conditions promote emissions in rapidly changing Arctic systems.

To that end, McCalley has been investigating the influence of microbes in the methane emission process in Arctic peatlands using isotopic analysis. Recently, based on work

Carrie McCalley and Tyler Logan collect a peat core for microbial community analysis.
Photo by Ruth Varner, UNH-EOS.

done as a postdoc at the University of Arizona, she was lead author on a paper published in Nature that detailed the surprise finding that one previously unknown species of microbe dominated the peatland landscape and was an important, unsuspected player in the methane emission process at their test site in Sweden.

“Often, when you read the literature on microbes they tend to look at orders or classes or families, not single species,” McCalley says. “We expected groups of microbes would matter so it was surprising and interesting to find that a single species played such big a role.”

Essentially, according to McCalley, what the research detailed in Nature shows is that methane emissions from thawing permafrost is large enough “that getting the specific microbial isotopic signature right could matter for how you interpret global methane in the atmosphere going forward.”

Microbiology is, of course, a well-established scientific field but the detailed microbial studies McCalley and others do today is relatively new and is due to rapid advances in technology.

“It’s very difficult to study microbes without looking at DNA, and the technology to do the DNA sequencing has been dropping in price exponentially in the past few years,” McCalley notes. “These great advances in the technology and huge reductions in the cost means it’s been a very rapidly developing field and we’re now able to ask these kinds of questions at the microbial level.”

She adds, “In the past, we’ve made hypotheses about what the microbes are doing and how they’re changing based on what we see in terms of fluxes in isotopes, and now we can start testing those hypotheses and eventually use this information to improve models.”

Notes Varner, “Through Carrie’s research and teaching, students at RIT will be exposed to a state-of-the-art understanding of ecosystems using links between geochemistry and microbiology. Moreover, Carrie’s move there won’t be a loss for EOS and UNH. Rather, it will be an opportunity for UNH to engage more—and a more diverse group of—students.”

by David Sims, Science Writer, Institute for the Study of Earth, Oceans, and Space.

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Spring 2015
In this Issue of *Spheres*…

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Spring 2015

Earth Systems Science

Head in the Clouds

Climate modeler Muge Komurcu probes the missing link in global climate models

WHEN MUGE KOMURCU looks skyward at passing clouds, she admires their beauty and mercurial nature like any good cloud watcher. But she notes, "When I see a cloud, I think about the small ice particles and cloud droplets inside."

The focus of Komurcu's scientific research is understanding how clouds work or, more specifically, modeling how they influence climate by either absorbing or reflecting sunlight—in large part a function of whether they are made up mostly of water or ice.

Muge Komurcu.
Photo by Zikri Bayraktar.

A native of Istanbul, Turkey, Komurcu came to the Earth Systems Research Center in early 2014 as a member of climate modeler Matt Huber's Climate Dynamics Prediction Lab and brought needed expertise in the biggest mystery of climate modeling—the role of clouds.

As Huber says, “Clouds are the heavy lifters in the climate system and they’re also the most uncertain aspect of climate models.”

Prior to UNH, Komurcu was a postdoc researcher at Yale University where she worked on clouds in global-scale models. At Yale, she led a multi-institutional team of researchers in a study comparing how clouds are currently represented in half a dozen general circulation models. The study was the first to show the difference in simulated cloud phases and how those differences affect clouds' radiative forcing properties, or their tendencies to reflect or absorb heat. As lead author, Komurcu published the study’s results in the Journal of Geophysical Research-Atmospheres.

"I ended up at Yale working on global-scale models because I like clouds and I realized they are not well represented in the models," Komurcu says. "And I knew that representation was worse in global-scale models because the resolution is very coarse and cloud-scale processes are extremely small. What's more, we don't really know some of the processes related to ice inside clouds."

The microphysics of ice crystals is complex and poorly understood, which means they are not well represented, or "parameterized," in models. The ever-shifting shapes of ice crystals, and how and where clouds are formed are all things that determine a cloud's radiative properties.

