EOS SPHERES

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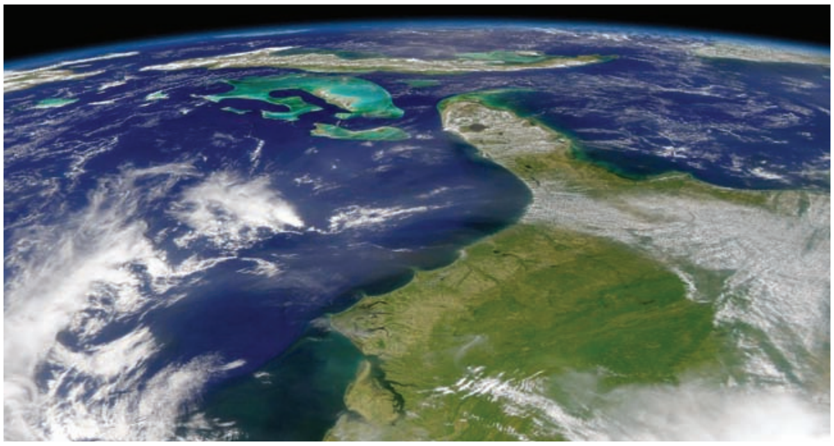
The Coastal Carbon Conundrum

IF IT WEREN'T FOR THE DEEP BLUE SEA, we'd be swimming in carbon dioxide. That is, studies appear to show that the world's oceans are taking up about 25 percent of the CO_2 annually belched into the atmosphere from burning fossil fuels and the destruction of forests. Scientists know this based on a series of cruises begun in the early 1990s that have looked at the uptake and release of the greenhouse gas in pelagic waters.



An image of the Eastern Seaboard from the Chesapeake Bay region to Florida taken by NASA's Sea-viewing Wide Field-of-view Sensor (SeaWIFs).

Photo: courtesy of NASA/GSFC and ORBIMAGE

But for the shallower and more complex coastal waters, says oceanographer Joe Salisbury of the Ocean Process and Analysis Laboratory and UNH-EOS interdisciplinary Coastal Carbon Group, "We don't know whether they are acting as a sink—sucking up CO_2—or actually putting more of it back into the atmosphere."

What's more, studies done in different parts of the world have turned up puzzling results showing that while some coastal waters act as a sink, others are a source of CO_2. "So trying to characterize the importance of coastal water in the global carbon cycle, to put a single number on it, has been difficult," Salisbury adds.

This past summer, Salisbury and graduate students Amanda Plagge and Jennifer St.Louis (see related story page 6) went fishing for answers while onboard NOAA's Research Vessel *Ronald H. Brown* for nearly a month as part of the Gulf of Mexico and East Coast Carbon Cruise.

The NOAA-sponsored cruise sought to understand the air-sea interaction of carbon and identify the CO_2 sources and sinks in the U.S. coastal regime—from the Gulf of Mexico to the Gulf of Maine. The scientists also measured the magnitudes, variability, and controls on CO_2 fluxes in this vast sweep of coastal water.

This missing puzzle piece is important to find because in order to make reasonable projections of future atmospheric CO_2 levels, the coastal zone carbon sources and sinks must be well quantified and the controlling processes understood.

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Photo: D. Sims, UNH-EOS

The 80-foot Appledore Island wind turbine can be lowered at the flick of a switch.

Winds of Change

Seeing the big picture with the help of alternative energy

ON SEPTEMBER 30, the diesel generators at the Marine Biological Laboratory on Appledore Island were shut down for the season as usual. But for the first time ever, the extensive atmospheric research being conducted by UNH scientists pressed on, and the measurements and data analysis will continue throughout the harsh winter months on the largest of the Isles of Shoals, six miles off the coast of New Hampshire and Maine.

The answer to the offshore power problem was blowin' in the wind; a unique, collapsible wind turbine designed specifically for Appledore is now supplying enough juice into a 7,000-pound battery bank for the AIRMAP program to gather much-needed year-round data in the marine environment.

"The system is working really well and is actually generating more power than we anticipated," says Kevan Carpenter, the AIRMAP project director in charge of the turbine's operation.

This unexpected bonus could not be timelier and has enabled the program to keep some power-hungry,

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EOS SPHERES

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From the Director

Moving From Analysis to Synthesis

IN HIS STATE OF THE UNIVERSITY 2007 address, President Mark Huddleston delivered a clear and compelling vision for our future, and an honest, straightforward appraisal of the challenges ahead. He raised many important points, but three in particular have stayed with me: research, in all its manifestations, is absolutely central to our mission; a university without a poet is not really a university; and, while we choose organizational rules to serve the mission of the university, these rules are not themselves the mission.

