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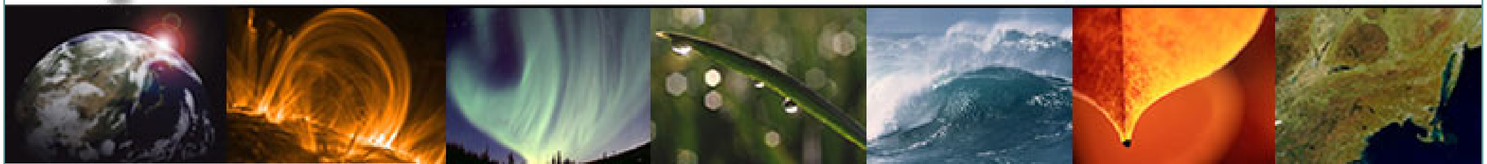

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Spring 2013
In this Issue of *Spheres*…

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EOS Director: Harlan Spence
Editor: David Sims
Designer: Kristi Donahue
Circulation: Laurie Pinciak

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Changing With the Times

Climate Change Research at EOS

In this issue of Spheres*, we focus on some specific aspects of current climate change research being done by scientists within the Earth Systems Research Center. The sampling is by no means exhaustive or all-inclusive. Rather, it uses the common thread of the National Science Foundation/NH Experimental Program to Stimulate Competitive Research (EPSCoR) program's "Ecosystems and Society" project to tie them loosely together. That project, being conducted in collaboration with colleagues across campus and around the state, well represents the trend of linking empirical science to relevant societal needs—a trend increasingly emphasized by national funding agencies and one that EOS researchers have been, and continue to be, deeply invested in.*

ECOSYSTEMS + SOCIETY

Making the Invisible Visible

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Mirror Mirror

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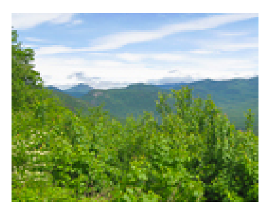
A Matter of Scale



BACK IN 2008, when forest ecologist Scott Ollinger happened to pore over six years worth of data he and colleagues had collected on forest sites across North America, he had the rare eureka moment. Read More…

Space Science

IBEX: The Little Satellite That Could, and Does

GALACTIC CLOUDS and magnetic ribbons. Such is the ethereal stuff that NASA's Interstellar Boundary Explorer, or IBEX, is out there probing and discovering. The mission has spent four and a half years imaging the edge of our solar system as well as sampling the raw "star stuff" out of which stars, planets, and humans are formed. Read More…

Ocean Science

The Yin and Yang of Coastal Carbon

BACK IN THE SPRING OF 2004, when the Center for Coastal Ocean Observing and Analysis (COOA) began monthly scientific cruises in the Gulf of Maine, the term "ocean acidification" had yet to enter the vernacular of climate change. Read More…

Around the Hall

News and Notes

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• From the Director: SwRI-EOS Launches Read more…

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Making the Invisible Visible

Vital "ecosystem services" that help provide quality of life are often taken for granted

WHEN NORTHERN OHIO's Cuyahoga River caught fire back in 1952, the depth of American environmental degradation was made manifest. The startling image helped spawn the environmental movement and the eventual passage of laws that cleaned up the nation's water and air.

In like fashion, if the ever-thickening blanket of planet-warming carbon dioxide were to blacken the sky, would mankind move with similar resolve to apply the brakes on global warming?

Cuyahoga River fire November 3, 1952.
Courtesy of Cleveland Press Collection at Cleveland State University Library.

"There is a critical need in the whole range of climate change science to make the invisible visible," asserts Cameron Wake of the Earth System Research Center, "and measuring carbon dioxide in the atmosphere is a great example."

If people could see the parts per million of the greenhouse gas in the atmosphere, Wake says, "I think there would be a different response to global warming and climate change. But the measurements that are part and parcel of science can be very difficult to comprehend because they often remain abstract."

And yet, climate change is increasingly becoming less abstract and more visible as extreme weather events change people's lives and society rapidly shifts from a posture of, at best, contemplating the impacts of global warming to adapting to its harsh realities.

"…so much of what is being done in the EPSCoR Ecosystems and Society project is about making these largely invisible ecosystem services more visible."

Close to home, Wake notes that work being done by EOS researchers and colleagues across campus and at collaborating institutions around the region is aimed squarely at helping society see the bigger picture of climate change by shifting the focus from simply safeguarding ourselves from increased coastal flooding and more extreme weather events to protecting the very ecosystems we are embedded in, and which support our lives in myriad ways.

"I see a real transition to the need to protect our ecosystems and preserve our quality of life, which comes through a range of services provided to us by healthy ecosystems," Wake says. "That's the big frame, and so much of what is being done in the EPSCoR Ecosystems and Society project is about making these largely invisible ecosystem services more visible."

The project is multifaceted with a diverse set of goals but, in a nutshell, the big scientific targets are: to better understand and value the current state of ecosystem services such as clean water supply, wood for fiber, fuel, timber, climate regulation (via carbon storage and changes in albedo), and opportunities for recreation; and, develop a suite of models and scenarios that will, in essence, help make the invisible visible and project future changes in ecosystem services resulting from change in climate and land use (see "A Matter of Scale" in this issue of *Spheres* for specifics on ecosystem services). The hoped-for outcome of all this is a set of informational tools that state decision makers can use to chart a sustainable future from tomorrow to 100 years from now.

In addition, the project is by nature interdisciplinary. Says Wake, "It's groundbreaking to have a group of scientists getting together and saying 'We want to help policymakers make better decisions'—that's an explicit goal of this research project."

That goal is not only groundbreaking but also well grounded, as gauged by the extensive engagement work Wake and others involved in the project do by collaborating with external partners on projects that are mutually beneficial and aimed at solving a real problem.

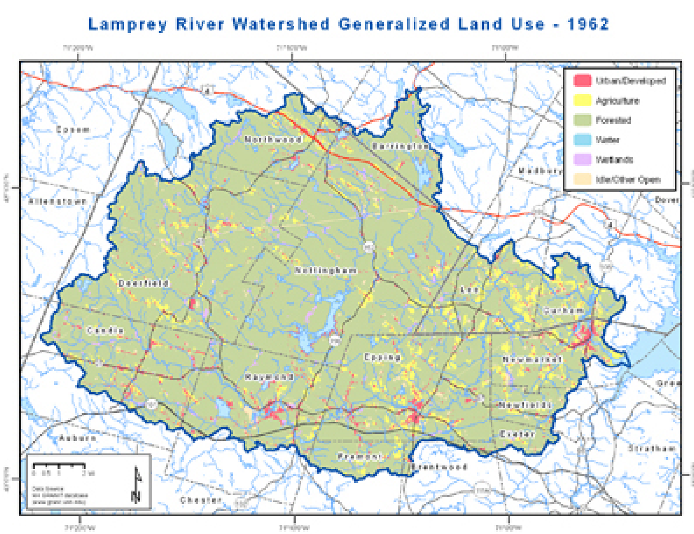
Says Wake, "I've worked with a lot of external partners, doing climate assessments for example, and they know that understanding the context for future climate conditions is crucial for effective decision making today."

The interdisciplinary nature of the project is mandated by its focus on a *place* that has disparate and interconnected challenges and issues. Those can only be addressed by understanding the entire system, which includes the physical and social sciences.

"It's groundbreaking to have a group of scientists getting together and saying 'We want to help policymakers make better decisions'…"

What's the story?

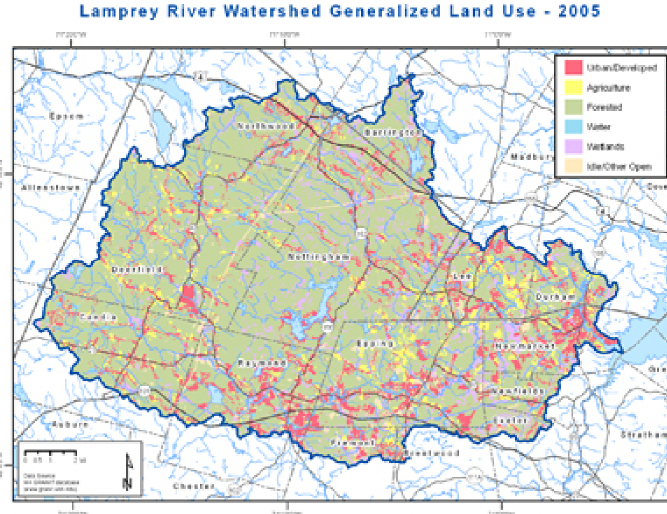
Developing a suite of scenarios that project into the future is a critical component of the work. These scenarios will provide plausible "storylines" on how land cover and climate might change across N.H. over the course of 90 years.



It's tricky work and will require two distinctly separate paths to achieve. The climate storylines will be derived using global climate models in a fashion similar to how the Intergovernmental Panel on Climate Change (IPCC) projects different scenarios of atmospheric levels of carbon dioxide. In this case, however, the scenarios will be scaled down to the state level with the aid of doctoral student Liz Burakowski's dynamic regional climate modeling (see "Mirror Mirror" in this issue of *Spheres*).

