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EOS SPHERES

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Vol. 7 Issue 1

How Low Can We Go?

Building a low-carbon society through engaged outreach

THE EVIDENCE IS OVERWHELMING, the recent discoveries unsettling. It's clear that society must urgently reduce carbon dioxide emissions to unprecedented levels over the next decade to begin stabilizing our climate system and avoid potentially catastrophic consequences. The climate of our future is literally in our hands.

Climate scientists have urged a reduction of greenhouse gas emissions by 80 percent below current levels by 2050. Impossible? Not if Carbon Solutions New England™ has anything to say about it.

CSNE is an unprecedented, collaborative effort designed to achieve nothing less than a "low-carbon society" through transformational change in every sector of society.

Launched at UNH and comprised of an interdisciplinary, cross-college leadership team, the effort's heart and soul is the process of "engaged outreach." Under this approach, UNH faculty and staff affiliated with CSNE actively engage with other public, private, and nonprofit institutions in an effort to create a clean energy future while sustaining New England's natural and cultural resources.

CARBON SOLUTIONS NEW ENGLAND™ CarbonSolutionsNE.org

Engaged outreach is a two-way street. Rather than academicians lecturing and downloading their expertise about the carbon cycle, greenhouse gas emissions, and climate change to the rest of us, they form partnerships with a range of institutions to help solve a shared problem.

"It has been said that universities are often focused on disciplines and society is focused on problems, which is why, aside from educating our youth, in many cases universities aren't helping to solve societal problems," says Cameron Wake of the Climate Change Research Center and CSNE director. Wake adds, "That's something we want to rectify."

Not to say the university or EOS has no history of engagement. To the contrary, one of the five major thrusts of the university's strategic plan is engagement, and, Wake notes, "EOS has a long history of outreach and, in fact, engaged outreach."

Forest Watch, Space Grant, GIS Day, Project SMART, are but a few examples of the engaged outreach spearheaded by EOS/UNH.

CSNE grew out of discussions between Wake, Berrien Moore, and George Hurtt of EOS, and Tom Kelly, UNH's chief sustainability officer. The brainstorming resulted in an effort to engage the university to its fullest

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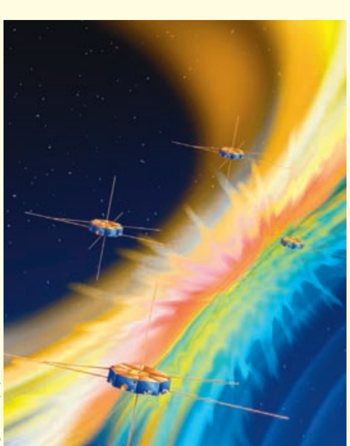

Image courtesy of Southwest Research Institute.

Artist's rendering of MMS Mission.

Seven Years Till Launch, Not a Moment to Lose

UNH's big Sun-Earth mission bumps into higher orbit

FOR THE PAST YEAR David Rau often felt as though he was in a holding pattern circling Morse Hall as NASA's multi-million-dollar Magnetospheric Multiscale Mission (MMS) inched along in its initial stage or "Phase A." Not that that was such a bad thing.

Says Rau, the Space Science Center's (SSC) systems engineer for the mission, "This has allowed us to design things at a more leisurely pace, to come up to speed on all the details of such a complex mission."

The holding pattern came to an abrupt halt when Phase B began in December and propelled the four-satellite, multi-institution mission into its busiest engineering phase.

"As far as engineering goes, this is the really exciting phase. Much of our final success depends on attention to detail right now," says Roy Torbert, UNH's principal investigator for the mission.

UNH has been awarded $61 million from NASA for its role in MMS, which will study the little-understood, fundamental process of magnetic

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EOS SPHERES

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From the Director

Beginning at the End

In *Four Quartets*, T. S. Eliot wrote, "What we call the beginning is often the end / And to make and end is to make a beginning. / The end is where we start from."

In beginning the nonpartisan think tank Climate Central, I return, in a sense, to an early part of my second career at the University of New Hampshire: the creation of the Complex Systems Research Center, which was focused on changes in the environment at a large scale, including changes in the global carbon cycle and climate. Perhaps I am in search of an infinite "do loop" so that nothing ever ends and everything is always beginning. I do not know. But I do know that these past twenty years with you, my colleagues and friends in the Institute for the Study of Earth, Oceans, and Space, have been the high point of my professional life. Your success and creativity have been my greatest joy. And as I leave, it is clear that the future of EOS shines ever brighter.

In time, each of you will eventually leave EOS since that is the nature of a finite life. But you will also know then, as I do now, that EOS will never leave you and, in fact, you will never really leave it. Each of you is part of the substance and magic of this place, and that does not end.

In this, my final *Spheres* column, I end by returning to Eliot's *Four Quartets*. "We shall not cease from exploration / And the end of all our exploring / Will be to arrive where we started / And know the place for the first time."