This clarity of language is welcomed, as is Mark Huddleston. To me, the president's comments about the path ahead echo the clear thinking of E. O. Wilson, whose book, "Consilience: The Unity of Knowledge," speaks to a central challenge of our mission. Paraphrasing Wilson, it is because of science and technology that access to factual knowledge is destined to become global and democratic. But to what end? The answer, Wilson asserts, is synthesis. "We are drowning in information, while starving for wisdom. The world henceforth will be run by...people able to put together the right information at the right time, think critically about it and make important choices wisely," Wilson wrote. At EOS and UNH, we must strive to extend our reach beyond analysis and into the realm of synthesis.

But of course, as Huddleston noted, without a poet in our midst, we are not whole. And so, as we begin the difficult work of synthesizing our science we should consider the words of our university colleague and the nation's Poet Laureate, Charles Simic. In his book "Wonderful Words, Silent Truth, " Simic writes of watching the great Serbian painter Bata Mihailovitch as he painted. Simic's "wonderful words" that finish his essay are worth reproducing here in full.

"It looked to me as if he was putting things in the right place, things he didn't know existed just a moment before. And he kept erasing! He erased as much as he painted. I understood then and there his admirable capacity to surprise even himself, to innovate, to break his old habits and make painting an adventure. Every day going into the unknown to find another image of himself and all of us existing."

"The rules we have chosen are not themselves the mission," our new president reminded us. As we synthesize our way into the future we must be prepared to erase, to surprise ourselves, to break old habits, to make our work an adventure.

– Berrien Moore III

Atmospheric Science

Winds of Change

– continued from page 1

high-maintenance, mercury-measuring instruments up and running. Should all continue to go well, the critical measurements will continue right through the winter—a significant development in the scientific investigation of this ubiquitous but tricky-to-measure airborne toxin.

"These will be the first continuous measurements of mercury and its chemical speciation year round in the marine environment," says AIRMAP principal investigator Robert Talbot, director of the Climate Change Research Center. He adds, "And the unique data should help answer many scientific questions regarding the largely unknown area of ocean-atmosphere cycling of mercury."

There is a small array of solar panels on the island as well, but the turbine's performance thus far hammers home the fact that the right alternative energy option for the winter season was chosen. Notes Carpenter, "Solar panels are an excellent source of power for the summer months but wind power takes over in the fall, winter, and spring. The data we have collected to date on the solar and wind power generated has given us more confidence that we made the right decision."

The decision wasn't exactly an easy one, in large part because Appledore is both home to a large breeding bird population and a migratory songbird stopover. It took over two years of planning, designing, and permitting before the turbine blades whirled and voltage flowed—and the birds were protected.

Juggling the potentially competing objectives of protecting the birds while at the same time gathering year-round data in the marine environment, Carpenter began looking for a collapsible wind turbine as the most practical and sustainable approach.

Photo: D. Sims, UNH-EOS

The wind turbine as seen from the 60-foot tower once used for spotting German U-boats in WWII and now home to AIRMAP instruments.

Custom-designed and built by engineer Robert Pechie of Northeast Wind Energy in Connecticut, the 7.5 kilowatt turbine rises 80 feet into the air, has no guide lines to support it, and can be lowered by a single person at the flick of a switch. If bad weather hits or bird problems arise, down it comes.

Notes Carpenter, "During any of the migratory periods bird monitors are going to walk the turbine twice a day to see if turbines of this size have an impact on bird populations." Walks made during the fall migratory season turned up no dead birds.

Ninety-five acre Appledore Island is the site of one of seven atmospheric observatories run by AIRMAP. The NOAA-funded, nine-year-old air quality and climate program seeks to unravel fundamental chemistry-climate connections in areas of New England directly downwind from major urban sources of emissions. The program's anchor observatory at Thompson Farm in Durham samples over 180 chemical compounds via state-of-the-art instrumentation. -DS

The Coastal Carbon Conundrum – continued from page 1

More than any other previous scientific endeavor, says Salisbury, the cruise, "provided a snapshot of broadscale coastal carbon cycling." What's more, in an attempt to better connect coastal and open ocean waters, in the scientific sense, the R/V *Brown* steamed a zigzag course into deep water and then back towards land as it made its way through the Gulf of Mexico and up the Eastern Seaboard.

Photo: Meg Graustein, U.Conn.

Ph.D. student Amanda Plagge onboard the R/V Ron Brown *covers up an air sampling system of a colleague from the University of Connecticut.*

As the ship plied the seas, and with an array of instruments making real-time measurements of the water, the scientists were able to actually chart their movement from waters that were acting as a carbon sink to those of a carbon source.