"The land cover side of the equation is really challenging because it's so closely tied to a whole range of potential decisions that people make," says Wake.

> *“How do we make our communities more resilient? A big part of that resilience comes from ecosystems and the services they provide.”*



Expansion of developed land is shown in red in the land use maps above. Population tripled and the area of developed land quadrupled from 1962 to 2005.
Courtesy of NH GRANIT.

Because projecting future land use across the state is more like reading tea leaves than empirical science, this part of the socioeconomic scenario work will be an educated guess at best. But it won't be boundless—it will be opinion "bracketed with context."

A range of opinions will be compiled by interviewing dozens of different stakeholders across the state who will be asked—from a variety of angles including economic, demographic, regulatory, etc.— what they envision for land use in the future. This data collection effort has been framed and informed by collaborating with Curt Grimm and Barbara Wauchope of the UNH Carsey Institute, which is involved in other aspects of the Ecosystems and Society project.


Barbara Wauchope


Curt Grimm

Grimm and Wauchope note that the scenario development process is an extension of the Carsey Institute's research on sustainable communities, and the information gathered through interviews and focus groups "contributes to a richer understanding of socioeconomic development in New Hampshire, as well as providing data for the modeling."

Says Wake, "Essentially, we'll take all that input and build a series of narratives that will be plausible storylines, and those narratives, along with the climate scenarios, will drive the models."

The models will include two, and possibly three, that have been developed at EOS over a period of decades—the Forest Carbon Water Balance Model (PnET), the hydrological FrAMES (Framework for Aquatic Modeling of the Earth System) Water Balance Model, and the DeNitrification-DeComposition (DNDC) ecosystem model. With data in hand, the researchers will attempt to couple the models to more fully resolve the big picture—something Wake notes will be "one of the grand challenges of the project."

Resilient ecosystems, resilient communities

Using the same climate modeling approach as the IPCC—scaled down to a much finer resolution to produce much finer land use scenarios—will provide a clearer understanding of not just future changes in precipitation and temperature as climate conditions shift but changes in overall ecosystem services. It's an important distinction; to provide decision makers with meaningful information on how to best chart the state's future, that information must be based on what the impacts to specific ecosystem services are going to be.


Photo by Michelle Day, UNH-EOS

"So that's an added layer of complexity," Wake notes, "and ultimately comes back to asking, 'How do we make our communities more resilient?' A big part of that resilience comes from ecosystems and the services they provide. And, for me, that's the connection between short-term efforts around adaptation and longer-term efforts at quantifying and communicating those ecosystem services to communities and decision makers."

Will Granite Staters, adapting to a changing climate, envision a future of one- or two-acre lots dotted across state with houses wired with high-speed Internet and people working mostly from home? Will many more thousands of acres of farmland be created to increase local food production? Will existing communities be made more dense and the state's agricultural and forestland remain as is? Will we cut down our forests to generate electricity?

Says Wake, "Down the road what we get from the scientific analysis of the scenarios will be very useful for communities when they think about how they want to grow and what they want to conserve." He adds, "I'd like to envision a future where our unique set of scientific capabilities leads to improved quality of life for New Hampshire citizens, where scientific analysis is married to the needs of decision makers in order to form a better union."

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

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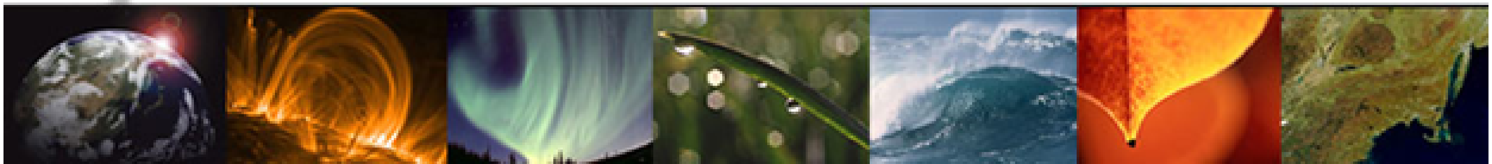

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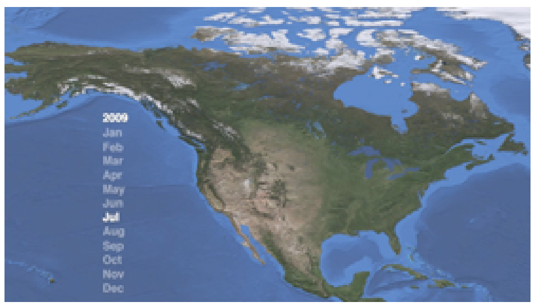
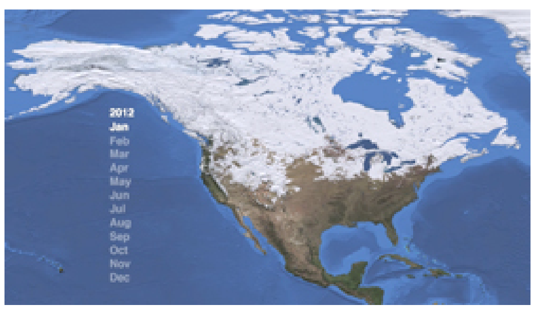
Climate Change Research at EOS

Mirror Mirror

The "albedo" or reflectivity of a surface is a key scientific variable in foretelling our climate future

THINK OF the Great Frozen North as a gigantic white t-shirt draped across the top of the world. Just as that attire would help you chill out under a hot summer sun, the massive "permanent" ice and snow of the Arctic region helps cool Earth's overall temperature by reflecting sunlight back out into space. Fresh snow reflects up to 90 percent of sunlight's energy or, in scientific terms, has a very high "albedo"—the Latin word for "whiteness."





North American snow cover from July 2009 to January 2012, from an mp4 movie of albedo change. Courtesy NASA Goddard Space Flight Center.

But increasingly, the Arctic t-shirt is fraying around the edges and exposing darker land and ocean waters that absorb the sun's heat. And in a vicious self-perpetuating cycle, this "albedo feedback" hastens the melting, which further lowers the albedo, which causes more melting, and so on.

The feedback cycle contributes to the dramatic reduction in Arctic sea ice cover that has been detected by satellites recently; all six years with the smallest area of sea ice at the end of the melt season have occurred since 2007, with 2012 marking a new record low.

Whereas the juggernaut of diminishing Arctic albedo is highly visible, much remains unknown and invisible about the role albedo is having on our changing climate. Scientists, including those at UNH and within EOS, are investigating how the reflectivity of surfaces—from forest foliage to agricultural fields to suburban backyards—is having an impact on local to regional to global climate.

One of the goals of such research is to improve climate change models and, therefore, improve the ability to look into the future to prepare for and adapt to a changing planet. And albedo research is a core aspect of the current EPSCoR Ecosystems and Society investigation involving EOS and other UNH scientists and collaborators around the state.

Researchers are making albedo measurements using aircraft, towers that loom above forest canopies, hand-held "albedometers," and taking snow samples that will be analyzed for heat-absorbing impurities and the morphological (and albedo influencing) differences between freshly fallen and well-aged snowpack.

Ph.D. candidate Elizabeth Burakowski's thesis work, funded entirely under the EPSCoR grant, is aimed squarely at eventually answering the question: How much does the phenomenon of albedo

"…all six years with the smallest area of sea ice at the end of the melt season have occurred since 2007, with 2012 marking a new record low."

contribute to climate change in the Northeast U.S.?

"Currently, that's unknown," she says.

To help nail that down, Burakowski is working from the ground up making hand-held and tower measurements locally and regionally.

Her albedometer and tower measurements made at the UNH Thompson Farm Research Station in Durham will eventually be compared to albedo readings made using a hyperspectral instrument mounted on an aircraft that flew over the farm in February and March to provide high-resolution, wide-scale measurements. In turn, the hyperspectral imagery will be analyzed alongside satellite images taken by the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard a NASA satellite that sees the Thompson Farm landscape in nothing less than 500-meter by 500-meter pixels, or 50 acres per image.

Liz Burakowski atop the tower at Thompson Farm.
Photo by Michelle Day, UNH-EOS.

Says Burakowski, "MODIS classifies Thompson Farm as 'deciduous broadleaf' even though in the 500-meter pixel there's pasture, a house, a barn, and mixed forest. When I'm on top of the research station's 120-foot tower in winter it's obvious how many white pines there are. It's a very heterogeneous landscape but they're characterizing the entire pixel as deciduous broadleaf because that's mostly what the MODIS instrument picks up."

Graduate student Jacki Amante collects snow samples at the UNH Burley-Demeritt Organic Dairy Research Farm in Lee, N.H.
Photo by Luke Barbour, UNH.

All of which means the albedo calculation derived from a MODIS image is based on some big assumptions that call into question just how accurate that albedo estimation, or "product," is.

"What we hope to do is take the hyperspectral data, which is comprised of many 5-meter pixels, and see how well the average of those matches the 500-meter pixel," Burakowski says. "If MODIS is over- or underestimating they'll need to reclassify the pixels based on the finer resolution land cover dataset we'll derive."