Thank you for all the years of exploration together; we end by beginning anew.

– Berrien Moore III

Space Science

Seven Years Till Launch

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reconnection in the Earth's magnetosphere. Phase B will last until May 2009, with launch planned for October 2014.

"Which is almost seven years from now!" Rau says with a broad smile and raised eyebrows in a mock "what-me-worry?" expression.

Years in the distance, yes, but there's a daunting amount of work to be done by SSC scientists, engineers, technicians, and students before the stack of four spacecraft rockets into orbit.

UNH is tasked with constructing critical elements of two Electron Drift Instruments (EDI) for each of the four spacecraft. In addition, the UNH team is responsible for building the central electronic computer that will control all the instruments designed to measure the spectrum of electromagnetic fields around the spacecraft.

This "FIELDS" investigation is a conglomeration of six experiment packages composed of a total of eleven sensors per spacecraft. Collaborators in the U.S. and Europe are building five of the six experiment packages. UNH is the lead institution for FIELDS and handles the management, scheduling, engineering, integration, and testing of the complete FIELDS investigation as well as building the EDI.

Notes FIELDS project manager John Macri, a 30-year veteran of the SSC who has worked on many big projects, including the 20-year-long Compton Gamma-Ray Observatory mission, "This is UNH's largest mission since GRO and I am very pleased to be part of the talented and experienced team that has been assembled for MMS."

Eventually, all the hardware and software built at UNH will be part of a constellation of four spacecraft sweeping through the Earth's magnetosphere as close as 10 kilometers (6 miles) apart. This small—relative to the vast reach of space—separation is needed because the critical physics of reconnection occurs on small spatial scales.

Photo: K.Donahue, UNH-EOS

Hans Vaith

Systems engineer Kristen Frederick-Frost notes that while bringing herself up to speed on the workings of the EDI, she marveled at the complexity of both the instrument itself and the task it was designed to achieve.

"The EDI shoots out an extremely weak beam of electrons that then circles around the ambient magnetic field about a kilometer out in space, returns back to the second EDI on the other side of the spacecraft, is recognized from the background noise of other electrons, and gets recorded. That's pretty impressive," Frederick-Frost says.

What's even more impressive is that such measurements are made while the spacecraft are plowing through the fast-moving, ever-shifting boundaries between Earth's magnetosphere and the interplanetary medium.

Each MMS spacecraft will have two microwave-oven-size EDIs. By measuring the displacement or "drift" of the two beams shot out by each EDI, the fundamental boundaries of the electric field associated with magnetic reconnection will be established.

Hans Vaith is UNH's lead engineer for EDI and has 17 years of experience working on EDI building, design, operation, and science, including for the Cluster and Equator-S spacecraft missions. According to Vaith, to solve the puzzle of how magnetic reconnection really works, instruments capable of making extremely precise measurements–and on a small spatial scale–are required.

"The task of EDI is to enable that precision by making measurements that can be used to calibrate the other instruments that are onboard MMS measuring electric and magnetic fields," Vaith says.

So why are four spacecraft needed? To resolve the three dimensions of space and the one dimension of time from each other. That is, a single spacecraft taking measurements while hurtling through space can never resolve anything spatially in time because any two measurements made will be in different places at a different time. And to figure out just what makes magnetic reconnection tick, this space-time resolution is mandatory.

Vaith, Rau, and Frederick-Frost are just three of the almost thirty SSC employees who will work on the MMS mission over the next six-plus years. The mission will also benefit from the new, world-class laboratory currently being completed at EOS, which will allow on-site thermal- and vacuum-chamber tests that previously had to be done at other institutions in the U.S. and Europe. -DS

How Low Can We Go?

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in helping the New England region deal with the whole issue of carbon emissions.

The answer, it turned out, was to strengthen the strategic partnership between EOS and the Office of Sustainability and take it to a new level. CSNE is the growing fruit of that partnership, which now involves a host of other UNH players and private organizations.

According to Kelly, one of the keys to CSNE is its commitment to pursuing a low-carbon society within a framework of sustainability.

"Ecosystems, our food system, and our cultural systems have to be sustained *simultaneously* so that we don't create new problems while trying to solve existing ones with blinders on," Kelly says.

For example, if biofuels are approached in a way that degrades ecosystem functioning and increases food insecurity, then it is clearly not sustainable. "So this approach requires both broad interdisciplinary and inter-sectoral collaboration, which also happens to be quite exciting," Kelly adds.

Tom Kelly

Photo: Perry Smith, UNH Photo Services

While creating a low-carbon society may sound daunting, it becomes less so when approached in bite-sized portions–regionally rather than nationally.

So as the name implies, CSNE is concentrating on New England, which Wake asserts already has a powerful set of tools for the task at hand.