How are these sources and sinks coupled, and how are they related? What are the physical and chemical characteristics associated with each, and where do the processes that contribute to the carbon cycling change as you get towards land? The cruise sought answers to these questions.

Salisbury took measurements using the ship's flow-through system, in which seawater just below the surface was pumped through a hole in the bottom of the *Ron Brown* and, in Salisbury's case, into a special contraption he built for the cruise dubbed the "beer keg."

Instruments inside the beer keg continuously measured temperature, salinity, nitrate concentration, and optical properties of the water. These data, in combination with continuous measurements of pH and CO_2 being made by other research groups onboard the ship, allowed UNH scientists to estimate the strength of the source or sink as well as provide information about the processes responsible for the in-water CO_2 status.

Optical measurements can provide a wealth of information about the amount of suspended particles that influences the light field in the water and, thus, modulates the CO_2 in the water column.

Explains Salisbury, "If there are a lot of particles in the water you're not going to get enough light and that will cut down on the productivity."

While the optical, oxygen and nitrate measurements will give some information about how the biology is influencing the CO_2, physical measurements such as temperature and salinity hold the key to understanding the capacity of a water parcel to absorb CO_2.

Ship scientists wanted cruise reports every week and, to that end, Ph.D. student Amanda Plagge, Salisbury notes, "was a huge help because she has a lot of programming capability and we were doing a lot of analysis on the fly to take our really raw data and bring them into some form we could share with everybody."

Both for the Gulf of Mexico cruise and OPAL's regular sampling in the Gulf of Maine, Salisbury's primary interest is in how rivers and constituents off the land contribute to carbon cycling, processes that are "very complex and very poorly understood," he says.

"The land delivers nutrients that stimulate biological productivity, which will consume CO_2. At the same time the rivers and land will flux out organic carbon materials that can be consumed by microbes, which will release CO_2."

According to Salisbury, one surprising discovery of the cruise, and something scientists had not seen before, was a huge plume of alkaline water, coming out of rivers or near shallow inland waters, that pushed its way over the Continental Shelf.

"It was thought that this type of plume was dispersed but we saw it go way out over the shelves. As CO_2 goes into the water it increases the acidity, but this plume of alkalinity decreases it acting like a big Rolaid. This activity might act as the first line of defense for increasing atmospheric CO_2," Salisbury postulates.

Also for the first time, the recent *Ron Brown* cruise provided a thread connecting the twice-monthly sampling OPAL has been conducting for four years in the Gulf of Maine with the bigger picture. By duplicating one of the transects—the Wilkinson Basin run, which OPAL scientists have been doing for years, the Brown data "will provide a lot more information about how we're connected to the rest of the world," says Salisbury.

"Now, we have some idea how the Gulf of Maine waters look in relation to a lot of other provinces under summer conditions..."

He continues, "We've been doing these measurements for a really long time but we've just been working this postage stamp area, you might say. Now, we have some idea how the Gulf of Maine waters look in relation to a lot of other provinces under summer conditions and we can also see the relationship of the water masses as we move away or towards the coastal area."

Salisbury notes that in order to fully resolve the coastal carbon conundrum a series of similar cruises will need to occur.

"This was one snapshot, and we'll need a bunch more over various seasons of the year to understand what the full range of processes are." Salisbury believes that serious efforts will be made to continue the investigation with a series of cruises in the future.

For more on work being done by the Coastal Carbon Group, visit http://ccg.sr.unh.edu -DS

Faculty Profile

The Simple Joy of Physics

Physicist Li-Jen Chen finds awe and joy in the laws that order our universe

WHEN PHYSICIST LI-JEN CHEN is trying to solve a problem and finds herself deeply puzzled by the data at hand, she sometimes puts a mat on the floor, sits with legs crossed, lowers her eyelids halfway, and lets go of her mind.

In her "quiet sitting" she lets thoughts float past like leaves riding the water, grabbing hold of nothing in particular save for greater clarity. The physical and spiritual process doesn't necessarily solve the problem at hand, but it is grounding and can help her tap into the very roots of her chosen profession.

Ever since her days as a teenager in Taiwan, Chen has experienced awe and joy on her path of physics.

"I started to fall in love with physics in senior high. I had a teacher who opened a way for me to think about fundamentals even while I was on a bus, or throwing a ball in the air," Chen says. She adds, "I often say that what attracted me initially to physics was its simplicity, and people will say, 'Simple?' But look at the laws that order our universe, they simply are. F=ma, Newton's second law of motion. How simple could it be?"

> *"I often say that what attracted me initially to physics was its simplicity, and people will say, 'Simple?' "*

Humm. "Simple" as, say, magnetic reconnection?—one area of Chen's research. Magnetic reconnection is a process in which the plasma or hot gas within magnetic fields—such as the Sun's corona or Earth's cocoon-like magnetosphere—breaks apart, reconnects, and liberates vast amounts of energy.