"You need to do very expensive lab studies and field experiments to understand all this," Komurcu says. "And the ice crystal formation process can change depending on a number of variables."

For example, over time inside a cloud, ice particles will grow larger and eventually fall out. But how they grow depends on the local temperature and vapor pressure, cloud circulations, and how the particles morph into different shapes that can affect whether or not they fall slowly or

"Clouds are the heavy lifters in the climate system and they're also the most uncertain aspect of climate models."

quickly. “And when they’re falling they can collect other ice particles, which will affect how long they’ll stay in the cloud. So everything is interrelated, and very complex,” Komurcu says.

A matter of scale

At UNH, Komurcu currently works on regional climate modeling as part of the National Science Foundation-funded Experimental Program to Stimulate Competitive Research (EPSCoR) Ecosystems and Society project. The work, she says, is similar in many respects to the climate modeling she did at Istanbul Technical University where she earned a master's in meteorology.

Photo by Jon Sullivan.

“The work in Istanbul was like the EPSCoR project but much smaller scale modeling and I used an earlier generation of the model I’m using now to simulate heavy precipitation and flooding at the regional level,” she says.

The next generation model she’s now using—the high-resolution regional Weather Research and Forecasting model—was developed at Pennsylvania State University where Komurcu chose to do her Ph.D. work. “At Penn State I did modeling and studied Arctic clouds and their influence on the regional climate of the Arctic.”

“I ended up at Yale working on global-scale models because I like clouds and I realized they are not well represented in the models.”

The multifaceted Ecosystems and Society project has a diverse set of goals, but central to the work is the development of a suite of models and scenarios that will project future changes in “ecosystem services” (such as clean water supply, wood for fiber, fuel, timber, climate regulation) resulting from change in climate and land use. The hoped-for outcome of all this is a set of informational tools that state decision makers can use to chart a sustainable future for the next century. The interdisciplinary project involves physical and social scientists, including economists, working together in collaboration.

The climate scenarios will be derived using global climate models in a fashion similar to how the Intergovernmental Panel on Climate Change projects different scenarios of atmospheric levels of carbon dioxide. In this case, however, the scenarios will be scaled down to the state level.

Komurcu’s EPSCoR work involves taking output from a global model and scaling it down to the regional level to obtain climate variables such as temperature and precipitation 100 years out.

“I’m working on high-resolution simulations of the future climate in New England,” Komurcu says. The high resolution allows her to model many processes in detail and make predictions about the intensity, frequency and duration of precipitation, as well as extreme events such as droughts, floods, heat waves, etc. It also helps the team to study regional and large-scale processes and their interactions.

On a personal note, Komurcu says, “While I was at Yale I experienced firsthand the social and economic influences of extreme events in New England, such as hurricanes Irene and Sandy and the Winter Storm Nemo. At the same time, the Yale Climate and Energy Institute started a climate initiative with speakers from different institutions, professors, scientists, and politicians talking about climate change, regional impacts, and policy. From my interactions with these experts I knew I wanted to use my expertise in atmospheric processes and modeling to simulate climate change in the northeast with an interdisciplinary study that might provide robust scientific results for policymakers.” She adds, “So, the Ecosystems and Society project is really a perfect fit.”

by David Sims, Science Writer, Institute for the Study of Earth, Oceans, and Space.

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Spring 2015

Space Science

Having a FIELDS Day

It's showtime for the Space Science Center as NASA's MMS mission gets underway

WHEN NASA's Magnetospheric Multiscale mission blasted off at 10:45 p.m. EDT on March 12, 2015, a decade's-worth of effort by Space Science Center scientists, engineers, machinists, and students was sent skyward on the first scientific mission dedicated to studying magnetic reconnection—a poorly understood, universal process in which magnetic fields reconfigure themselves and release enormous amounts of energy.

It can be said that, after the successful launch via a 190-foot Atlas V rocket and deployment of the four, octagonal 11.5 feet (3.5 meters) wide by 3.9 feet (1.2 meters) high satellites, SSC personnel released an enormous, collective sigh of relief.