> *"...if we're really able to focus our efforts, we should be able to solve this problem."*

"New England has formidable intellectual and entrepreneurial capabilities. We produce students, ideas, we have considerable ingenuity, and we have the financial resources. So in our region, if we're really able to focus our efforts, we should be able to solve this problem."

Wake and others involved in the effort believe CSNE is the lens through which the disparate but related efforts to reduce carbon emissions will be focused on solving the problem.

Early on in the formulating discussions, the question arose of why, exactly, would others want to collaborate with UNH in such an effort? The answer was simple.

Says Wake, "We have a strong track record of reducing greenhouse gas emissions here at UNH." The most recent effort is a project that will pipe enriched and purified gas from Waste Management's landfill in Rochester, N.H. to the Durham campus. When the pipeline comes online in 2008 it will achieve a 57 percent reduction below 1990 levels.

In addition to the track record, UNH, like universities in general, brings another important tool to the table—the ability to collect and analyze data.

Says Wake, "So if people have direct questions that can be answered with data, we can go out, get the data, do analysis, and provide decision-relevant information." He adds that this process can really only work when all interested parties are together talking and asking questions in a dialog of give-and-take, which comes back to the importance of engaged outreach.

Important, too, in this collaborative effort, is the fact that everything is "transparent" and public.

For example, front and center on the CSNE website is a tool called the "DeCarbonizer," an effort being led by Hurtt, that quantifies and illustrates how different actions will reduce greenhouse gas emissions from the region.

The DeCarbonizer's transparency lies in the fact that, for example, if someone questions how simply washing clothes in cold water can reduce carbon emissions by the amount shown in the web tool, the data are clearly described and all the assumptions are laid bare right on the website.

Notes Wake, "And if this promotes discussion that's great, if people don't agree with the assumptions, that's fine. We'd love to talk to them about it."

The important thing is that everyone collectively work towards actual solutions, which is precisely what the DeCarbonizer is built upon. Even more precisely, the DeCarbonizer is based on carbon reduction "wedges." First introduced by Princeton University scientists Stephen Pacala and Robert Socolow in 2004, wedges represent the amount of emissions that can be saved by changing current behaviors using existing technologies.

> *"...a strong case can be made that New England should take the lead in this effort."*

Hurtt notes that while the DeCarbonizer is based on the wedge concept of Pacala and Socolow, a key difference employed by CSNE is applying the wedge concept to the regional scale and dramatically increasing the goal from stabilizing emissions to *reducing* them by 80 percent by the year 2050.

Cameron Wake

Photo: Lisa Nugent, UNH Photo Services

Says Hurtt, "For the nation to meet this challenge, New England must meet it. In fact, a strong case can be made that New England should take the lead in this effort. The DeCarbonizer is being built to quantify the potential strategies that could be implemented here and, in so doing, advance the debate from what we *could* do to meet the challenge to what we should do to meet it."

George Hurtt

Photo: K.Donahue, UNH-EOS

Wake and Hurtt have also created a course, "Building Wedges: Testing Strategies to Reduce Carbon Emissions in New England," in which students investigate potential wedges that will be incorporated into the DeCarbonizer (see Fall 2007 *Spheres* story). Wake and Jenna Jambeck, an environmental engineer with the UNH Environmental Research Group, are currently teaching a second version of this class.

The DeCarbonizer is one of three CSNE initiatives, the other two being an analysis of the economic impact of pursuing renewable energy (led by UNH professor Ross Gittell of the Whittemore School of Business and Economics), and a regional tally of "who's doing what" already with respect to emissions reductions (led by UNH political science professor Stacy VanDeveer). In addition, CSNE is supporting efforts to develop a UNH "energy lab" to help foster emerging alternative energy technologies in New England.

The project's "continuum of engagement," Wake says, involves a variety of partners with different levels of expertise. Clean Air-Cool Planet, for instance, is very good working with businesses and community organizations while another partner, the EOS-based New Hampshire Carbon Challenge, tackles the issue at the individual household level. Together, under the umbrella of CSNE, solutions are crafted from the household to the regional level.

The "take-away" of all this, Wake notes, is for people to realize that CSNE is both a set of tools and a process that requires effective collaboration. "Solving this problem requires a transformational response in our region, and we are helping lead that response." -DS

For more on Carbon Solutions New England, see www.carbonsolutionsne.org.

The Whole is Bigger Than its Parts

The current state of the oceans requires immediate action and attention. Solutions based on an ecosystem approach hold the greatest promise for delivering desired results. From a scientific perspective, we now know enough to dramatically improve conservation and management of marine systems through the implementation of ecosystem-based approaches.

—Executive Summary, Scientific Consensus Statement on Marine Ecosystem-Based Management

WE NOW KNOW enough to act. This same statement can be heard these days countering decades of hand-wringing and debate on global warming and climate change. We've altered a big, complex system and the time to act is now if we hope to prevent potentially catastrophic consequences.