Just 40 years ago, the process of reconnection was thought to be impossible. Like strong magnets repelling each other it was thought differing plasmas might stream past one another but never connect. Space physicists have come a long way in showing that reconnection is indeed occurring, but they've hardly nailed it down. Consider the problem of energetic electrons.

According to Chen, studies of solar flares in particular show that up to half of the explosive energy spewed out during magnetic reconnection is, most curiously, carried away by extremely fast-moving electrons. Traditional theoretical studies predict that most of this energy is carried away by ion jets in a fluid-like ejection—like a balloon filled with water being squeezed in the middle and water streaming out the north and south poles. How the electrons, and so many of them, can gain so much energy during reconnection has been a long-standing puzzle.

To picture reconnection, imagine two streaming contrails billowing from a jet at 30,000 feet. Over time, the white trails will widen and blur and, sometimes, pinch together to form periodic X-shaped regions followed by oblong "islands." Simpler still, a link of old-fashioned hot dogs could also visually represent the shape of reconnection.

A mainstream theory holds that the mysterious, fast-moving electrons are primarily accelerated at the X region (the hot dog link), where the reconnection magnetic fields are annihilated. But Chen made a discovery that runs counter to this theory, and she recently published a paper on the topic in *Nature Physics* with colleagues from the Space Science Center.

Looking at data from the four-spacecraft Cluster mission of the European Space Agency, which launched in the summer of 2000 to study Earth's magnetosphere (and included components designed and built at the Space Science Center), Chen noticed that when the satellites flew across a series of reconnection sites, the observations were most unexpected.

"The observed energetic electrons have more to do with island dynamics than the acceleration at X lines," she says. And this puts a new wrinkle on the deep mystery and, in a nutshell, imposes a new constraint on current theories of electron acceleration. This is how scientific progress, step by step, is made—but always with surprise.

Chen served as lead author on the paper with SSC collaborators Amitava Bhattacharjee, Pamela Puhl-Quinn, Hongang Yang, and Naoki Bessho, and an array of international colleagues.

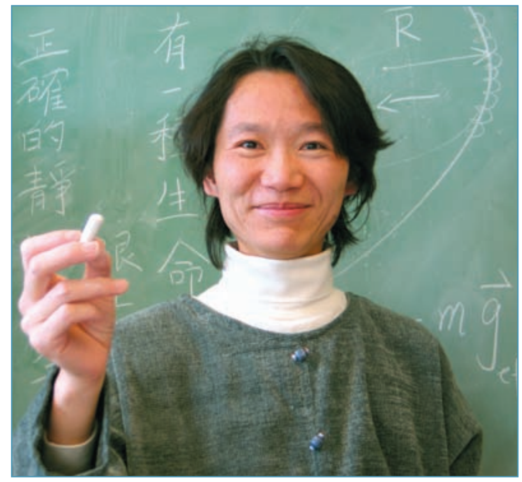


Photo: D. Sims, UNH-EOS

As a teacher, Space Science Center physicist Li-Jen Chen strives to emulate the high school instructor she had in her native Taiwan who made the fundamentals of physics "come alive."

It was Bhattacharjee, Paul Professor of Space Science, who recruited Chen to UNH from the University of Iowa where the two had initially collaborated.

"Li-Jen combines an understanding of basic plasma theory very well with an astute eye for observations, and thus she is able to use observations to pose challenging questions for theorists," says Bhattacharjee, a theoretical plasma physicist.

> *"Li-Jen combines an understanding of basic plasma theory with an astute eye for observations, and thus she is able to use observations to pose challenging questions for theorists."*

Chen, who is poised to be promoted to a faculty position as a research assistant professor as *Spheres* goes to press, hopes to eventually share her love of physics with not just college students, but kids in grades K-12.

"I hope to open the path of physics to children and teenagers so they can feel the awe and joy. I'd like to establish a physics adventure program for young people and their families and teachers," she says. Yes, she adds, the subject matter can be hard, but it's hardly inaccessible. "I think a good teacher makes the physics come alive. After all, the principles are operating everywhere, and you are within it. You are it." -DS

Working in the Dark

THERE IS MUCH that is world-class within the Institute for the Study of Earth, Oceans, and Space. But you'd never imagine that the unadorned, black plastic and gunmetal, aluminum-stud wall at the back of Room 249—the Magnetosphere-Ionosphere Research Laboratory—was one of them.

Behind the wall, which appears to be in need of finishing sheetrock, is a unique, two-chambered, 20-foot-long, 8-foot-deep, 7-foot-high very clean and very dark room where delicate, ultra-low-light cameras and other light-sensitive instruments used on rockets and in satellites can be calibrated with high precision. The only other facility in the world capable of such fine-tuning is in Japan.