The approach, notes the Earth Systems Research Center's Scott Ollinger, who is leading the hyperspectral remote sensing effort, is like "using the aircraft as a stepping stone between your field measurements and the MODIS global sensor." (See "A Matter of Scale" in this issue of *Spheres*.)

A tough read

Jack Dibb, research associate professor and director of ESRC, has done work on the Greenland ice sheet for over 20 years, including recent analysis of how well MODIS is reading the huge, flat, white surface for the albedo signature.

"We and other researchers have validated the MODIS albedo product for simple scenes like Greenland or Antarctica and it's reasonably good," Dibb says. But even in such a "simple" environment, topographic undulations and varying angles of the sun can create shadows and subtle variations in light that confuses MODIS and makes an albedo pixel less sharp.

"Researchers are making albedo measurements using aircraft, towers that loom above forest canopies, hand-held "albedometers," and taking snow samples…"

Imagine, then, a landscape like New Hampshire's where there are no ice sheets or even 10,000-acre wheat fields that present MODIS with a relatively bland, easy read.

Says Dibb, "The management units in this part of the world are pretty small—a bunch of backyards, a hay field, a tree farm, a clear-cut forest of 20 acres—all these little blocks of land that all look different. How does MODIS reproduce that? We don't know." Referring to Burakowski's work he adds, "But Liz is trying to make the first detailed effort to understand what the MODIS albedo product is really telling us or how good it is for this area."

Liz Burakowski and Michelle Day ascend the tower at Thompson Farm to make albedo measurements.
Photo by Evelyn Jones, NH EPSCoR.

Indeed, Burakowski's work is aimed at eventually improving the capacity of climate models to accurately predict how changing albedo will alter our future climate.

"…we're most interested in various options New Hampshire citizens and policymakers might choose between for future land use patterns."

Says Burakowski, "The data I gather is going to be useful when I run the climate model, which currently uses parameters based on global averages from MODIS, not on local or regional measurements for the Northeast. When I put in the data that reflect what we've actually collected in the field, I can then run a series of land cover experiments to simulate what land cover was like in 1850 and also what it would look like today and in the future under different scenarios." (See related story "Making the Invisible Visible" for more on scenario work.)

There are specific modules in the climate model that deal with how snow cover evolves over time—an aspect Dibb and master's student Jacqualine Amante are currently working on under the EPSCoR project. Amante is collecting snow samples in the region to ascertain how various chemical compounds, particularly black carbon, or soot, impact albedo. It is timely work; a landmark report released in mid-January showed for the first time that airborne black carbon—from diesel trucks, woodstoves, forest fires, etc.— is second only to carbon dioxide as a contributor to global warming.

When soot falls out of the atmosphere and lands on ice and snow it can darken the surface and initiate other physical processes, like changing the shape and size of snow grains, which in turn can have a big impact on albedo. Research Dibb conducted recently at Summit Station on the Greenland ice sheet shows that airborne soot presents a bigger threat and, indeed, the new report also bears this out. What's not clear, however, is whether impurities in snow, like soot, speed up or slow down the changes in the shape and size of snow grains—something Dibb and Amante are investigating.

Like Burakowski's research, understanding more fully how snow morphology changes over time, thus changing its albedo properties, will increase the climate models' accuracy at making future climate change projections.

Notes Dibb, "As part of the total EPSCoR project effort, we will take this climate model, which Liz's work will have helped us gain more confidence in with respect to albedo, and apply it to a range of possible future scenarios, including what we're most interested in—various options New Hampshire citizens and policymakers might choose between for future land use patterns."

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

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"Hurricane Sandy really changed the landscape

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Climate Change Research at EOS

Building Shelter From the Storm

The landscape of climate change adaptation has greened substantially in recent years

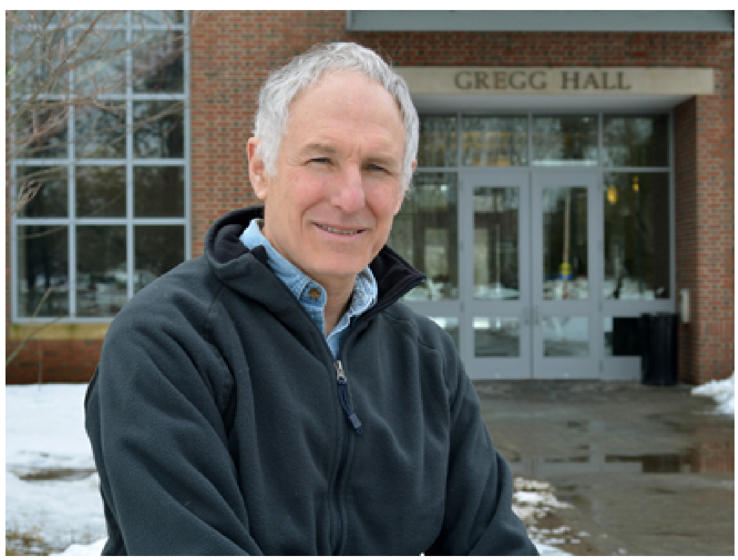
AMONG OTHER THINGS blown away by Hurricane Sandy in October 2012 was the notion that climate change was a thing of the future and that humanity had plenty of breathing room before having to gear up against its onslaught.

"Sandy really changed the landscape and caused a step increase in climate change adaptation thinking," says research professor Paul Kirshen.

At least that's what Kirshen, a civil engineer with joint appointments at EOS and the UNH department of civil engineering, is seeing in his line of work.

For example, Kirshen has ongoing climate change adaptation projects underway in the Boston area but after Sandy immediately saw evidence of that step change in interest and concern.

"Agencies that were just thinking about climate change and what do to at their facilities are now issuing requests for proposals. I can name two cases in the Boston area where managers of large infrastructure systems have decided they want to spend hundreds of thousands of dollars right now to plan what do to if another Sandy comes along," Kirshen says.



Paul Kirshen
Photo by Kristi Donahue, UNH-EOS.

Closer to home, Kirshen works with Cameron Wake of the Earth Systems Research Center within EOS as part of the New Hampshire Coastal Adaptation Workgroup on several climate change adaptation projects, including one in Exeter, N.H.

The two researchers are also part of the UNH-led Infrastructure and Climate Network (ICNet) funded by the National Science Foundation in an effort to forge more common ground between the disparate worlds of engineers and climate scientists.

Notes Wake, "The ICNet project is about building a network among engineers and climate scientists who live in very different worlds. We think about things differently, use different languages, publish in different journals, and rarely work together. So it's not easy for climate scientists to go talk to engineers, and vice versa, but Paul is different because he has a foot in both fields."

Says Kirshen, "I'm a civil engineer trained in systems analysis but the field I work in is called 'adaptation.' And while I wouldn't call my research unique, it is groundbreaking because the *and caused a step increase in climate change adaptation thinking…"*

whole field of adaptation is pretty new."

To wit, although Kirshen has been doing civil engineering adaptation work for a couple of decades, only in the last five years have people begun to realize society can, and must, practice adaptation engineering.

"The kind of engineering planning we have to do now is different from the past, which always built infrastructure for the long term under unchanging climate conditions," Kirshen says. "Today, we have to design with the explicit recognition that the climate is changing, and one approach requires an emphasis on flexibility and adaptive management."

If you build, it might come

Kirshen's particular approach to this flexible and adaptive civil engineering is to plan for the long term and implement measures only when climate change manifests itself, instead of over fortifying against an uncertain future.

This incremental, progressive method to infrastructure design and building is aimed at protecting people, buildings, and budgets at the same time.

"Because the changes are uncertain—for example, we can only say that between now and 2050 we'll see between a one- and two-foot rise in sea level—what you want to do is closely monitor the climate so that when it's clear it has changed to a certain critical value for certain types of infrastructures you know now it's time to take action," Kirshen says. "You don't build prematurely, you build when you need to."

Conceptual design of a modular floodwall that can be increased in size as needed due to sea level rise. Image prepared by the Woods Hole Group, Inc. for a NOAA-funded UMass-Boston, UNH, UMD project "Coastal Flooding and Environmental Justice: Developing Strategies for Adapting to Climate Change." Courtesy of Paul Kirshen, UNH-EOS/CE

"The kind of engineering planning we have to do now is different from the past, which always built infrastructure for the long term under unchanging climate conditions."

That's easier said than done, of course, because due to natural variability and long-term decadal signals like El Niño and the North Atlantic Oscillation, an extreme event could signal either a climate change threshold or just an anomaly.

Says Kirshen, "So it's very difficult to detect when you're at a changed climate, and I'm working with colleagues on techniques to better ascertain when the climate has actually changed."

That work entails statistical trend analysis combined with decision theory and, Kirshen notes, "What we're including in the analysis are the implications of over- or under-building, which is why you really care about trend detection."

In other words, boiled down to the bottom line, it's infrastructure planning that tries to provide an accurate heads up for decision makers so that the biggest bang for the climate change buck can be achieved.

"You always hear about the astronomical cost of adaptation from people, but this work shows them that they needn't do anything until they have too. Of course," Kirshen cautions, "when you finally do rebuild infrastructure under current conditions, you need to make it climate change resilient."

The term "resilience" is now part and parcel of civil engineering climate change adaptation work. Kirshen notes that it came out of ecological literature of the 1970s but is now being applied to designing infrastructure systems so that they can "recover or bounce back" rather than crumble or wash away in the wake of insults hurled at them due to changing climate.