Equally big and complex and, indeed, intimately connected with our climate system, the world's oceans, too, are in need of repair. There has been a dramatic shift in productivity and health in the planet's oceans from bygone days and, scientists tell us, this requires immediate attention.

In recent years this message has been hammered home by entities like the Pew Oceans Commission and the United States Commission on Ocean Policy, the latter for which EOS fisheries and ocean policy expert Andrew Rosenberg served as a commissioner.

"We need to learn from our mistakes and find new approaches to foster recovery."

As Rosenberg says, "Clearly, ocean ecosystems were very much more productive in the past. We need to learn from our mistakes and find new approaches to foster recovery. Some progress has been made, but there is a long way to go."

At the annual meeting of the American Association for the Advancement of Science held in Boston this past February, Rosenberg presented, among other topics, work related to an ecosystem-based management approach to restoring the oceans that he and his Ph.D. student, Verna DeLauer, are doing.

Unlike the traditional and current resource management style, which focuses on a single species, sector, activity or concern, ecosystem-based management accounts for the interconnectedness of systems and looks at the system as a whole. The goal is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide and sustain "services" humans want and need.

These services include seafood, medicine, nutrient cycling, water purification, shoreline protection from erosion and storm damage, moderation of weather and climate, recreation, and spiritual, religious and other nonmaterial services.

According to DeLauer, whose work is funded through a grant from the Communication Partnership for Science and the Sea or COMPASS, because the concept of ecosystem-based management is complex, it can be easier to engage people by focusing on the services they use and gain from a healthy marine environment.

"Having a better grasp on the services and goods we gain from the environment is a way for people who aren't steeped in the details of ecosystem-based management to get their heads around the importance of this approach," DeLauer says. (See sidebar story on DeLauer's unique work on ecosystem-based management from the perspective of developmental psychology.)

At the core of ecosystem-based management is the evaluation of the inevitable tradeoffs that occur when trying to both protect and maintain the services derived from the ocean. That is, you can't have it all, as history has clearly shown.

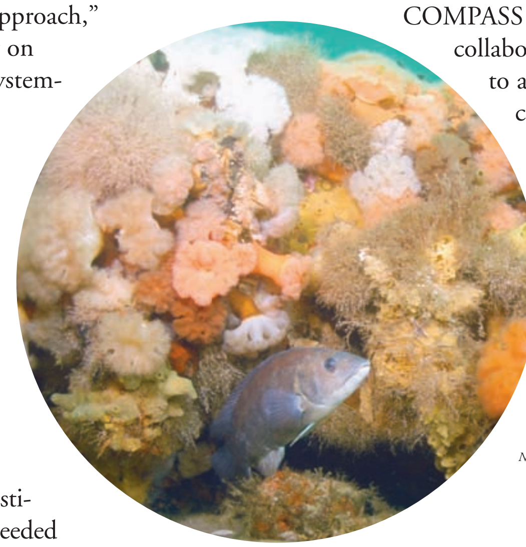
To make these evaluations, sophisticated mathematical models are needed – just as climate change projecting relies on complex simulations of Earth's biogeochemical and physical processes. Part of DeLauer's work with COMPASS involves coordinating the development of one such modeling tool for two pilot projects in the Gulf of Maine; the southwest New Brunswick portion of the Bay of Fundy, and Stellwagen Bank National Marine Sanctuary plus the area in-shore to Boston and Cape Ann.

Says DeLauer, "These are areas of comparable size that are used in multiple ways, which will help us evaluate the different tradeoffs resource managers must make among a range of critical ecosystem services."

Known as MIMES, for Multi-Integrated Model for Ecosystem Services, the tool is actually an integrated suite of models that can look at how the function/value of ecosystem services change under different management scenarios. The model can accurately discern what will happen to the other, linked, critical ocean-based services if a decision is made to, for example, protect a certain coastal habitat.

Says Rosenberg, who also works with COMPASS as one of the program's three senior scientists, "You can't just pretend that fishing or coastal development or water quality happen in isolation. Some relatively weak links with respect to ecosystem-based management have been made, but nobody has yet to actually identify the real tradeoffs in any comprehensive way, in my opinion."

COMPASS is a collaborative effort to advance marine conservation science and communicate scientific knowledge to policymakers, the public, and the media.



At left, a Cunner among marine invertebrates in Stellwagen Bank.

Photos: Tane Casserley, Stellwagen Bank National Marine Sanctuary

Rosenberg is also a founding member of an effort called the Massachusetts Ocean Partnership Fund, which is trying to bring constituent groups and government together across all of the marine interests to support the development of an integrated, multi-use, coastal ocean management plan for the state.