The little room is, so to speak, the house that Brent built.

Photo: D. Sims, UNH-EOS

Ph.D. student Brent Sadler illuminated by the diffuse light of an integrating sphere, shown at the bottom right.

Brent Sadler worked for 20-plus years as a software engineer before finding his way back to school at UNH to study physics at the undergraduate level. Now a Ph.D. candidate working with research associate professor Marc Lessard of the Space Science Center, Sadler is a current Space Grant fellow and the principal designer, engineer, and fabricator of the little room—the Facility for Optical Calibration at Low Light Levels, FOCAL^3 for short.

At the heart of FOCAL^3 is a device called an integrating sphere, a 20-inch green globe that resembles something out of an early science fiction movie. The integrating sphere creates a completely uniform source of diffuse, low-level light—like that emitted by aurora or far-away stars.

"It's a very white light in that it has a nice spread of frequencies, and we can turn the intensity way down so you almost can't see it, but a camera can see it," Sadler says. He adds, "The whole reason we built the room was so we'd have a top-notch calibration facility for cameras that take pictures of aurora."

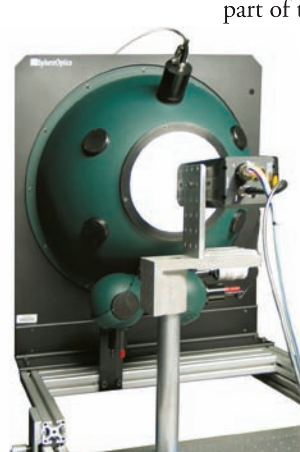
Indeed, Lessard notes, "When I came to the Space Science Center in 2004 I knew I was putting in a proposal to calibrate the Canadian e-POP satellite imagers, and having a world-class facility like this opened up that door to that work."

The Enhanced Polar Outflow Probe (e-POP) payload will be launched on a small satellite in November 2008 to study, among other things, aurora. The imagers for the satellite were calibrated in the darkroom by Lessard and his students, and were recently returned to the University of Calgary, the lead institution for the mission.

The room was also used by Lessard's Ph.D. student, Sarah Jones, to calibrate the special camera she built for the Rocket Observations of Pulsating Aurora sounding rocket launched last February from Poker Flat, Alaska, to study pulsating aurora—dim, ephemeral, circular patches of auroral light unlike the more familiar, sweeping aurora borealis. And undergraduate students George Clark and Morgan O'Neill used FOCAL^3 when they worked with Eberhard Möbius to build and calibrate the star sensor that will fly on the upcoming Interstellar Boundary Explorer (IBEX) mission for which Möbius is the UNH principal investigator.

According to Lessard, other institutions that do similar work requiring calibration for rocket- or satellite-based imagers use the "quick and dirty" method of shining a light on a white screen—to diffuse the light—and taking a picture. "It's a basic technique, but adequate enough for some applications," Lessard says. He adds, in reference to the potential draw the darkroom has for continued instrument calibration built both within the SSC and at outside institutions, "When you have an optical integrating sphere in a clean-dark room you have a very special tool."

Not only is the room dark as night, it's as clean as a whistle. There can be no contamination for the optical instruments being calibrated to study aurora or instruments, like the IBEX star sensor, that will be integrated into a satellite bound for outer space. In the vacuum of space any dust or oils that hitch a ride can cause severe problems—electrical arcing, for instance—that can destroy instruments and mission objectives.



Sadler hooked up with Lessard after hearing the space scientist talk to his "Introduction to Research in Physics" class. Recalls Sadler, "They always encourage people to get research work for the summer and I was looking for something, but I had no idea what."

When Lessard described his work using sounding rockets to take pictures of aurora with super-sensitive, highly specialized cameras, Sadler was hooked. "I liked that it involved optics and that his research is a bit more terrestrial—that it's the magnetosphere and part of the Earth as opposed to looking at particles in deep space," Sadler says.

For his thesis project, Sadler will work with Lessard on the phenomenon of "neutral upwelling" that occurs in the polar cusp region of Earth's magnetosphere and is likely related to auroral phenomena. Sadler notes that once the e-POP satellite is in Earth orbit—and with imagers calibrated in "his" room onboard - it will provide informa-tion that will help him in this work. -DS

Faculty News

Michael Keller was named Chief of Science for the National Ecological Observatory Network (NEON) in Boulder, Colorado.

The Interstellar Boundary Explorer payload, which includes the UNH hardware contributions, was delivered for spacecraft integration at the end of September, according to principal investigator **Eberhard Möbius**. IBEX is well on track for launch mid June 2008.