Fail-safe or safe-to-fail?

Making structures climate change resilient can actually recognize and include eventual "failure" into the design. That is, since engineering design standards have always been based on hard-and- fast numbers and structures are not supposed to fail, a new kind of thinking is indeed required to build things so they're not necessarily fail-safe but instead, in some instances, "safe-to-fail."

"Today we realize that under the regime of a changing climate we simply can't protect everything, some things are going to fail and we have to be prepared to deal with that as part of the plan," says Kirshen.

Today, infrastructure must be designed with "the explicit recognition that the climate is changing."
Photo by Tim Hayes courtesy of Piscataqua Region Estuaries Partnership.

For example, under the new planning paradigm, a community might build decades-long protection up to a certain level of flooding but then, knowing that level will eventually be exceeded, put in an evacuation strategy as part of the master plan. That said, the plan would also provide for flood-proofing the most vulnerable buildings prior to evacuation so that when the waters recede people can return and get on with their lives.

"I think that's the future, we don't necessarily have to invest in a massive seawall but, rather, design our communities over the next few decades so that they are floodable, we adopt a smaller, more decentralized approach," Kirshen says.

He adds that, up till now, there haven't been many opportunities to push this type of approach, but the times they are a-changin'.

"The hardest thing, and this is changing because of Hurricane Sandy, has been people saying climate change is too far away and too expensive to deal with. Those same people are now realizing they don't have the luxury of taking that stance and, slowly, they're starting to ask for help." Kirshen adds, "Now, with some solid information in hand, it's really a matter of the politicians, planners, and community members having the courage and confidence to act."

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

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Spring 2013

Climate Change Research at EOS

A Matter of Scale

Downsizing continental-scale research to the local level is a key element of the Ecosystems and Society project

BACK IN 2008, when forest ecologist Scott Ollinger happened to pore over six years worth of data he and colleagues had collected on forest sites across North America, he had the rare eureka moment.

The data, derived from a novel combination of NASA satellites and aircraft, flux towers, and leaf-level measurements, had been gathered to probe various chemical properties of forest canopies. But when analyzed collectively, they revealed something completely unexpected and potentially crucial for piecing together the big picture of how forests can influence climate: forests with high levels of leaf nitrogen have a two-fold effect on climate by simultaneously reflecting more solar radiation (having a high albedo) and absorbing more carbon dioxide than their low-nitrogen counterparts.

“Bits and pieces of evidence for this had been around for years but nobody put them together before because it was not a question we had even thought to ask,” says Ollinger, a professor in the ESRC and department of natural resources and the environment.

White Mountain National Forest.
Photo by Michelle Day, UNH-EOS.

The newly discovered link between foliar nitrogen and canopy albedo added an interesting twist to understanding the climate system and raised intriguing questions about the underlying nature of ecosystem-climate interactions.

And the finding lends itself perfectly to the scientific goal of the Ecosystems and Society project—quantifying the current state of ecosystem services in New Hampshire—because it helps continue to pave the way for larger-scale research to be downsized to the regional and state level, and flips a critical line of scientific questioning on its head.

"Fifteen years ago, where climate change was concerned, most of us were thinking just about how changing climate would affect ecosystems, not how ecosystems would affect climate change," Ollinger says in reference to long-term work conducted in the EOS terrestrial ecosystems lab within the ESRC.

But looking at the spectral and field data he and colleagues had collected on a continental scale from subtropical forests of Florida to the subarctic boreal zone, Ollinger notes, "We started thinking, 'That's a big change in albedo, shouldn't that matter to climate? If you have that much of a difference in surface heating that's related to a nutrient cycle, shouldn't that matter?'"

It should, and does—globally, regionally, and locally.

Over the years, Ollinger and colleagues in the lab have been very successful at securing continued NASA funding to scale local research up to the continental level—such as long-term work done at the Bartlett Experimental Forest in New Hampshire's White Mountains. Now, with the Ecosystems and Society project, they will continue to apply the effort in reverse.

“Bits and pieces of evidence for this had been around for years but nobody put them together before because it was not a question we had even thought to ask…”

Says Ollinger, "With the EPSCoR project, as well as one we're doing in conjunction with the New Hampshire Agricultural Experimental Station at UNH, we have some renewed vigor to bring what we've learned at the national scale back down to the local level. And of course this all ties into investigating the current state and value of ecosystem services in the face of future land use decisions in New Hampshire."

Ecosystem services: regulating, provisioning, cultural, and supporting

Ecosystem services is a catchall phrase but tries to encompass the many things natural ecosystems provide to the benefit of humans. Forests, for example, play a large role in the Earth's climate system by helping regulate the mean annual temperature and have a similarly large role in the global hydrological cycle.

Forest soils are superb at filtering water and the Granite State's plentiful and pristine waters are heavily dependent on forests that blanket 80 percent of the state. In New York, had regions of the Catskills and Adirondack mountains not been preserved more than a century ago, New York City would not have a similarly plentiful supply of good water. That service would have to be replaced by enormously expensive water treatment plants.

Graduate student Paul Pellissier at Harvard Forest.
Photo by Michelle Day, UNH-EOS.

The supply of water is considered a "provisioning" ecosystem service. The United Nations 2005 Millennium Ecosystem Assessment, a report that former EOS researchers helped author, formally defined four categories of ecosystem services. In addition to provisioning, there are regulating (control of climate and disease), supporting (nutrient cycles and crop pollination), and cultural (spiritual and recreational benefits) services.

"Now that we're in an era where we know more about how plants, for example, don't just respond to how the Earth system works but contribute to how it works, we need to understand how our own management of the landscape—manipulating the location, structure, and composition of ecosystems—will affect climate and the quality of our lives," Ollinger says. He adds, "And because we manage land at the local level, we really need to understand the climatic consequences of land management at that local scale."

Human created and dominated

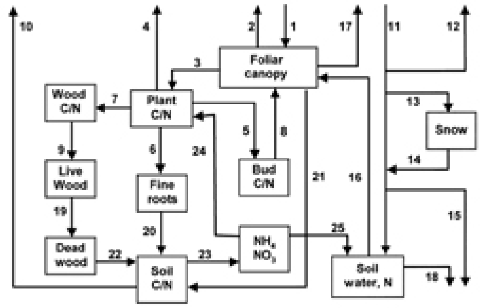
“Fifteen years ago… most of us were thinking just about how changing climate would affect ecosystems, not how ecosystems would affect climate change.”

To understand that local scale, and sites in Durham specifically, Ollinger's lead role in the EPSCoR project involves hyperspectral aircraft flights that will, among other things, provide Liz Burakowski with her finer resolution albedo data (see "Mirror Mirror" in this issue of *Spheres*).

And although the work he and colleagues have done across North America used hyperspectral imagery (which, as the name implies, "sees" the landscape below using a wide range of the electromagnetic spectrum to achieve finer resolution), the focus was forest canopies. They were not looking at how the structure and chemistry of the species of grasses that comprise a suburban lawn or a fallow field influence spectral properties; they are now.

"There's some very basic research that needs to be done for that kind of system, a system that is very human created and dominated," Ollinger says. And this is tightly coupled with another basic research aspect of the EPSCoR project—the social science side of things.

To accurately build narratives or scenarios of what New Hampshire will look like in the future, the researchers need to understand the human values, attitudes, and decision-making processes that influence how people manage that human-dominated landscape. What drives people to do what they do and, if understood well enough, could that be predicted?



A diagram representing the basic structure of PnET (from Ollinger et al. 2002), a process-based ecosystem model that captures the dynamics of carbon, water and nutrient cycling in forest systems. Boxes represent pools of live and dead/decomposing biomass and soil, and numbered arrows represent fluxes of carbon, nitrogen and water.

The terrestrial ecosystems lab has done computer simulation modeling (using, among others, the Forest Carbon Water Balance Model, or PnET, developed at the ESRC over a period of decades) that forecasts what forests will do under different climatic conditions and environmental stressors—insect infestation, pollution, etc.—and how they will continue to serve as a sink for carbon, or not.

"So far our lab and many others have primarily focused on how climate and other environmental changes over next century will influence forests and other ecosystems," Ollinger says. "There are a lot of different drivers in that model, but at end of day, my guess is the most important thing that will affect the future of northeastern ecosystems in the next 100 years is land management."

The Granite State has plentiful and pristine water because of its widespread forests.
Image courtesy of Paul Lempke.

"…the Granite State's plentiful and pristine waters are heavily dependent on forests that blanket 80 percent of the state."

And that entails human drivers of ecological change that, as complicated as mathematical models simulating biogeochemical processes are, add a level of complexity that is far more challenging because it is much harder to quantify.

But the EPSCoR project is helping to meet that challenge by bringing together an interdisciplinary group of researchers, including those from the Carsey Institute at UNH, who will add in the sociological aspects (see "Making the Invisible Visible" in this issue of *Spheres*).

After all, just few decades ago, what was considered a climate model was focused almost entirely on the atmosphere, with anything below—the land and oceans—being completely static.