"It's an effort to breakdown barriers, link separate interests that traditionally have gone off on their own as if things were not related," he says. It is, in other words, a potential model for ecosystem-based management at the state level that could someday help serve as a model for a federal management plan if, as Rosenberg notes, "we can ever pass a national oceans bill" as recommended by the U.S. Commission on Ocean Policy and others. -DS

For more on COMPASS, visit www.compassonline.org.

Graduate Student Profile

Managing the Humans in Ecosystem-Based Management

Using developmental psychology to help improve the world's oceans

EMBEDDED IN THE CONCEPT of ecosystem-based management is the natural tension that arises when people must choose between competing interests. For her Ph.D. work, Verna DeLauer has opted to dive right into the thick of that tension.


Photo: D.Sims, UNH-EOS

Verna DeLauer

DeLauer, who is in her fifth year working with OPAL's Andy Rosenberg (see related story at left) and has a background in education, is looking at the emerging ocean management strategy from the perspective of adult, human cognitive development.

"Developmental psychology has been applied to different fields to enhance organizational and individual change but this is very new in the environmental field," DeLauer says.

Just as ecosystem-based management is multi-layered and complex, so, too, are the perspectives and values people bring to the negotiating table. And so, when hard choices between the various "services" provided by ocean ecosystems must be made by people with different backgrounds and agendas, rough waters can become that much trickier to navigate.

According to DeLauer, when looking at these personal differences from a developmental perspective, they are not about what people know or what their intellectual understanding of ecosystem-based management is but, rather, are about *how* people know–how someone "makes or constructs meaning" related to the ecosystem-based management concept and all it entails.

People, in other words, have different ways of making sense of the world around them. The developmental theory DeLauer is studying refers to these as differences in "meaning-making complexities."

So if ecosystem-based management is thought of as a curriculum, stakeholders "come to class" with varying capabilities to make sense of it.

"You wouldn't try to teach second graders 6th-grade material nor would you expect them to understand it," DeLauer explains. "Instead you would teach second graders what they are capable of understanding at that point in their lives. And this is how adult learning should be seen as well."

> *"Developmental psychology has been applied to different fields to enhance organizational and individual change but this is very new in the environmental field."*

Using a particular developmental theory while she works with a cross-sectoral group in Massachusetts, DeLauer has identified seven distinct stages at which people in this group make sense of the ecosystem-based, decision-making process and their approaches to that process. These seven distinct realities dramatically color how each person perceives and reacts to the work at hand.

"Developmental change takes time," DeLauer says. "It's like someone saying with respect to a decision they made in the past, 'Gosh, if I'd only have known that five years ago.' Now they have a perspective on this same issue and they can see it and understand it in different ways."

According to DeLauer, with a more complex meaning-making system in hand, individuals will see the concept of ecosystem-based management in a more complete and holistic way, which of course can help people give and take more productively.

"It's kind of like developmental psychology is the best kept secret in the world because it's as fundamental to who we are as is our intelligence. It governs what we value, how we value, and how we make decisions." -DS

Faculty/Student News

With **Berrien Moore** stepping down as director of EOS, Space Science Center director **Roy Torbert** was named EOS Interim Director and OPAL's **Janet Campbell** assumed duties as Interim EOS Associate Director for Research and Academics. **Jim Ryan** was named new director of the SSC, while **Andy Rosenberg** replaced Campbell at OPAL's helm. Rosenberg also reports that he was appointed to the Ocean Studies Board of the National Academy of Sciences, which is responsible for coordinating studies on ocean sciences for the NAS as well as providing input to Congress and the federal administration on a range of issues.

In early March, research associate professor **Jack Dibb** and research project engineer **Eric Scheuer** of CCRC were gearing up for NASA's Arctic Research of the Composition of the Troposphere from Aircraft and Satellites or ARCTAS mission. The two are in familiar territory for the mission aboard NASA's DC-8 "flying laboratory." CCRC director **Bob Talbot** has a funded experiment onboard the DC-8.

Research assistant professor **Joe Salisbury** and colleagues were recently awarded a $600,000 grant from the NASA Carbon Cycle Research Program to study productivity and carbon export from coastal regions.

Virginia Sawyer, an R&D fellow and Earth Science master's student, will be going to sea on Woods Hole Oceanographic Institution's *R/V Knorr* this spring to participate in the International Chemistry Experiment in the Arctic LOwer Troposphere or ICEALOT cruise to the North Atlantic/Arctic.

In early March, CSRC graduate students **Katelyn Dolan** (M.S.) and **Justin Fisk** (Ph.D.) took part in national and international meetings, respectively, focused on improving humanity's understanding of and ability to predict the carbon balance, biome pattern, and effects on biodiversity of global climate change.