The MMS payload in the process of being lifted onto the Atlas V rocket at the Cape Canaveral Air Force Station Vehicle Integration Facility. Photo courtesy of NASA.

After all, when $1.1 billion-worth of sophisticated space science hardware, which took an international team from twelve institutes ten years to construct, gets stacked atop of a rocket filled with 313 tons of kerosene and liquid oxygen, it's a risky venture.

Indeed, SSC scientists and engineers recall the moment in 1996 when the European Space Agency four-satellite Cluster mission, which carried a host of UNH-built instruments, failed to achieve orbit soon after launch and sent hopes and hardware up in smoke. It took four years until Cluster II could be constructed and, this time, successfully launched.

Cluster II is still up there doing science and, like MMS, is dedicated to studying aspects of Earth's magnetosphere—a multilayered, comet-shaped magnetic shield that, in its tail, extends as far as 60,000 kilometers away and protects us from dangerous solar and cosmic rays. And, like MMS, the quartet of Cluster satellites allows for three-dimensional, temporal and spatial measurements, which essentially provides for more accurate and comprehensive science (think of watching a baseball game on TV via one camera pointing down the third base foul line—hard to know who's on first).

But MMS is dedicated largely to probing the inner workings of a very specific phenomenon associated with Earth's magnetosphere—magnetic reconnection. Flying together as a tightly coordinated, pyramid-shaped fleet through the magnetosphere, the MMS probes will be the first to capture magnetic reconnection as it actually occurs in an effort to understand its basic physical process, something that has eluded scientists since the dawn of the space age.

To do so, each satellite carries 25 identical instruments that will provide a multi-dimensional view of the reconnection process as they gather identical data at four different points in space 10 to 100 kilometers apart. This is necessary because the area where magnetic reconnection occurs—the so-called "diffusion region"—is moving about 100 kilometers per second and passes by the satellites in just a tenth of a second. Together, the four satellites will be able to take a snapshot of this "action zone" and provide extremely precise time resolution of the process.

"From this long, complex mission we certainly attained new skills, such as the ability to now build 'mechanisms' but it also provided the realization that UNH cannot do such large missions on its own."

The stacked MMS spacecraft being encapsulated in the payload fairing. Photo courtesy of NASA.

Big numbers for big science

Space Science Center and department of physics scientists, engineers, graduate and undergraduate students constructed two Electron Drift Instruments, (EDI) for each of the four spacecraft and built the central electronic controls for all the instruments built to measure the spectrum of electromagnetic fields around the spacecraft. This "FIELDS" instrument suite is comprised of six sensors per spacecraft.

The team also took the unexpected, add-on task of rescuing the engineering and construction of a mission-critical instrument—the Spin-plane Double Probe—designed to pay out 60 meters (192 feet) of spaghetti-like, high-tech cable tethered to an orange-sized metallic sphere that will measure electric potential in the vacuum of space (see "From Drawing Board to Onboard" in the Winter 2011 Spheres). These spheres will measure the electric fields a safe distance from the spacecraft themselves, which could interfere with getting "pure" signals from the surrounding space.

"...until you have all the spacecraft instruments calibrated and really playing together it's hard to do much that's meaningful... We are truly on the verge of having each individual spacecraft ready and then the quartet will come together. That's when the science begins."

The task of building the probes added another 16 precision instruments UNH was responsible for and represented the very first time in the SSC's long, proud history of building space instrumentation that a complex "mechanism" containing moving parts was constructed. This made the SSC team decidedly nervous simply because the more moving parts there are, the more things can go wrong—and you can't send a mechanic into Earth orbit to unstick a gear or take a kink out of a cable.

So when the actual deployment of these key mission components began during the spacecraft "commissioning" phase, SSC team members once again held their collective breath as the probes were spooled out 17 meters at a time during initial deployment, which was done in stages to reach the full 60 meters.

