EOS SPHERES

Institute for the Study of Earth, Oceans, and Space • A University of New Hampshire Research Institute • Morse Hall, Durham, NH

Spring 2007

Vol. 6 Issue 2

On the Ground Floor of Outer Space

WHEN ED CHUPP ARRIVED AT UNH IN 1962, only five years had passed since the Soviet Union lobbed humankind's first artificial satellite into Earth orbit. Sputnik I, a 183-pound metal basketball that sped around the planet every 98 minutes, was a stunning cold war wake-up call and lit a fire under U.S. efforts to join the space race.

It was Sputnik that spurred Congress to create the National Aeronautics and Space Administration in October of 1958, and it was a good time to be in the space business.

"NASA offered a lot of support for people to get started in research and help the space program," Chupp recalls, "so I was very successful getting proposals approved in those early days."

Now, after some 45 years of research and teaching, of launching balloons and building satellite instruments to study gamma rays, emeritus professor of physics Edward L. Chupp has put down his proposal-writing pen, put aside his course syllabi, and has the luxury of looking for new gems in decades-old data he gathered.

"The scientists may get old but the data doesn't," Chupp says with a gravelly laugh.

Already, analysis of data from a major eruption on the Sun captured by the Solar Maximum Mission satellite in 1989 is revealing new things and will likely lead to published papers. Chupp was the principle investigator for the Gamma-Ray Spectrometer on board the SMM spacecraft, which flew for nearly a decade and was the object of NASA's very first in-space satellite repair mission.

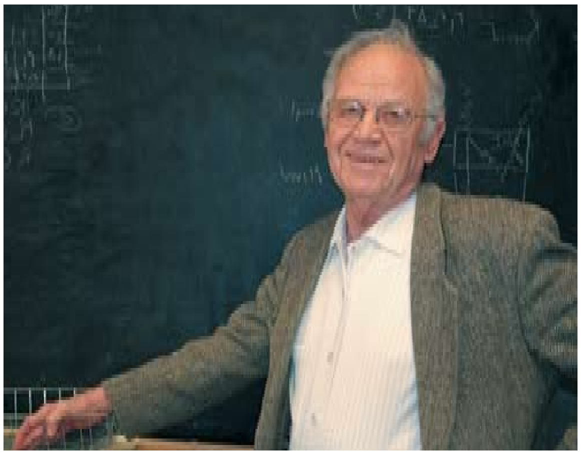

Photo: K. Donahue, UNH-EOS

Professor Emeritus Edward L. Chupp

Those were heady days indeed but Chupp is content to slow down and feels fortunate to have launched his career when he did.

"I don't write proposals anymore and I'm happy to just work on data analysis now without being under pressure, except my own. Besides, better to let the younger scientists compete for the money now," Chupp says. He pauses and adds, "Of course, the young people have a tough row to hoe with the cuts at NASA and the new manned exploration program, which is driving the future of space science and astrophysics. Science is taking a back seat, and that's not good in the long run for the country, in my opinion."

Nearly half a century ago, work in fundamental physics was in the driver's seat. Arriving at UNH after stints at the Lawrence Livermore Laboratory and Boeing, Chupp's first NASA-funded work involved using a small particle accel-

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Photo courtesy of Karen Von Damm

The arm of the remotely operated vehicle (ROV) Jason II measures the temperature of the newly discovered Medusa hydrothermal vent.

Medusa Down Deep

THE EASTER BUNNY was very good to oceanographer Karen Von Damm this year.

At 8 p.m. Easter Sunday, following an onboard egg hunt, Von Damm happened to be on watch as the research vessel *Atlantis* plied the waters above the East Pacific Rise off the coast of Mexico.

A chemical oceanographer and hydrothermal vent specialist, Von Damm was among the first of the crew to see video images of a newly discovered vent or "black smoker" coming back from the ship's camera-studded, remotely operated vehicle "Jason II" a mile-and-a-half below the surface.

The vents, which are associated with the spreading tectonic plates of the Earth's crust deep under the ocean, are mineral chimneys rich with extraordinary ecosystems that thrive in extreme temperatures and without the benefit of sunlight. And they have been the subject of Von Damm's research for years.

But hunting for the black smokers was but one of several objectives of the National Science Foundation-

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EOS SPHERES

EOS Spheres is published seasonally by the Institute for the Study of Earth, Oceans, and Space at the University of New Hampshire. We welcome comments and suggestions.

Spheres Newsletter
Institute for the Study of Earth, Oceans, and Space (EOS)
Morse Hall, Room 309
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Circulation: Clara Kustra
Printed with soy inks on 100% post-consumer recycled paper, manufactured chlorine-free.

From the Director

Spring is Busting Out all Over

AS WE IN NEW ENGLAND know so well, our long-awaited spring comes very slowly and then, suddenly, summer is upon us. In like fashion, we in the university community have patiently waited 12 months as two central leadership positions at UNH–president of the university and president of the UNH Foundation–remained open. Both have now been filled with two exceptional appointments.

Dr. Mark Huddleston will serve as the University of New Hampshire's 19th president. He brings three decades of experience in public and private higher education as a faculty member, dean, and senior administrator. During his 24 years at the University of Delaware, he chaired the Department of Political Science and International Relations, served as associate provost for international programs, and was dean of the College of Arts and Sciences. From 2004 to the present, Dr. Huddleston was president of Ohio Wesleyan University.