Ph.D. student **Lina M. Saavedra Diaz** of OPAL was one of just 15 women worldwide to receive a two-year fellowship under the UNESCO-L'ORÉAL International Fellowships for Women in Science program. Diaz is working on developing co-management approaches for "artisanal" or low-technology fisheries in small communities on both the Atlantic and Pacific coasts of Colombia. She will be working with several communities directly to find ways to meet local needs and reduce overexploitation of coastal resources.

In January, graduate Ph.D. students **Matthew Argall** and **Hyomin Kim** helped SSC research project engineer **Paul Riley** successfully deploy an Autonomous Remote Real-Time observatory on the coast of Antarctica. The second-generation observatory provides real-time ionospheric measurements via Iridium modem.

Mathematical Modeling for the Rest of Us

Putting today's standard scientific tool in the hands of everyday folks

IT'S HARD for even the casual observer of science these days not to encounter the ubiquitous, and mildly threatening, concept of mathematical modeling. Indeed, even many K-12 educators are now being *required* to understand modeling so they can get students up to speed on this standard tool in today's scientific toolbox and delve more deeply into such timely and important topics like Earth's carbon cycle. And this, say Scott Ollinger and Sarah Silverberg of the Complex Systems Research Center, can be daunting.

"We continue to hear from teachers in many places that modeling is something they increasingly see in state and national educational requirements. And they're saying if they don't understand modeling themselves, how can they teach it to their students?" Ollinger says.

Ollinger and Silverberg, along with UNH colleagues Mary Martin, Rita Freuder, Lara Gengarelly and Annette Schloss, are part of an international effort that, in part, aims to eventually make modeling just another one of the three Rs.

Along with team members from UNH and other institutions, Ollinger and Silverberg are working on the Global Learning and Observations to Benefit the Environment (GLOBE) Carbon Cycle Project. The project links an international team of scientists and educational outreach specialists with the GLOBE educational community.

> *"...models should include those that are conceptual or experiential as well as the mathematical models people generally expect."*

Under the GLOBE program, primary and secondary school teachers and students will gain knowledge about current carbon cycle research, develop strong analytical skills, and increase their overall environmental awareness through classroom experiments, field exercises, remote sensing, and computer modeling.

Ollinger and Silverberg have focused their initial efforts on the modeling end of things and have developed a series of simple models geared towards middle- and high-school students.

"What we have come to realize after working with teachers," Ollinger notes, "is that when we develop models, they should include those that are conceptual or experiential as well as the mathematical computer-based models people generally expect."

For example, Silverberg, along with project evaluator Lara Gengarelly of the UNH Department of Education, developed a hands-on "model" of a pretend paperclip factory that demonstrates some of the essential ingredients of basic modeling without math or computers.

"It's not designed to teach them anything about the carbon system but, rather, shows them how a system works," says Silverberg, who did her master's degree research at UNH on carbon cycling in northeastern U.S. forests.

For the paperclip factory model, which has been piloted at several area schools, students break into three groups representing, respectively, the factory workers, those who run the paperclip store, and the customers.

With a pile of paperclips to "produce," some basic rules about how many paperclips can be made by each worker per day, and so fourth, the students see a system that has a "pool" or "stock" of material that changes through time based on the inflow and outflow or "flux" of that material. By the time they complete the task they've been introduced to some basic terms and principles of modeling.

After the hands-on modeling, students take the data they've recorded about their system and make a graph similar, it turns out, to what they would get using a computer model.

The desired end result of this activity is for students to eventually see that if they didn't want to go through all the paperclip shuffling, they could use a simple math equation to achieve the same result.

Says Ollinger, "So you get students to understand that, although math is a component of modeling, with nothing more than addition, subtraction, multiplication and division they can begin to build and use models that quickly take them beyond what they thought was possible with simple arithmetic. And in doing so, they overcome the fear that modeling is beyond their reach."

The hands-on exercise essentially provides the ABCs of a new language and, for example, gives students a better understanding of key modeling concepts of inputs, outputs, and standing stocks.

Key, too, is the concept of the paperclip factory representing a simple "one-box" model, with one input (paperclips produced) into the box (the paperclip store) and one output (paperclips sold).

One would think going from a paperclip factory to modeling Earth's carbon system would be an order-of-magnitude leap in complexity. But, Ollinger notes, "The difference is not very great at all and can still be initiated using addition, subtraction, multiplication, and division."

Four boxes, representing, respectively, the atmosphere, oceans, plants, and soils, connected with arrows representing inputs and outputs—the global carbon cycle.

Explains Ollinger, "Once students understand the basic principles, you can introduce them to a system, let's say carbon moving through a forest ecosystem, that has a certain set of flows, and the stocks are behaving pretty stably, the pool sizes aren't changing radically from one year to the next."

Then, into this stable forest ecosystem a new flow is added–increased fossil fuel combustion and greenhouse gas accumulation–and the model begins to reflect the changes or "forcings" to the system: Will the trees grow larger and store more carbon? How fast will the new carbon be transferred to soils? When will a new equilibrium be reached and how much of the atmospheric buildup will the forest be storing at that time?