As of April 24, all 16 of the probes had smoothly and successfully deployed to 60 meters and were getting initial readings of electric fields. Of the achievement, Craig Tooley, project manager for the MMS mission at NASA's Goddard Space Flight Center, said, "Outstanding! This is truly an accomplishment of science and engineering prowess. But it is also a testament to what can be accomplished by perseverance, without which all the talent and brilliance usually amount to little."

Additionally, as of April 19, the EDI instrumentation on all four spacecraft were tracking electric and magnetic fields by shooting coded beams of electrons into space and recapturing them as designed after they've been bent and displaced in kilometer-sized arcs by the local magnetic and electric fields. “This is another remarkable accomplishment given that there is no vacuum chamber on the planet big enough to have tested this capability prior to launch,” noted UNH MMS FIELDS project manager John Macri.

Looking back, looking ahead

Roy Torbert, the UNH principal investigator for MMS and mission deputy PI, leads the FIELDS commissioning process. As of May 8th, all FIELDS deployments and instrument checkouts were completed successfully. It will still take several more months of complex preparation before the spacecraft are oriented in their proper orbits and the science phase can swing into full gear.

Reflecting on the decade-long effort undertaken by the SSC, Torbert notes, “In a sense, MMS represents a culmination of the extensive work done in space science at the university. It is based on previous successful NASA and European Space Agency missions in which UNH has participated, such as the Cluster, SOHO, ACE, WIND, and POLAR satellites, as well as our theoretical and numerical simulation work, where the process of reconnection has been observed and simulated, but never studied as rigorously as will be done on MMS.”

*The UNH contingent gathered for the MMS launch under a Saturn V rocket—the type used to launch the Apollo astronauts to the moon—at the Kennedy Space Center.
Photo by Ronald Black, Southwest Research Institute.*

Torbert adds, "From this long, complex mission we certainly attained new skills, such as the ability to now build 'mechanisms' but it also provided the realization that UNH cannot do such large missions on its own. I think our SwRI-EOS connection is the only way we could achieve this type of effort in the future. For missions like these there is just too much infrastructure that is too expensive for a relatively small university-based enterprise to maintain."

With an extended mission phase very likely—after all, Cluster is still going 15 years after launch —Torbert believes the prime MMS work, and UNH participation, will continue until 2022.

EOS director Harlan Spence, mission co-investigator on the MMS Energetic Particle Detector Suite (EPD), which is a separate experiment from FIELDS, notes that like all the spacecraft instrumentation EPD continues to go through a period of fine tuning and adjustment so that everything is in sync when the science phase begins.

"Everything is on and appears to be looking good but the temperatures are a little bit lower than we predicted. And since our measurements are temperature dependent, having it a little bit colder means we need to do some additional tweaking—there are a lot of thresholds to tweak given all the individual detector elements we have on the four different spacecraft, which takes a fair amount of time."

Adds Spence, "At this point we could start doing science with the suite but until you have all the spacecraft instruments calibrated and really playing together it's hard to do much that's meaningful. We have already seen how well all the instruments are operating, and have just recently begun looking at particles and fields data together during particularly interesting intervals. We are truly on the verge of having each individual spacecraft ready and then the quartet will come together. That's when the science begins."

by David Sims, Science Writer, Institute for the Study of Earth, Oceans, and Space.

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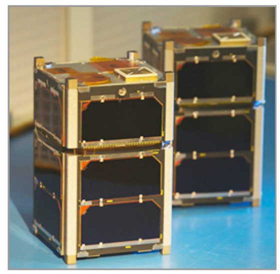
Spring 2015