Over time, the modeling evolved and began to incorporate physical and biogeochemical processes on land and in the oceans. The next generation of models will have to include human activity as another component.

Notes Ollinger, "We haven't made that transition, but we're at least at a point in our fields where we recognize the importance of bringing sociological research into the fray—trying to understand more of what drives human activity and including that in the models."

Editor's note: Other EOS faculty working on aspects of the EPSCoR Ecosystems and Society project include, Ruth Varner, Mary Martin, Wil Wollheim, Richard Lammers, with additional graduate students Danielle Grogan, Nathaniel Morse, and Paul Pellissier. The principal investigator for the project is Jan Nisbet, UNH senior vice provost for research.

ECOSYSTEMS + SOCIETY

ESRC faculty involved in climate change research, but not part of the Ecosystems and Society project, include Heidi Asbjornsen, Steve Frolking, Changsheng Li, Michael Palace, Alex Pszenny, Barry Rock, Alexander Shiklomanov, and Jingfeng Xiao.

Additionally, research project managers Mark Twickler and Joe Souney head up the West Antarctic Ice Sheet (WAIS) Divide Science Coordination Office, and Twickler directs the National Ice Core Laboratory-Science Management Office.

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

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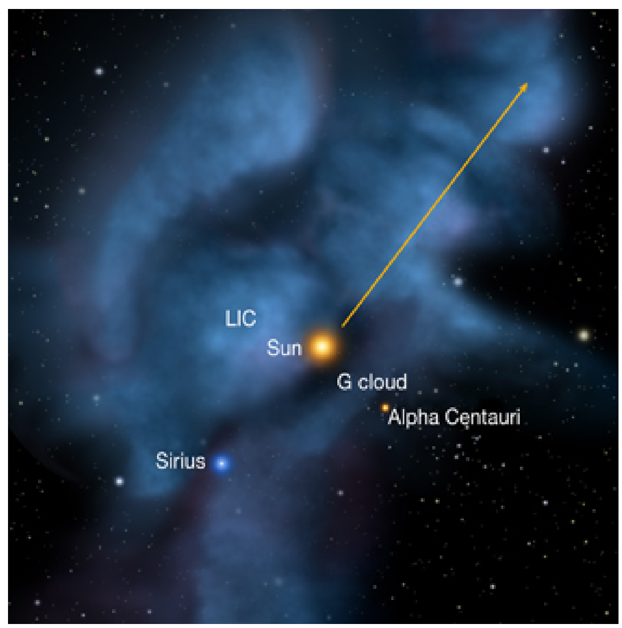
IBEX: The Little Satellite That Could, and Does

The bus-wheel-sized Interstellar Boundary Explorer breaks new ground in outer space

GALACTIC CLOUDS and magnetic ribbons. Such is the ethereal stuff that NASA's Interstellar Boundary Explorer, or IBEX, is out there probing and discovering.

The mission, in which Space Science Center researchers are deeply involved, has spent four and a half years imaging the edge of our solar system as well as sampling the raw "star stuff" out of which stars, planets, and humans are formed.

The effort has resulted in remarkable and unexpected findings: our solar system appears to be moving through the Milky Way galaxy at a speed and in a direction different than previously thought; and a bright, enigmatic "ribbon" of energy wraps a portion of our sun's heliosphere—the gigantic bubble that surrounds our solar system and helps shield us from dangerous incoming galactic radiation.



This image shows the nearest interstellar gas clouds around the solar system, including the Local Interstellar Cloud (LIC) and G Cloud, along with positions of neighboring stars in the plane of our Milky Way galaxy. The arrow shows the sun's motion relative to neighboring stars.
Image courtesy of P.C. Frisch, University of Chicago.

The former finding is crucial for understanding our place in the cosmos through the vast sweep of time—where we've come from, where we're currently located, and where we're going in our journey through the galaxy, all of which has major implications on the size, structure, and protective nature of the heliosphere.

And the ribbon—a discovery analogous to that of Earth's radiation belts and magnetosphere in the 1950s—"paints" an image in the sky of the interstellar magnetic field, a phenomenon that heretofore was completely unknown and also appears to play a critical role in shaping our heliosphere.

"We really are discovering how the interstellar magnetic field shapes, deforms, and transforms our entire heliosphere," says Nathan Schwadron, lead scientist for the IBEX Science Operations Center at EOS. "These are the first global measurements of the heliosphere that have ever been made, so in that sense, it is similar to discovering the properties of the magnetosphere for the first time."

A riddle wrapped 'round the heliosphere

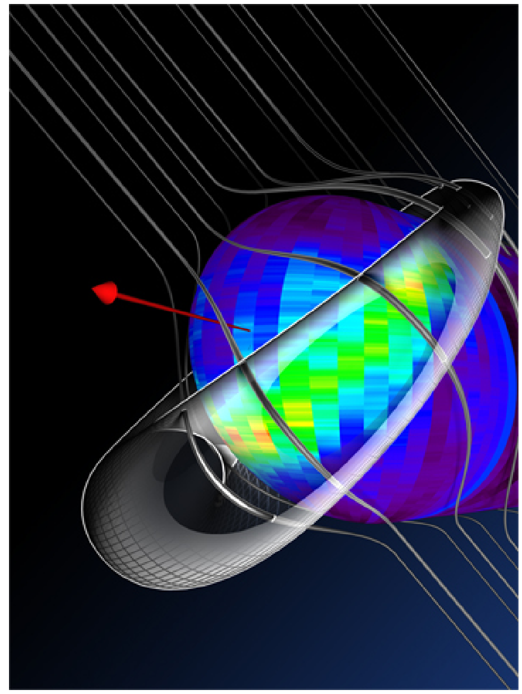
The initial discovery of the ribbon was not only completely unexpected but had to be puzzled over for three years before astrophysicists came up with a workable explanation of what and why the ribbon was.

“These are the first global measurements of the heliosphere that have ever been made…"

Indeed, over a dozen theories were put forth before Schwadron, along with mission principal investigator Dave McComas of the Southwest Research Institute, came up with one that, in Schwadron's words, "checks all the boxes, agrees with all the available observations, and matches the mathematical modeling results remarkably in terms of what the ribbon actually looks like."

According to this "retention theory," the ribbon exists in a special location where neutral hydrogen atoms from the solar wind move across the local galactic magnetic field. Neutral atoms are not affected by magnetic fields, but when their electrons get stripped away they become charged ions and begin to gyrate rapidly around magnetic field lines. That rapid rotation creates waves or vibrations in the magnetic field, and the charged ions then become trapped by the waves. This is the process that creates the ribbon.

Says Schwadron, "If you think of the ribbon as a harbor, and the solar wind particles it contains as boats, the boats can be trapped in the harbor if the ocean waves outside it are powerful enough. This is the nature of the new ribbon model. The ribbon is a region where particles, originally from the solar wind, become trapped or 'retained' due to intense waves and vibrations in the magnetic field."



A three-dimensional diagram of the retention region shown as a "life preserver" around our heliosphere bubble along with the original IBEX ribbon image. The interstellar magnetic field lines run from the upper left to lower right around the heliosphere. The red arrow shows the direction of travel of our solar system.
Image courtesy of Adler Planetarium/IBEX Team.

This explanation appears to solve two important components of the ribbon's mystery: what is the physical mechanism that creates and sustains it, and does it actually exist in space or is it some sort of optical effect?

"The theory puts forth the hypothesis that says the ribbon is actually a physical region in space, *not* an optical effect," Schwadron says. "It's a region where the ions are physically confined roughly perpendicular to the magnetic field."

“If you think of the ribbon as a harbor, and the solar wind particles it contains as boats…they can be trapped if the ocean waves outside it are powerful enough.”

Importantly, Schwadron notes that as spot-on as the retention theory appears to be, it is a hypothesis that will need to be tested and that work towards that very end—including "pencil and paper" mathematical analysis by scientists like the SSC's Marty Lee—is already underway.

Says Schwadron, “The theory seems to have the right stuff, but there’s still a lot to flesh out. People like Marty have to come in with even more sophisticated physical models and put things to the test.”

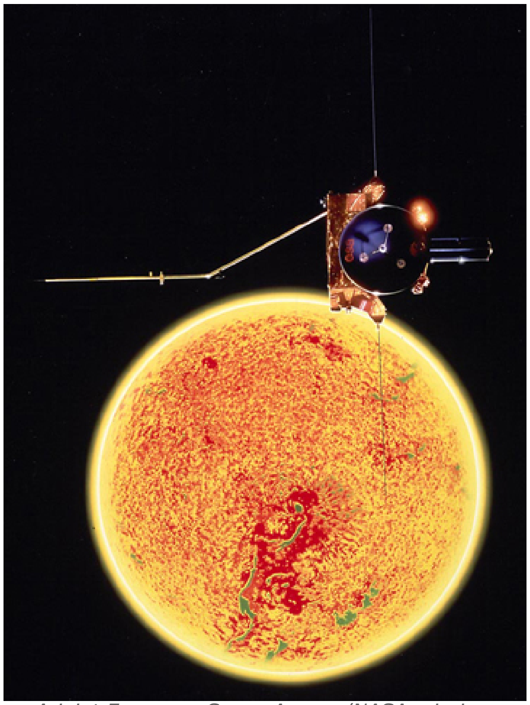
But the biggest test for the theory will come with the passage of time as the sun heads towards solar maximum and the properties of the solar wind change. Since the ribbon is formed from neutral solar wind materials, the presumption is that the ribbon, too, will change.