Ben Chandran was awarded a $437,000 grant from NASA's Solar and Heliospheric Supporting Research and Technology Program to study the heating of the Sun's corona and the origin of the solar wind.

Barry Rock joined NASA's James Hansen in providing expert testimony in Vermont's successful court case against the Automobile Manufacturers of America requiring more stringent fuel standards by 2012.

The textbook **Amitava Bhattacharjee** co-authored, "Introduction to Plasma Physics with Space and Laboratory Applications," was awarded the Basic Science Book Award 2007 by the International Academy of Astronautics.

Andrew Richardson of Complex Systems published papers in *Agriculture and Forest Meteorology*, which was highlighted as a "highly cited" paper, and *Global Change Biology*.

CCRC's **Bob Talbot**, **Huiting Mao**, and **Jeff Sigler**, concurrently submitted/published four separate papers on mercury research—two in *Geophysical Research Letters* and two in *Atmospheric Chemistry and Physics*.

Graduate Student Profile

From Shore to Ship

YOU MIGHT SAY THAT Jennifer St.Louis eventually found her way aboard the NOAA Research Vessel *Ronald H. Brown* by being barkeep to a bunch of Maine clam diggers.

The second-year master's student in oceanography tends bar at a seafood restaurant, Ken's Place, in Scarborough. Her regulars make their livings digging for clams, but in the summer of 2005, a severe outbreak of red tide put the clammers out of business, and St.Louis was there to listen and console.

Photo: K. Donahue, UNH-EOS

Oceanography master's student Jennifer St.Louis

"You get to know these people really, really well," she says of her customers, who found themselves out of work for six weeks and on government assistance when the state closed shellfish beds. The harmful algal bloom that summer was of historic proportions, and led to the closing of shellfish beds from central Maine to south of Cape Cod, representing more than 35 percent of the nation's clam harvest.

St.Louis, a self-proclaimed big talker, thoroughly enjoys her work as a bartender. But that summer, with a freshly minted bachelor's degree in geology from the University of Colorado and percolating, ill-defined plans for graduate school, she began to imagine other ways of helping her shellfishing friends besides plying them with libations.

She arrived at UNH in the fall of 2005 as a continuing education student not sure what her master's work would be. After courses in physical oceanography, paleoclimatology, and biogeochemistry, a focus began to emerge.

"I became really interested in climate change and, more specifically, the problem of ocean acidification and the calcium carbonate system," St.Louis recalls.

> *"...this issue really does have big-picture implications."*

When carbon dioxide dissolves in the ocean it increases the acidity (lowers the pH) of the water. Theories suggest that if oceans tend to acidify under conditions of increased atmospheric carbon dioxide, calcium carbonate shells—from those of clams and oysters to the tiny phytoplankton critical in the ocean ecosystem—will tend to dissolve. Not good news for shellfishers, or anyone else for that matter, and therein lies the connection with St.Louis' regulars at Ken's Place.

"If clams can't make their shells, clam diggers can't work. If people can't get fried clams in Maine this will affect tourism, and so on. So this issue really does have big-picture implications," St.Louis says.

While she's currently focused on sampling and analyzing the calcium content of waters in the Gulf of Maine, her ultimate goal is to apply her research towards policymaking.

"I really want to be involved in, and have an impact on, resource management in our coastal waters," she says. "But in my master's thesis work now, I'm hoping to establish a baseline dataset for the Gulf of Maine and put that in a couple of models to project future implications of acidification in those waters."

St.Louis will measure calcium content from water samples taken in the Gulf of Maine to compare with alkalinity measurements made by Joe Salisbury and others in OPAL over a four-year period.

As part of the Gulf of Mexico and East Coast Carbon Cruise aboard NOAA's R/V *Ron Brown* (see cover story), St.Louis collected 200 water samples and over time will analyze those for calcium content—eventually comparing her results with the alkalinity measurements made by researchers onboard the *Brown* from the University of Georgia. The comparison will help her see how well the calcium measurements "track" or mirror the alkalinity of the waters.

By comparing all these data she hopes to be able to identify different "provinces" of water—those very high in calcification and those that are very low—to see what physical characteristics such as salinity, pH, and temperature influence how different types of water calcify at different rates. The data from the Gulf of Maine will provide a temporal perspective while data from the GOMECC cruise will provide a spatial snapshot of calcification in surface waters. All of this will help provide a better big-picture view of what might happen as atmospheric CO_2 levels continue to rise globally, including the worst-case scenario.