Faculty, Staff, and Student News

Space Science Center



FIREBIRD II

The dual-satellite FIREBIRD II CubeSat mission that was launched in late January is performing beyond expectations reports **Harlan Spence**, UNH principal investigator on the mission. "Both spacecraft are doing an excellent job, the data quality are fantastic, and we're seeing everything we'd hoped for in terms of the microbursts and their associated structures." The 4x4x6-inch Focused Investigations of Relativistic Electron Burst Intensity, Range, and Dynamics CubeSats brave a region of space 400 miles above Earth to probe a mysterious physical process within our planet's dangerous radiation belts known as microbursts, which involves electrons moving at nearly the speed of light during 100-millisecond events. Microbursts are thought to be one of the primary mechanisms by which the outer radiation belt loses energetic particles to Earth's atmosphere after the occurrence of powerful solar storms. Such storms can dramatically change the intensity of the radiation belts and so FIREBIRD II is closely aligned with the twin-spacecraft Van Allen Probes mission that is currently orbiting in the same general vicinity and for which Spence also serves as a principal investigator. "During a second magnetic storm we encountered after launch of FIREBIRD II, all four spacecraft were close to each other and were able to look at waves and particles in a different way, and from those comparisons we can start learning about the physics of how particles are lost from the radiation belts to the atmosphere."

Jimmy Raeder

Jimmy Raeder received funding from the Air Force Office of Sponsored Research to include data assimilation using an Ensemble Kalman Filter into his global magnetosphere model, known as Open Geospace General Circulation Model. The work will be performed in collaboration with Tomoko Matsuo at the University of Colorado Boulder and Jeff Anderson's Data Assimilation Research Testbed group at NCAR.

Raeder and his Ph.D. student **Shiva Kavosi** (first author) also had a paper published in Nature Communications titled "Ubiquity of Kelvin-Helmholtz waves at Earth's magnetopause."

Ph.D. candidate **Jason Shuster** recently published two papers in Geophysical Research Letters targeted at elucidating the outstanding mystery of magnetic reconnection

From the Director

All in a Month's Work

Harlan Spence

WHILE THE record-setting snow piled up during the winter onslaught spanning late January through February of 2015, many in New England hunkered down for the duration with cabin fever. The eventual arrival of spring in March came slowly in a meteorological sense, but signs of emergence from the historic snow-induced hibernation were all around us. As this issue of Spheres attests, EOS was bristling with renewed energy this spring season, with important activities ranging from major mission milestones reached, to discovery-class science results reported, to new projects, advocacy, and engagement completed.

I need only look at my calendar during the month of March to witness a remarkable period of key activities, granted just a mere cross section of the greater activity in the institute but representative of the busyness and excitement of our business.

Personally, this period included the early successful operations of the FIREBIRD-II CubeSat mission, which, earlier in the year, we had watched roar into space from Vandenberg Air Force Base in California. CubeSats represent the smallest spacecraft missions we do at less than $1 million but they yield big science and provide outstanding opportunities for student involvement (see, for example, the story about undergraduate Chrystal Moser in this issue of Spheres). Just weeks later, from the Kennedy Space Center on the other coast, the UNH FIELDS and Energetic Particle Detector suite teams enjoyed the long-awaited launch and initiation of the Magnetospheric Multiscale central to NASA's Magnetospheric Multiscale (MMS) mission. Shuster is becoming more involved in efforts to process data that will be obtained from instruments on board the four MMS satellites. Since the successful MMS launch in early March, Shuster has been working alongside UNH researchers **Matthew Argall** and **Rich Messeder** to understand and develop data products for the UNH-built Electron Drift Instruments (EDI) for which **Roy Torbert** is principal investigator. Shuster's professional goal is to continue studying magnetic reconnection as a post-doctoral researcher and share discoveries from the "MMS Era" of plasma physics research with both professional and public audiences. Shuster also reports that he and fellow graduate student **Fathima Muzamil** recently gave a talk at Noble High School in North Berwick, Maine about MMS and magnetic reconnection.