"If the theory is correct, over the next several years we should see some substantial changes in its appearance, particularly in the latitudinal ordering of the ribbon," Schwadron says.

Slow down, you move too fast

The mission's other major discovery—that our solar system is moving through the local galactic medium more slowly and in a direction different than measured previously by the joint NASA/European Space Agency Ulysses mission—has also caused puzzlement.

In an effort to resolve the disparities between the two spacecraft's measurements, IBEX and Ulysses scientists met at EOS for three days in mid-February to compare data and analysis. Among other reasons, sorting this out could help determine in which distinct galactic cloud we are currently


A joint European Space Agency/NASA mission, Ulysses charted the unknown reaches of space above and below the poles of the sun.
Image courtesy of ESA.

sailing through and, in turn, what our place in the universe is.

Previous Ulysses measurements of the interstellar gas flow of the galactic medium indicated a faster speed and different orientation of travel, both of which seemed to place our solar system in a region between the two closest interstellar clouds—the Local Interstellar Cloud and the G Cloud, the latter which contains Alpha Centuari, our closest neighboring star three light years distant.

However, IBEX's recent measurements appear to put our solar system into the local cloud, which seems to be consistent with what astronomers have determined by peering through the galactic medium, where they see the solar system at the cloud's leading edge. The spectroscopic measurements through the galactic medium allow astronomers to see what clouds are there and how they are moving.

"From this…you can determine that the sun has gone through environments where the heliosphere has been very small or very large…"

Says Eberhard Möbius, UNH principal scientist for the IBEX mission, "From this, and within certain confidence levels, you can project the temporal paths and determine that the sun has gone through environments where the heliosphere has been very small or very large—all of which, as we have now learned, has a significant influence on the radiation environment of the solar system and, ultimately, our planet."

With this cosmic roadmap in hand, scientists can then try to connect the dots through time looking for evidence of evolution of life on Earth, with its ups and downs and extinctions and changes in climate. "This is a focus area of research we've gotten on in just the last ten to fifteen years," Möbius says.

The research has opened a new window into gauging the potential habitability of planets in a specific star system that would also have a protective bubble, or "astrosphere." That is, for exoplanets with astrospheres it's much more likely that some type of life has evolved because, like our heliosphere, the bubble would have provided buffering from the full force of galactic cosmic rays while at the same time waxing and waning to allow varying levels of radiation to drive genetic mutations and, thus, the evolution of life.

Says Möbius, "Once we understand our own home environment—where we are and have been in the galactic medium—and what controls it, then we can tweak our models and look for other habitable places in the galaxy using much sparser data."

Which brings matters back to the disparity between Ulysses and IBEX data regarding where we are at the moment. Could the dueling data be the result of differences in initial measurement, subsequent analysis techniques, or true differences in space and time?

Möbius notes that by cosmic standards the space/time difference between Ulysses—a mission that ran from 1990 to 2009 and took interstellar gas data through 2007—and IBEX is a mere nano-blink, and it is highly unlikely that a system operating on the scale of hundreds of thousands to millions of years would vary in any measurable way over the course of a decade.

"Is there something in the analysis of the Ulysses or IBEX data that we're doing differently and we don't know it?" Möbius wondered prior to the February meeting with mission scientists.

In the meeting's wake Möbius notes, "We looked at potential culprits in observation methods and analysis that could lead to the observed differences in the velocity vector, but haven't found any yet. We need to wait for the next round of data analysis on both sides to be completed for further guidance."

Meanwhile, IBEX, parked safely in a uniquely stable orbit, will be providing plenty of additional data through the years to come to both nail down the ribbon retention theory and provide further insights into our current position in the cosmos.

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

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The Yin and Yang of Coastal Carbon

Ocean Process Analysis Laboratory scientists have been collecting data in the Gulf of Maine for nearly a decade to help solve a coastal ocean carbon cycle puzzle

BACK IN THE SPRING OF 2004, when the Center for Coastal Ocean Observing and Analysis (COOA) began monthly scientific cruises in the Gulf of Maine, the term "ocean acidification" had yet to enter the vernacular of climate change.

Just five years later, the Federal Ocean Acidification Research and Monitoring Act was passed and, in its wake, the National Oceanic and Atmospheric Administration established its Ocean Acidification Program in recognition that the problem of rising ocean acidity "is emerging as an urgent environmental and economic issue on our nation's east and west coasts and in many areas of the world."

UNH carbon dioxide sentinel buoy off Appledore Island after January 2013 Nor'easter.
Photo by Shawn Shellito, UNH-EOS.

Making measurements relevant to tracking ocean acidification—although not named as such—was already one part of why the COOA cruise "transects" were initiated: to better understand the complex dynamics of coastal ocean waters, most particularly the role they play in either storing or out-gassing atmospheric carbon dioxide.

"The biggest thing we were asking at the start was, 'Is the Gulf of Maine a sink or source of carbon dioxide?' At the time, no one on the East Coast knew very well what the coastal ocean was doing in this regard," says Doug Vandemark, research associate professor and director of the Ocean Process Analysis Laboratory (OPAL).

He adds, "And it was important to find out because, among other things, if our region's ocean is a big sink, is it large enough that we need to include it in the total ocean budget for CO_2 uptake?"

What *has* been generally known is that continental shelf systems like the Gulf of Maine are highly productive biologically because they receive large nutrient input from both the land and adjacent ocean waters.

And because the annually recurring process of biological growth uses carbon dioxide, it has been suggested that these systems serve as pumps that draw the gas out of the atmosphere and sink it into the deep blue sea—an important role in the global ocean carbon cycle despite the fact that coastal systems represent just seven percent of the global ocean surface.

After gathering enough data year after year to provide a time series—measurements of sufficient length, consistency, and continuity to determine climate variability and change—COOA researchers have now shown that the Gulf of Maine is neither a clear sink nor source of carbon dioxide but, rather, a sort of recycling center for the greenhouse gas.

Says Vandemark, "Although like most coastal systems the air-sea CO_2 exchange is highly variable in both time and space, we've concluded that the Gulf has both a time of year when CO_2 is sinking and a time when it's ejecting the gas. And in most years, the exchange turns out to be in net balance."

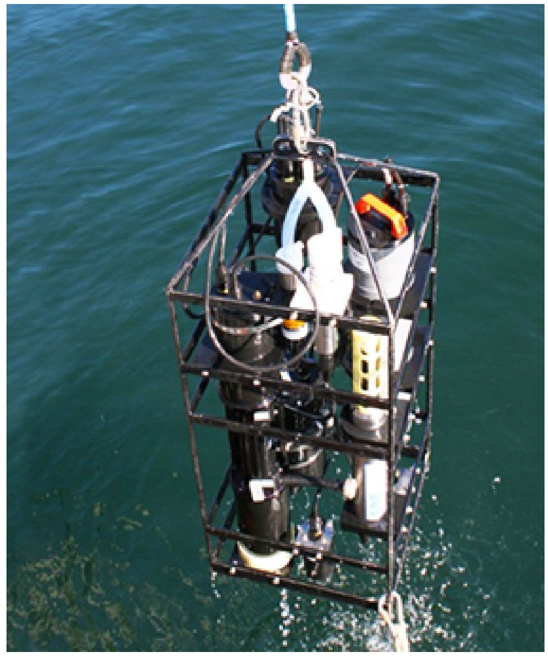
"…if our region's ocean is a big sink, is it large enough that we need to include it in the total ocean budget for CO_2 uptake?"

A marginal sea

One reason for this net balance is that the 69,120-square-mile body of water is a semi-enclosed basin or what's known as a marginal sea because several effective gateways, including channels around big George's Bank, limit what is exported permanently out of the system.

"While we do observe a lot of biological production, we don't have the pumping/export mechanism to flush the organic carbon out before it comes back up and is recycled," Vandemark says. "That is the most fundamental observational result from our time series data so far."

Vandemark adds that a next step in the scientific inquiry is seeking to understand how fragile this balance is over time. "This has required expanding our observations and attempting to develop models for how that balance is maintained by a mix of key processes, including seasonal temperature, wind, ocean mixing, and biological changes."



Instrument package used during the COOA cruise "transects" to better understand the complex dynamics of coastal ocean waters.
Photo by Shawn Shellito, UNH-EOS.

Since 2010, and with recent additional support from NOAA's Ocean Acidification office, the scientists' data collection has focused on hourly measurements at the UNH carbon dioxide buoy located northeast of Appledore Island. The buoy is now routinely deployed for nine to ten months per year by a UNH team headed by OPAL research scientist Shawn Shellito and research professor Jim Irish of the UNH Ocean Engineering program.

A recent addition to the buoy is the region's first autonomous ocean acidity (pH) measurement sensor. The complement of daily chemical, biological and physical oceanographic data recorded by this buoy will serve as the foundation for understanding the Gulf of Maine's fragile carbon balance.