By creating this package for teachers in the classroom, which essentially captures what scientists do to understand the carbon cycle, it is the hope of the project scientists that a deeper and broader message will emerge.

"Ultimately, we hope to really help teachers, students, and the public at large to have a deeper appreciation for how the Earth works and understand that the carbon cycle is an integral part of the functioning of the planet," Ollinger says. He adds, "We're tinkering with this critical cycle quite a bit but there's a real lack of understanding of what this means, why we should care, and what we're going to do about it." -DS

For more on the GLOBE Carbon Cycle project, visit globecarboncycle.unh.edu.

Recipe for a New Paradigm: Mix Cupful of Students and Faculty, Add Water

FOR SOME 400 YEARS, the New England landscape has been intensively altered in a variety of ways. Shifting through time, the land has been deforested and tilled, rivers have been dammed and diverted, wetlands filled, cities built, roads paved. Industries have come and gone, fields have lain fallow, reverted back to forest, cut again and blanketed with blacktop.

It would seem obvious that, through all this, a big impact would be wrought on the region's hydrological cycle. But how? History does not accurately record the details.

As climate change and water problems gain a new sense of urgency in science and public policy circles, hydrologists are keen to take their science to the next horizon–to understand the inherent variability in the water cycle, to gain a predictive capability, and determine just how humankind influences the great cycling of water in all its forms.

A nascent National Science Foundation pilot project, which includes researchers from the Water Systems Analysis Group within the Complex Systems Research Center, will make inroads to this new horizon by focusing on the history, and future, of human-water interactions in Northeast corridor of the U.S. from 1600 to 2100.

The project, "Humans Transforming the Water Cycle: Community-Based Activities in Hydrologic Synthesis," will kickoff this summer with a seven-week-long institute managed by hydrologist Mark Green, who recently came to the CSRC from the University of Minnesota. Other CSRC researchers participating in the synthesis project include principal investigator Charlie Vörösmarty, and scientists Steve Frolking, Wil Wollheim, Richard Lammers, and Balaz Fekete.

The summer institute will engage Ph.D. and post-doctoral students from around the country and Europe who, with a panel of 25 faculty, will begin to formulate this hydrologic synthesis in the Northeast. The ultimate goal is to apply this model to other regions nationally.

Says Green, "The Northeast has had so many emblematic changes going back more than 400 years. If you can understand the impact humans have had on the hydrologic cycle in the Northeast through time, you can apply that to other regions undergoing urbanization right now."

The pilot project is one of two "test beds" for developing this synthesis model. Also involved in the project is a hydrology group from the University of Illinois. The three-to-four-year NSF-funded project is part of a larger, multi-institutional group known as the Consortium of Universities for the Advancement of Hydrologic Science or CUAHSI (pronounced "coo-Ah-see").

CUAHSI is the umbrella organization tasked with organizing the U.S. hydrologic community (www.cuahsi.org) and has four components, including conducting hydrologic synthesis.

According to Green, during the institutes over the next four summers, small groups of students will each focus on a specific time frame in 100- to 150-year chunks using different approaches with existing tools, for example, small watershed models, larger basin models, and statistical approaches. The end result of each institute will be a summary of what is known, what the information gaps are, and a series of hypotheses that need to be addressed in order to fill those gaps.

"The project wants to take the first step of identifying whether humans have exerted a large influence on the hydrologic cycle. It seems intuitive to say 'yes,' but we want to make sure that large-scale data confirm this."

Eventually, when all these chunks of data are synthesized, it is hoped that a clearer picture will emerge of how, or if, humans transform the hydrologic cycle.

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Indeed, it has been hypothesized by at least one researcher that the hydrologic system is, in fact, incredibly resilient and that humans haven't impacted it as much as we might think. If the synthesis project can show that to be the case, Green notes, "A secondary very good question is, 'Why is the system so resilient to all this activity on the landscape?'"

Photo: K.Donahue, UNH-EOS

Mark Green

Clearly humans can change the hydrologic cycle on very small scales—damming a river, say, or filling in and paving over a large wetland area. But because hydrology is inherently variable, with alternating dry years and wet years and decadal cycles like El Nino, this causes the "signals" to spike in the upward direction and then back down again.