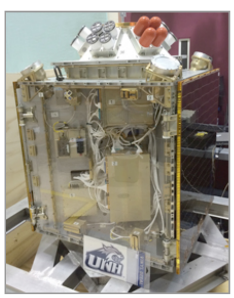
For the MMS mission, **Matt Argall** notes that as a graduate student he analyzed data from the Cluster mission in an effort to frame questions that the MMS mission will be able to answer and created techniques that will allow MMS to better focus on its primary science objectives. With MMS now poised to begin its science phase, Argall will be responsible for creating and maintaining the merged data product and for some processing of the EDI data. "My work with simulations and data will also be ongoing, along the lines of MMS's primary mission objectives."

Jichun Zhang was awarded $508K from NASA's Heliophysics Guest Investigators Program for a three-year project titled "EMIC waves and associated relativistic electron precipitation."

Ph.D. candidate **Trevor Leonard** reports that using data from Interstellar Boundary Explorer (IBEX) observations of the interstellar neutral (ISN) gas flow over the past six years, he and other IBEX team members have improved the determination of the ISN flow direction and speed. "Knowing the properties of the ISN flow is essential to understanding the interaction between the heliosphere and the interstellar medium." The sun's heliosphere shields us from galactic cosmic rays, which could make Earth uninhabitable, and changes in the interaction between the heliosphere and the interstellar medium can alter the effectiveness of this shielding.

mission and celebrated our largest spacecraft mission involvement, in this case with a total cost greater than $1 billion. I also had the privilege of presenting science results from the ongoing Lunar Reconnaissance Orbiter CRaTER (Cosmic Ray Telescope for the Effects of Radiation) and Van Allen Probes ECT (Energetic Particle, Composition, and Thermal Plasma instrument suite) science investigations at conferences in Arizona and Los Angeles.

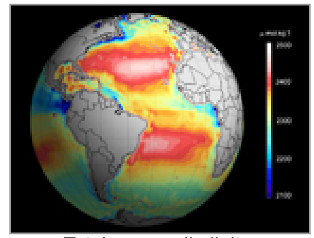
Moreover, and otherwise dominated by my space science and planetary projects, in March I was busy at work advancing causes relative to the "E" and "O" in the institute's name. For instance, it was my honor to have been asked by the National Science Foundation to be part of a three-member panel to brief Capitol Hill about the contributions of geoscience research to the nation. Of all my activities in March, that was ultimately the most important; we need only read the daily news to learn about assaults on the geosciences, which underscores the need for educating the public and decision makers about the many values of our research. In that vein, I hope that you will share this issue of Spheres with others as a way to broaden the impact of our important communication process.
– *Harlan Spence*


CATSAT

SSC senior project engineer **Mark Granoff** is leading an effort to open a new exhibit at the McAuliffe-Shepard Discovery Center featuring a small satellite built beginning in the late 1990s by Space Science Center faculty, staff, and students. The Cooperative Astrophysics and Technology SATellite, or CATSAT, was designed as a small, rapidly built, inexpensive space mission funded under the University Space Research Association's Student Explorer Demonstration Initiative. Says Granoff, "For the exhibit, I am reaching out to former CATSAT colleagues to help us recall the story of the USRA STEDI program, and of UNH successfully competing to win the bid to built this satellite under the direction of former SSC professor David Forrest." CATSAT former associate principal investigator Ken Levenson (now with Raytheon) is a key partner in the current effort to tell the CATSAT story. Granoff notes further that while the design and fabrication of CATSAT was fully realized, the little satellite never flew in space due to launch vehicle and risk limitations, but that CATSAT ultimately launched a large number of UNH students into successful, high-profile aerospace careers. "With a bit of sprucing up, CATSAT will be 'flying high' at the MSDC and we are looking forward to seeing CATSAT in this fitting place of honor in the near future." Aerospacefest will be held Saturday, June 13 from 10:30 a.m. to 4 p.m. at the MSDC in Concord. Financial support for the effort is being provided by the Northern New England Section of the American Society of Mechanical Engineers, EOS/SSC, professor **Eberhard Möbius**, and the Sophron Foundation.