Without the long-term time series shipboard data, which have been supplemented by the UNH buoy-based measurements, the scientists would have something more akin to the old lead-line soundings used to measure the ocean bottom—a very fuzzy understanding of the bigger picture.

"…we've concluded that the Gulf has both a time of year when CO_2 is sinking and a time when it's ejecting the gas."

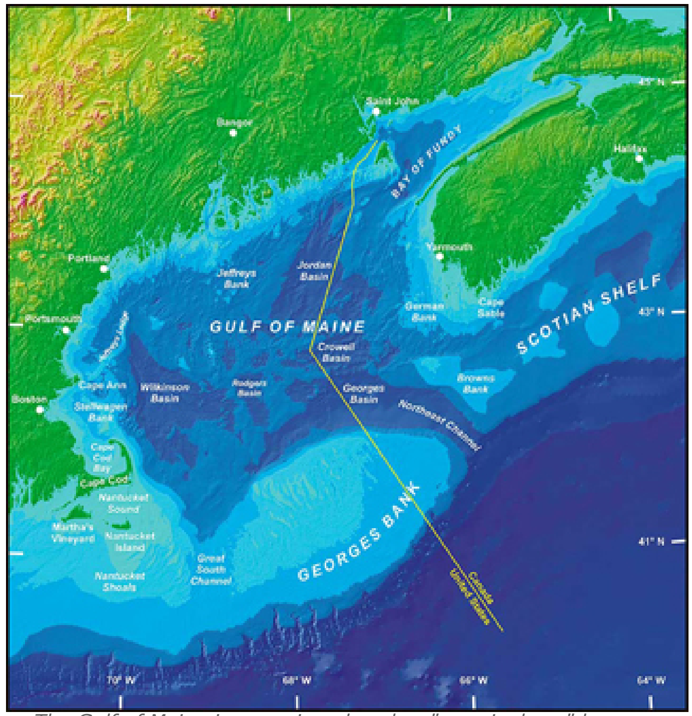
But as carbon dioxide levels continue to rise in both the atmosphere and the ocean, even longer-term measurements, on the scale of decades, will be required to help develop the models needed to accurately predict what the future may hold.

Model meets data

"The cruise and buoy data have shown us that there is profound variability in the water temperature, salinity, and probably biology on a year-to-year basis," says OPAL oceanographer Joe Salisbury. "We can tell a lot about what's causing the variability in CO_2 by looking at how temperature and salinity change, but we aren't able to see clear trends over the nine years and we need to continue to make measurements on the scale of decades for a clearer picture to emerge."

Among other physical ingredients, the temperature, salinity, and biology of coastal waters cause carbon dioxide and acidity levels to vary on wide spatial and temporal scales.

For example, Salisbury, who specializes in studying the effects of freshwater input from the region's many large rivers on the Gulf of Maine, notes that cruise and buoy data record the impact of storms and subsequent plumes of tea-colored freshwater that pour into coastal waters. Such sediment- and nutrient-loaded water can have profound impacts, such as darkening the coastal in-water light field, resulting in dramatic impacts on biological production, or lack thereof.



The Gulf of Maine is a semi-enclosed or "marginal sea" because several effective gateways, including channels around George's Bank, limit what is exported permanently out of the system.
Digital bathymetry map by Ed Roworth and Rich Signell of the U.S. Geological Survey, courtesy of the Regional Association for Research on the Gulf of Maine.

But teasing out what it all means with respect to carbon dioxide and levels of acidity is extremely difficult without a robust, coupled physical-biological ocean model that is driven by real data. No such model currently exists and Salisbury is in the process of trying to develop an "observationally oriented" model that doesn't include all the vagaries of coastal ocean processes.

"The cruise and buoy data have shown us that there is profound variability in the water temperature, salinity, and probably biology on a year-to-year basis…"

Notes Vandemark, "One thing we've learned well is that the coastal ocean is very messy, but Joe is modeling the biophyiscal coupling in a fairly simple way that provides valuable first answers to guide future measurement and modeling work."

A decade of data for the decade ahead

Looking at their ocean carbon dioxide time series data, Salisbury points out, "We're trying to simplify the analysis to basically one dimension—looking at time series data in a place that's a highly three-dimensional system. There's input to the waters from below, from the side, from the north, sometimes from the south, from river waters of the Penobscott and Kennebec, small local rivers with different signature, etcetera, and we're using very simple models to try and figure that all out. But it's an extremely complex story."

To address this complexity, the two scientists are also working with modelers at Rutgers University to help improve that group's Regional Ocean Modeling System, which has been used to simulate the air-sea flux of carbon dioxide (the exchange of the gas between the surface of the sea and the overriding atmosphere) on the northeast continental shelf without the inclusion of real-world measurements, which remain sparse.

"In order to model whether the Gulf of Maine is going to continue to stay in that balance or become a sink or source," Vandemark says, "we need to know what our predictive capabilities are and how good they are. That requires more time-resolved, long-term measurements so we can look at actual data one year versus ten years later to see if the models get it right. That's one thing our data will go towards for the next decade."

In addition to the joint work with Rutgers and Salisbury's modeling efforts, continued and expanded measurements will be made in the Gulf of Maine to track shifting levels of carbon dioxide and ocean acidity in both time and space. The group has deployed instruments across the Gulf of Maine, including sites in the Northeast Channel in the middle of the Gulf, an estuary in Casco Bay, and within the Stellwagen Marine Sanctuary east of Boston.

The need for expanded measurements related to ocean acidification was hammered home by a study published this past January that demonstrates how vulnerable the Gulf of Maine is to acidification. The study, whose lead author is former UNH graduate student Aleck Wang—now a chemical oceanographer at the Woods Hole Oceanographic Institution, was based on a summer 2007 investigation aboard NOAA's Research Vessel *Ronald H. Brown* in which Salisbury, along with former graduate student Amanda Plagge, participated.

Says Salisbury, "We've known for some time from our observations that the Gulf of Maine's coastal and bottom waters are poorly buffered against changes in acidity. However, this study puts our system in the context of all coastal waters from Maine to Texas, and suggests that we'll be the most vulnerable in the coming years."

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

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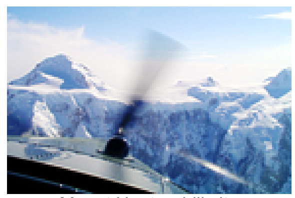
Faculty, Staff, and Student News

Earth Systems Research Center

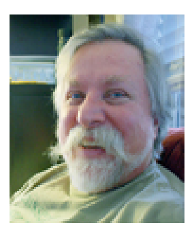
In May, **Cameron Wake**, **Liz Burakowski** and colleagues from Dartmouth College and University of Maine will travel to Mount Hunter in Alaska's Denali National Park on an ice core paleoclimatology project. The effort culminates five years of reconnaissance missions to identify the ideal drilling site and seeks to recover two surface-to-bedrock ice cores of 250 meters each by mid-June. The project is an attempt to reconstruct changes in annual precipitation and atmospheric circulation and deposition of different pollutants in central Alaska. The data will essentially fill a large spatial hole in existing Arctic ice core paleoclimate records.


Mount Hunter drill site

Michael Palace will be a featured speaker at the TEDxPiscataquaRiver conference Friday, May 3 in Portsmouth, N.H. TED, short for Technology, Entertainment, Design, is an international program providing an "immersive environment that allows attendees and speakers from vastly different fields to cross-fertilize and draw inspiration from unlikely places." TEDx programs are local, self-organized events. A tropical ecologist by training, Palace also integrates audio field recordings into electronic music and will talk about the creative process, idea sharing, and interdisciplinary aspects of science.

Jingfeng Xiao coauthored a paper recently published in Environmental Research Letters. The main finding of the study, which was based in southwestern China, is that spring droughts could reduce plant growth and carbon uptake. The paper is featured in environmentalresearchweb.org/.

Ross Gorte joined the ESRC as an affiliate research professor of forest management policy. Gorte is a former senior policy specialist for the Resources, Science, and Industry Division of the Congressional Research Service in Washington, D.C.


Ross Gorte

Postdoctoral researcher **Eric Kelsey** won first prize for his poster "A Surprise in the North Pacific: Results From Applying a New Nonlinear Method for Calibrating Ice Cores" presented at the annual American Meteorological Society's 25th Conference on Climate Variability and Change in Austin, Texas. Kelsey is currently director of research at the Mount Washington

From the Director

SwRI-EOS Launches

I AM DELIGHTED TO ANNOUNCE an exciting, new EOS initiative: the creation of a research collaboration agreement between the University of New Hampshire and the Southwest Research Institute (SwRI) of San Antonio, Texas. The agreement builds upon existing collaborations between the two institutions on several space projects, many of them detailed in prior issues of *Spheres*, and which include the Magnetospheric Multiscale, Solar Orbiter, Van Allen Probes, and Lunar Reconnaissance Orbiter missions, among others.


Harlan Spence

But this formal agreement does much more than simply recognize past and ongoing collaborative projects in the Space Science Center; it prepares us to collectively take on larger and more complex projects, not only in space science, but also in the Earth and ocean sciences.

The agreement's preamble articulates the goals of this joint venture, which, in sum, are to seek research opportunities that enhance and fulfill our respective educational and scientific missions with the intent to advance our individual and mutual interests in space and Earth systems science, instrumentation, and discovery.