"There are plankton in surface waters that have tiny, beautiful little shells, and with increased ocean acidification, if they can't make their shells, well, that's the base of the food chain right there and that's going to have a big impact down the line." -DS

Student News

George Hurtt reports that eight current Research&Discover students, from every stage of the multi-year program, presented papers at the 2007 AGU Fall Meeting in early December—the largest number ever. The students are 2007-09 R&D Fellows **Katelyn Dolan**, **Virginia Sawyer**, **Mimi Szeto**, and **Erica Lindgren**, and 2007-08 R&D Interns **Emily Glick**, **Jordan Goodrich**, **Haley Wicklein**, and **Jennifer Wurtzel**.

Earth Sciences/Geochemical Systems master's student **Elizabeth Burakowski** presented her thesis work entitled, "Trends In Wintertime Climate Variability In The Northeastern United States: 1965-2005." The study was the most comprehensive analysis on changes in winter climate across the region using data that was subjected to rigorous quality control. The data were analyzed for trends since 1965 in minimum, maximum, and mean temperatures, snowfall, and snow covered days. The results clearly indicate that winters have been warming over the past four decades at an average of +0.77 degrees F per decade, and that snow-covered days have been decreasing at a rate of -2.6 days per decade. The results are of particular importance for the future of winter tourism and recreation in the region.

Undergraduate **Morgan O'Neill** spent her summer at the Space Research Centre in Warsaw, Poland writing software as part of her ongoing work on the IBEX mission.

Undergraduate Student Profile

The Isle of Crete

A two-part Space Grant internship takes an undergraduate from Africa to the top of Mount Washington

THE PERPETUAL SMILE ON ELENA CRETE'S FACE dimmed a bit at 35,000 feet late last spring as she was on her way to the Cape Verde Islands off the coast of Africa. The 20-year-old UNH Earth Sciences major and New Hampshire Space Grant Consortium intern spent the three-plane, 21-hour flight—from takeoff to touch down—wracked with nausea. But again on solid ground, Crete bounced back and exuded her signature enthusiasm throughout a month-long scientific field campaign for which she worked 13-hour days as the "hands and feet" of the operation.

Photo: courtesy of Elena Crete

Elena Crete swaps out air sample filters atop a 100-foot tower in Cape Verde.

Seven days a week, 12 to 15 times a day, Crete would go up and down the 150 stairs of a 100-foot-high, construction-scaffolding tower to collect air samples and attend to instruments as part of the international Reactive Halogens in the Marine Boundary Layer field campaign—otherwise known as RHaMBLe in the adroit acronym- potpourri of modern science.

Photo: courtesy of Elena Crete

Crete trudged up and down the tower stairs 12-15 times per day.

"I'm really clumsy and I'd fall down a lot. The tower was pretty much open so I'm lucky I didn't fall through one of the holes," the junior from Londonderry, New Hampshire says with a grin.

Indeed, stuck on the volcanic island of Sao Vicente for a month with a job to do, Crete would have been hard-pressed were she afraid of open, high places (aeroacrophobic) or afraid of wind (anemophobic). The Erector Set-like tower swayed gently in the warm, dry winds while Crete changed out filters and fussed over mist chamber systems in an experiment designed to shed light on the role marine halogen emissions (airborne sea salts like chlorine, for example) play in atmospheric chemistry, including the destruction of ozone.

"She was thrilled with the whole experience, had a great time, and remains enthusiastic," says Alex Pszenny of EOS and the Mount Washington Observatory and UNH's principal investigator on the RHaMBLe campaign. Moreover, Pszenny notes, Crete's zeal did not slacken for the second part of her Space Grant internship, which largely entailed transferring 40-years worth of climate data from high-altitude sites near Mount Washington off paper records to a computer database.

"By putting it in digital format all that data can now be accessed by more people, more scientists can analyze it, and it can be synthesized with other climate data," Crete asserts with pride.

In addition to being chief scientist at the Mount Washington Observatory, Pszenny, an atmospheric chemist, has been investigating marine-based halogen chemistry for nearly two decades. The Cape Verde campaign, which was sponsored mainly by a British-based study known as SOLAS (for Surface-Ocean/ Lower Atmosphere Study), was the latest experiment in a series that Pszenny started in 1988 when he was working for the National Oceanic and Atmospheric Administration.

"Halogen chemistry, as far as we know, is most important in the marine boundary layer and, over the last decade, an increasing amount of evidence suggests that it has a number of potentially important roles in the overall composition of the troposphere," Pszenny says.

One important implication is that halogens in the marine environment may play a key role in the destruction of ozone in the lower atmosphere (the troposphere) by similar chemical reactions that create the ozone hole in our high-latitude stratosphere.

"The details are different," Pszenny explains, "but the basic story is the same; if you have active halogens you can destroy ozone. And it appears there are active halogens out there."