Ocean Process Analysis Laboratory

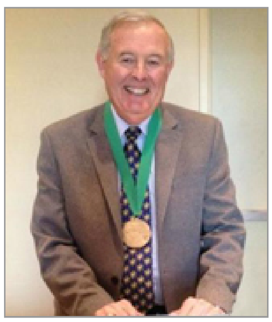
In collaboration with colleagues in Europe, **Joe Salisbury** and **Doug Vandemark** coauthored a paper published in Environmental Science and Technology about how pioneering techniques that use satellites to monitor ocean acidification are poised to revolutionize the way marine biologists and climate scientists study the ocean. The new approach offers remote monitoring of large swathes of inaccessible ocean from satellites by using thermal cameras to measure ocean temperature and microwave sensors to measure salinity. Together, these can assess ocean acidification more quickly and over much larger areas than has been possible before via single-point, in situ measurements from research vessels. Among the satellites being used for the groundbreaking work are the European Space Agency's Soil Moisture and Ocean Salinity sensor and NASA's Aquarius satellite.



Total ocean alkalinity from space.
Photo courtesy of Ifremer/ESA/CMES

Jamie Pringle was funded by the National Science Foundation for a four-year, $370K project titled "Basin scale forcing of flows on western-boundary shelves." Studies of the alongshore flow along western-boundary continental shelves have failed to explain why the mean flows exist. For example, along the east coast of North America from Cape Hatteras to the Labrador Sea, the waters flow to the southwest except when winds are strong enough to reverse the flow. Pringle's research aims to find the causes of this average southwestward flow by linking it to the larger scale ocean basin circulation. He hypothesizes that these flows are not driven by phenomena over the continental shelves (winds, river inflows, etc.) but are instead driven by the winds over the entire ocean. If this hypothesis is supported by his modeling and observational data it will help the research community understand how global-scale changes in climate drive changes in the coastal flows around North America. The regional flows are important both locally—for example, they bring cold water down from the Labrador Sea and cool New England—and globally as they are an important pathway linking the high latitude oceans to temperate oceans.

Earth Systems Research Center



Barry Rock

Professor emeritus **Barry Rock** was selected by the Youth Learning as Citizen Environmental Scientists grant-making organization as the first recipient of its Youth Environmental Science Medal in recognition of his formative work in the development and implementation of inquiry-based, experiential K-12 science education. Rock is founding director of the UNH Forest Watch program, which since it began in 1991 has involved more than 350 schools across New England in K-12 student measurements and health assessments of white pine—a known bio-indicator species for exposure to ozone in the air. Rock was presented with the medal March 13 at the National Science Teachers Association National Annual Meeting in Chicago, Illinois.

Scott Ollinger received a new grant of $127K over three years from the Northeastern States Research Cooperative to study carbon cycling at the Bartlett Forest in the NH White Mountains.

Ph.D. candidate **Jonathan Buzan** of the Climate Dynamics Prediction Lab published his first paper in February with lab director **Matt Huber** as coauthor in Geosciences Model Development. Titled "Implementation and comparison of a suite of heat stress metrics within the Community Land Model version 4.5," the goal of the work is to have a common predictive framework for measuring heat stress globally.

In April, former Ph.D. student **Claire Treat** coauthored on a paper published in Nature titled "Climate change and the permafrost carbon feedback." Now a postdoctoral researcher with the University of Alaska and the U.S. Geological Survey in Menlo Park, California, Treat's contribution was based on her dissertation work on carbon losses from permafrost soils under aerobic and anaerobic conditions.

Recent Ph.D. graduate and current EOS postdoc **Liz Burakowski** was lead author on a paper published in Remote Sensing of Environment titled "Spatial scaling of reflectance and surface albedo over a mixed-use, temperate forest landscape during snow-covered periods." ESRC coauthors include **Scott Ollinger**, **Lucie Lupine**, **Jack Dibb**, and **Mary Martin**. Burakowski rejoined EOS as a postdoctoral researcher to work on a UNH (NH EPSCoR) project in cooperation with scientists at the National Center for Atmospheric Research. She will continue to reside at NCAR in Boulder, Colorado where she has been working since completing her Ph.D. at UNH last year.