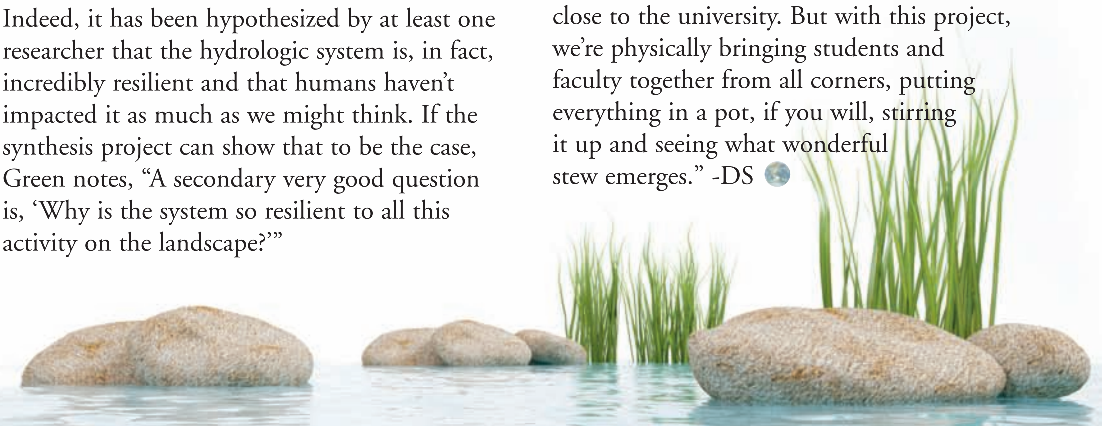
Says Wil Wollheim, "So you have all these different signals superimposed upon each other, it makes it very difficult to separate out those that are attributable to human activity."

And the impacts of climate change, of course, can further obscure the picture. But as Richard Lammers notes, in spite of the very real and very global impacts climate changes can have on the hydrologic system, "If you build a dam, for example, that will dominate any climate change signal for that river and for the fish in that river."

Swelling human population around a watershed can also completely outweigh any climate change signal in the data. Ideally, after all the project's synthesizing is done, the scientists will be able to separate the impacts of climate change from the human signals.

Although synthesis approaches are not uncommon in other disciplines, the tack taken for the CUAHSI project is a new one for the field of hydrology. And through it, Lammers says, a new generation of researchers will be empowered to address these important questions in a new light.

"If students followed the traditional path in hydrology, they would just work with their advisor in their local water catchment area close to the university. But with this project, we're physically bringing students and faculty together from all corners, putting everything in a pot, if you will, stirring it up and seeing what wonderful stew emerges." -DS



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Twenty-five Hundred Down 97,500 To Go

IN LATE JANUARY, after enduring months on the coldest, driest, and windiest continent on Earth, researchers closed out the inaugural season on an unprecedented, multi-year effort to retrieve the most detailed record of greenhouse gases in Earth's atmosphere over the last 100,000 years, including a precise year-by-year record of the last 40,000 years.

Working as part of the National Science Foundation's West Antarctic Ice Sheet Divide (WAIS Divide) Ice Core Project, a team of scientists, engineers, technicians, and students from multiple U.S. institutions recovered a 580-meter (1,900-foot) ice core–the first section of what is hoped to be a 3,465-meter (11,360-foot) column of ice. The 1,900-foot section represents approximately the top-most 2,500 years of the story.

Joe Souney of the Climate Change Research Center is the operations manager for the WAIS Divide Science Coordination Office. Souney recently returned from Antarctica and is now planning this summer's "core processing line" where portions of the recovered core will be sliced and diced in exacting fashion and parceled out for principal investigators to begin various analyses.

"For example, scientists interested in the atmospheric gases will get inner core samples to avoid potential problems caused by minute fractures on the outside of the ice cores," Souney explains.

The core processing, which will be set up at the National Ice Core Laboratory in Denver, Colorado, provides the next generation of ice core researchers, i.e., graduate students, an opportunity to get their hands dirty, so to speak.

Says Souney, "It's important that people have both the intellectual knowledge as well as a good understanding of the mechanics and logistics behind what it takes to recover and read an ice core." -DS

For more information about the WAIS Divide Ice Core Project, visit www.waisdivide.unh.edu

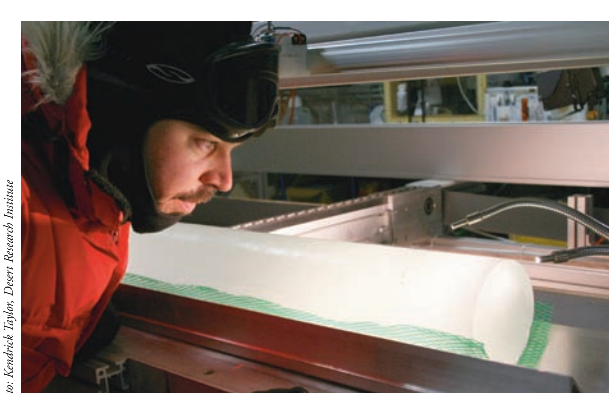

Photo: Kendrick Taylor, Desert Research Institute

Joe Souney examines a one-meter section of the WAIS Divide ice core recovered from a depth of 500 meters.