However, Pszenny adds, "standard" models of ozone and related chemistry in the marine boundary layer are not able to accurately reproduce the observed distribution and variations in ozone concentrations, especially in relatively unpolluted air.

"Generally, the models predict too much ozone overall and too little variation during a 24-hour period. Both of these discrepancies suggest that the models are missing a sink process for ozone. Halogen chemistry may be that sink, or part of it. We're trying to determine how effective an ozone sink halogens really are so that the processes can be more accurately simulated by the models," Pszenny notes.

From Crete's perspective, getting deep into marine boundary layer halogen chemistry was not exactly the point of her Cape Verde adventure. Rather, she wanted to get her feet wet in some aspect of real-world, big-picture climate science to see if her passions meshed with her potential career path, which she thinks will be more policy-oriented.

"I know it sounds really corny, but ever since I was little I knew I wanted a job doing something where I could literally make the world a better place," she says.

So upon her arrival at UNH, and after taking a class in global environmental change, she became keenly interested in atmospheric science knowing how Earth's big, complex, dynamic ocean of air affects everyone and everything.

Looking to expand her newfound academic interest and get some hands-on experience, Crete eventually ended up in the office of atmospheric chemist Rob Griffin of EOS and the Earth Sciences department. While Crete talked to Griffin, Pszenny happened to walk by and was hailed down to join the conversation. In what Crete calls a "crazy chain reaction," within a week of talking with Pszenny she was offered the opportunity in Cape Verde and soon thereafter secured the Space Grant fellowship. She was Africa-bound.

The experience was life changing for the young woman in a number of ways, including helping to stoke the fires of further education.

"I want to go to graduate school now, and I never, ever thought of that until after this summer," Crete says. She hopes to focus her Earth system science studies on the policy side of things. "I really want to bridge the science and political worlds to help get people motivated to change things, to solve global problems." -DS

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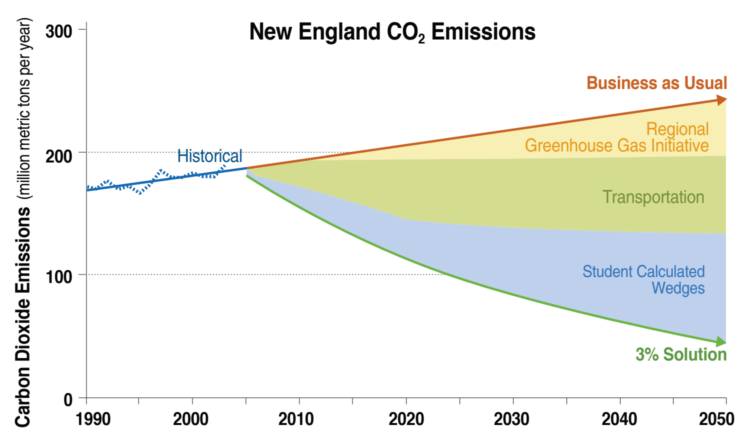
Fixing Climate Change

Students help identify tools already in the toolbox

IN ITS FOURTH AND FINAL ASSESSMENT released in late November, the Intergovernmental Panel on Climate Change effectively halted further speculation over human-induced global warming, clearly laid out the gloom in store should humankind opt for business as usual, and reasserted a ray of hope originally proposed in 2004 by Stephen Pacala and Robert Socolow of Princeton University: all the tools we need to solve the problem for the next half century are currently in hand.

To that end, EOS professors George Hurtt and Cameron Wake taught a new course this past semester entitled, "Building Wedges: Testing Strategies to Reduce Carbon Emissions in New England," in which seven graduate students and two advanced undergraduates dove headlong into finding ways to use these problem-solving tools or "wedges" for reducing regional carbon dioxide emissions. A wedge represents the amount of emissions that can be saved by changing current habits with existing technologies. The students looked into wedges such as biofuel for home heating, solar hot water, and moving freight by rail instead of truck.

Wake and Hurtt focused their class, and their students, on identifying and quantifying regional wedges because the problem of reducing carbon emissions is actually being tackled from region to region rather than on a global or even national scale. The Regional Greenhouse Gas Initiative (see yellow wedge in graph) is just such an example.



The work of the class was done in conjunction with, and will eventually be integrated into, the efforts of Carbon Solutions New England—a public-private partnership that includes Wake, Hurtt and others from UNH, and is working to promote collective action in New England to achieve a low-carbon society. The ultimate goal of the class is to incorporate the student-calculated wedges into CSNE's computer web model and inform decision makers on the relative effectiveness of different strategies to bring regional emissions down, at three percent per year, to 80 percent of their current levels by 2050—the "3% solution."

To learn more about the work of Carbon Solutions New England, go to http://carbonsolutionsne.org/.