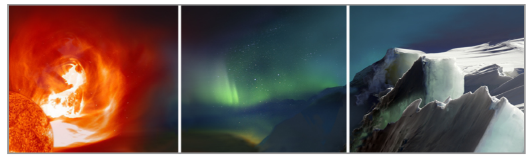
Liz Burakowski

Ph.D. student **Alexandra Thorn** was lead author on a paper published in Ecosphere titled "Generalization and evaluation of the process-based forest ecosystem model PnET-CN for other biomes." ESRC scientists **Scott Ollinger** and **Jingfeng Xiao** are coauthors. The other biomes are grasslands, shrublands, and savannas. The work was funded by the NSF MacroSystems Biology program.

Steve Frolking coauthored five papers on topics ranging from remote sensing of global crop production and seasonal dynamics of canopy-scale photosynthesis to simulation of water resources required for crop production in China.

Ph.D. candidate **Danielle Grogan** was lead author on a paper published in Science of the Total Environment titled “Quantifying the link between crop production and mined groundwater irrigation in China.” It is her first publication based on her dissertation. Says Grogan, “China, one of the world's ‘breadbaskets,’ has used irrigation to help expand and intensify its agricultural production over the past several decades. We modeled China's agricultural system to quantify irrigation water sources, and determine the sustainability of its irrigation water use. We found that nearly one third of China's irrigation water comes from unsustainable groundwater pumping and this unsustainable water source is directly responsible for approximately 20 percent of food produced in China annually. I am currently expanding the work in this study to look at unsustainable groundwater pumping for irrigation on a global scale.” ESRC coauthors on the paper include **Alex Prussevitch**, **Richard Lammers**, **Dominik Wisser**, **Stanley Glidden**, **Changsheng Li**, and **Steve Frolking**.

Michael Palace was first author on a paper titled “Estimating forest structure in a tropical forest using field measurements, a synthetic model and discrete return lidar data “ in Remote Sensing of Environment. Palace was coauthor on the paper “Tropical-Forest Biomass Estimation at X-Band from the Spaceborne TanDEM-X Interferometer” in IEEE Geoscience and Remote Sensing Letters.


Sun-to-Ice

Erik Froburg and **Ruth Varner** note that the Leitzel Center serves as the education and outreach partner on the NSF-funded Sun-to-Ice project lead by EOS director **Harlan Spence**. Sun-to-Ice aims to investigate extreme solar events and their effects on Earth by detailed studies of each process in the chain from sun to ice, as energetic particles travel to Earth, enter our atmosphere, and ultimately collide with our planet. The Leitzel Center brings intensive STEM professional development to high school physics, chemistry, astronomy, and Earth and physical science teachers. Teachers are paired with Sun-to-Ice researchers or collaborators to explore a specific research topic. The resulting projects range from a high school teacher and student co-creating a capstone project to run a computer model that simulates deep dielectric charging on Mercury, to an entire class designing and testing instrument payload vehicles that can descend at a velocity so controlled that a raw egg in the payload will remain undamaged. Varner directs the Leitzel Center and Froburg is the center’s educational program coordinator.

Madeleine Mineau was awarded a Carsey School of Public Policy Summer Scholar Fellowship for the summer 2015 to do a project titled "Strahler stream order as a classification system in water policy: implications and alternatives.” Mineau will evaluate stream classification systems used in water policy with a focus on stream order and the Shoreland Water Quality Protection Act in NH.


WAIS Divide ice core
Photo by Heidi Roop, NSF.

Joe Souney and **Mark Twickler** of the West Antarctic Ice Sheet (WAIS) Divide Science Coordination Office at UNH were coauthors on the paper “Precise interpolar phasing of abrupt climate change during the last ice age” published April 30 in Nature. Twickler and Souney led the planning, logistics, and execution for the collection and processing of the WAIS Divide ice core.

by David Sims, Science Writer, Institute for the Study of Earth, Oceans, and Space.

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