The collaboration combines the longstanding, complementary strengths of our two organizations in compelling ways. The 60-plus-year history of space science at UNH should be well known to *Spheres* readers; the SSC encompasses "studies ranging from

Observatory and a research assistant professor at the Judd Gregg Meteorology Institute of Plymouth State University.

Ocean Process Analysis Laboratory

Chris Hunt attended the ASLO (American Society of Limnology and Oceanography) conference in New Orleans late in February and gave a talk titled "Modeling the export of DOC from large watersheds and its influence on the optical properties of coastal waters." **Joe Salisbury** (OPAL), **Wil Wollheim** and **Rob Stewart** (ESRC) were co-authors.

Historical marine ecologists **Karen Alexander** and **Bill Leavenworth** of OPAL and **Jeff Bolster** of the UNH department of history were featured in the film "Cod Comeback?" broadcast on PBS in February. The film, an episode in the series "Saving the Ocean" hosted and produced by marine biologist and writer Carl Safina, explores the historical collapse of the rich cod fishing grounds of New England and Canada and looks for signs of recovery in the wake of widespread closures in the 1990s. The film can be viewed at http://video.pbs.org/video/2324025884.

Amanda Plagge started a postdoctoral position at the Thayer School of Engineering at Dartmouth College where she did her bachelor's and master's degrees. Plagge is working with a new faculty member who has a background in fluid dynamics and blade/propeller design but who is interested in wind energy—Plagge's topic of interest.

As part of her dissertation work, Ph.D. student **Rachel Feeney** is interviewing commercial fisherman from the N.H. area in an effort to determine whether the multi-species, groundfish catch-share system that went into effect in May 2010 is achieving theorized benefits. She is evaluating the biological, social, and economic impacts of the management regulations. Feeney is also working full time as a social impact analyst at the New England Fishery Management Council.

Space Science Center

Professor **Lynn Kistler** was named director of the Space Science Center. Kistler succeeds **Roy Torbert**, who now serves as director of the new Southwest Research Institute-Earth, Oceans, and Space Department (SwRI-EOS) located in Morse Hall.

EHIS calibration team

Cliff Lopate (principal investigator) and **Jim Connell** (co-investigator) report that the first flight instrument of the Energetic Heavy Ion Sensor (EHIS) for the first next-generation GOES-R weather satellite was recently tested at National Superconducting Cyclotron Laboratory at Michigan State University and delivered to Assurance Technologies Corporation for environmental testing. EHIS is part of the Space Environment In-Situ Suite (SEISS) for the satellite, which when launched will be the first in a series of four to replace the nation's aging, 30-year-old weather satellites in NOAA's Geostationary Operational Environmental Satellite Program. UNH has been contracted to build four EHIS instruments for the GOES-R, -S, -T, and –U satellites. EHIS, wrapped in protective foil and under nitrogen purge to ensure cleanliness for space operations, is pictured above at the test

the ionosphere to the Earth's magnetosphere, the local solar system, and out to the farthest reaches of the universe"—the center's catchphrase.

For over 40 years, the Space Science and Engineering Division at SwRI has also been a space science leader, with impressive capabilities and infrastructure for developing spacecraft instrumentation, avionics, and electronics for government and industry as well as serving as the lead institution for several full NASA missions.

The joint venture builds on the strengths of our two organizations—extending both in dimensions they do not presently have and thus providing opportunities for the next generation of scientists and engineers working on research projects that map to our institute's core.

After nearly a year of exploratory discussions and planning, the collaboration agreement recently became official upon signing by UNH President Mark Huddleston and SwRI President Dan Bates, and is now rapidly taking form and already leading to positive outcomes. On March 11th, SwRI opened a new department, the SwRI-Earth, Oceans, and Space Department (SwRI-EOS), located in Morse Hall on the UNH Durham campus.

This co-location with EOS enables additional and enhanced opportunities for working together on mutual projects. The first director of SwRI-EOS is a very familiar face to those at EOS and UNH—Professor Roy Torbert, former long-term director of the SSC. In addition to Torbert, nine UNH engineering and accounting staff will join SwRI-EOS, as will one SwRI scientist. We anticipate more staff will join as research ramps up with several new and ongoing efforts; joint proposals are already under review or in development as part of our new venture.

At a time when federal and state funding has put enormous pressures on higher education in general, and on research in particular in our case, we are excited by how this strategic alliance with SwRI makes us not only more robust, but opens up broader opportunities for our scientists and our students.

facility. Team members from left to right (kneeling) are, Dan Tran, Kevin Mello, Frank Kudirka, (standing) Dwayne Rhines, Cliff Lopate, Bruno Pape, Colin Frost, and Jim Connell.

In short, with this development we have grown our collective institutional strengths. While you read this issue of *Spheres,* consider the many dimensions of our current scientific research and how these will grow with the SwRI-EOS collaboration now in place.
– *Harlan Spence*

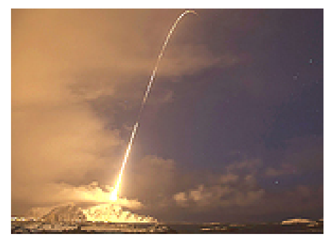
In January, **Allison Jaynes** successfully defended her thesis titled "Pulsating Aurora: Source Region & Morphology" and has moved on to a position with the Laboratory for Atmospheric and Space Physics at the University of Colorado. Jaynes is working on high-energy radiation belt physics through analysis of the Van Allen Probes' Relativistic Electron Proton Telescope (REPT) instrument data. REPT is part of the Energetic Particle, Composition, and Thermal Plasma (ECT) instrument suite, which is led by EOS director **Harlan Spence**.


Allison Jaynes

SSC scientists were part of NASA's latest round of selections for proposed CubeSat missions planned for 2014 launch. UNH, in partnership with Montana State University, will develop components for the Focused Investigations of Relativistic Electron Burst Intensity, Range, and Dynamics (FIREBIRD) II nanosatellite. Ph.D. candidate **Alex Crew**, along with his advisor and UNH mission lead scientist **Harlan Spence**, worked with Montana State on the first FIREBIRD mission, which was developed under the National Science Foundation's CubeSat program and is slated for launch this year.

Ian Cohen was named a NASA Student Ambassador for 2013 following a two-month internship at the Goddard Space Flight Center last summer working as part of the Magnetospheric Multiscale mission team. NASA inducted 86 "top-performing" interns into the 2013 NASA Student Ambassadors Virtual Community, a vital component of the agency's ongoing effort to engage undergraduate and graduate students in science, engineering, mathematics and technology (STEM) research and interactive opportunities.

Marc Lessard is principal investigator for the second Rocket Experiment for Neutral Upwelling, or RENU II, rocket launch recently funded by NASA. A follow-up to the first RENU launch in December 2010 from Norway's Andøya Rocket Range, which Lessard also led, RENU II is aimed at further measuring the complex, underlying physics behind the phenomenon of neutral upwelling or "satellite drag." The RENU multi-instrument payload will include five contributions from UNH's Magnetosphere-Ionosphere Research Laboratory and involve several graduate students. Launch is tentatively set for winter 2015-16.


RENU I rocket launch


Will Fox

Research scientist **Will Fox** reports he is the principal investigator on a recent two-year grant to run experiments on the OMEGA Extended Performance laser facility at the University of Rochester. The goal is to conduct controlled experiments on the dynamics of magnetic fields between colliding magnetized plasmas—an effort aimed at understanding the plasma physics in similar natural systems, such as the interaction between the solar wind and Earth's magnetosphere. The grant includes research funding and experiment time for four days on the machine. Fox also received an allotment of 7.8 million hours on the Kraken supercomputer at Oak Ridge National Laboratory for 2013 to develop and run advanced simulations in support of these experiments. UNH collaborators on the research are affiliate professor **Amitava Bhattacharjee** (now at Princeton University), **Kai Germaschewski**, and **Naoki Bessho**.

Taking part in February's IBEX meeting at EOS (see "IBEX: The Little Satellite That Could, and Does") were research associate professor **Harald Kucharek**, research project engineer **David Heirtzler**, and Ph.D. student **Trevor Leonard**. For the mission, Kucharek and Heirtzler have been keeping tabs on the special operations for the interstellar observations and providing the necessary data quality checking, while Leonard is doing the detailed data analysis work by sifting out the usable times and comparing the observations with the model that **Marty Lee** has worked on. **Eberhard Möbius** notes this work is being done in close collaboration with colleagues at the Space Research Centre in Warsaw, Poland who run another more sophisticated model.

Chuck Smith reports that funds remaining from last summer's Project SMART program will allow the space science/balloon project team to do some hardware development for three nighttime balloon flights in April and May. The night flights will conduct further science and take video images of aurora. Last July, SMART high school teachers and students successfully built, flew, and recovered a scientific payload that had been carried aloft by balloon to 105,700 feet. The aim of the current work, which is being done under the guidance of the program's veteran N.H. physics teachers Lou Broad of Timberlane Regional High School in Plaistow, Scott Goelzer of Coe-Brown Northwood Academy, and Rich Levergood of Londonderry High School, is to create a more powerful platform on which to build future experiments.

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