Mr. Donald Wilson, currently vice principal of university relations at the University of Sydney in Sydney, Australia, has accepted the position of president of the UNH Foundation. He brings to the foundation a strong background of more than thirty years in the development field.

During this period of transition we were most fortunate to have UNH Interim President J. Bonnie Newman and interim president of the UNH Foundation David Brownell step forward to serve these positions so extraordinarily.

Finally, as *Spheres* goes to press, the House is marking up the 2008 federal budget and it appears NASA's budget will be increased by nearly $300 million above the president's request, with a significant portion of this increase going to science.

After a long winter it appears that spring is busting out all over.
– Berrien Moore III

Earth/Ocean Science

Medusa

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funded *Atlantis* cruise. Moreover, some skeptics within the scientific community doubted that vents would be found in this region of seafloor.

"When we wrote the proposal for the cruise all of us really thought there would be hydrothermal activity down here," Von Damm said onboard *Atlantis* just after the discovery. She adds, "There was some evidence for it but a lot of people thought it wasn't very strong, and so you feel a little bit of a vindication. I was smiling a lot when those images appeared."

Added expedition leader Emily Klein of Duke University, "I've been going to sea for 20 years and I've been hoping to find my first hydrothermal vent site and finally I have. I'm ecstatic."

No wonder. Among the other creatures Jason had found was a pink form of the jellyfish order *Stauromedusae,* so named because of resemblances between the protruding tubework casings that festoon the chimney and the serpent-haired Medusa of Greek myth. Thus, the new find was dubbed the Medusa hydrothermal vent.

The bell-shaped jellyfish sighted near the vents "are really unusual, and the ones we found may be of a different species because nobody has seen types of this color before," said Von Damm, of the Complex Systems Research Center.

Even at vent-water temperatures of 700 degrees Fahrenheit, and without the aid of sunlight, a diversity of species—including 8-foot-long tube worms and giant clams—form colonies around these cracks that ring the globe.

Back on land, Von Damm notes that because the ship's instruments measured hydrothermal plumes in the water column—an indication of the vents within kilometers of the area—she believes other black smokers were in the area, which is different from a region she's been studying since 1991.

Photo courtesy of Karen Von Damm

The bell-shaped jellyfish of the order Stauromedusae *sighted nearby helped spawn the name of the new vent.*

Von Damm has been working on the chemistry of the hot springs at the East Pacific Rise at 9-10 degrees north latitude (referred to simply as "9 North") after she and colleagues discovered a new volcanic eruption at the site and were able, for the first time, to observe "time zero" in terms of the hydrothermal system's re-initiation and establishment of its biological communities.

On the dozen expeditions since, they have collected samples from the site and traced the evolution of the hydrothermal system. These include research cruises in early 2002, late 2003, March 2004, and late 2006.

With respect to hydrothermal vents and the recent vindicating find, Von Damm says, "I think over time we've learned there are hot springs almost everywhere on the mid-ocean ridges. You might not find them for several kilometers or even several tens of kilometers, but they're fairly ubiquitous with magma."

With each new discovery of a black smoker comes fresh excitement. Says Von Damm, "Every vent has a little different chemistry and they help us understand the processes going on in the oceanic crust and this helps us piece the puzzle together."

And because these dark, deep-sea environments differ starkly from other habitats on Earth where life flourishes, observations here could shed light on how extraterrestrial life might have evolved in similarly "harsh" environments on other planets. -DS

On the Ground Floor of Outer Space

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erator in the basement of DeMeritt Hall to study atomic spectral lines created by passing a proton beam through a thin carbon foil, which allowed direct measurement of the lifetime of atomic states.

Several of Chupp's graduate students did thesis work using the accelerator, which was eventually encased in concrete for safety reasons. The accelerator will remain entombed beneath the new DeMeritt Hall soon to be constructed on the same site.

Eventually Chupp moved from the basement of DeMeritt to the UNH football fields where he launched small, high-altitude balloons carrying gamma-ray detectors he, colleagues, and graduate students built. The balloons took the instruments above Earth's atmosphere, which absorbs the energy of this region of the electromagnetic spectrum.

Gamma-rays are the most energetic form of "light" and are produced in the hottest regions of the universe, including on our Sun and in supernovae, which can have gamma-ray bursts.

But what goes up must come down. Of the balloon launches and subsequent payload recoveries Chupp recalls, "We'd get a call from someone up in Vermont saying, 'We have your payload here, it about hit our barn.'"

> *"We'd get a call from someone up in Vermont saying, 'We have your payload here, it about hit our barn.'"*

The laissez-faire-football-field-launch-pad era came to an abrupt end after one balloon failed to achieve proper altitude and, instead, made a lazy, looping journey around Logan Airport in Boston and a very active Pease Air Force Base—just a stone's throw from Durham.

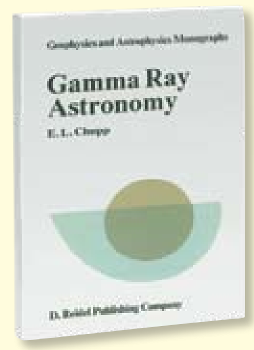
"I got a call from NASA a few days later," Chupp says, a twinkle in his eye. "They said I wouldn't be getting any more money for balloon work unless I started launching from their balloon facility in Texas."

The days of doing "hands-on" physics in the laboratory was the best part of Chupp's career. In the late 1960s, however, he was ready to move from balloons to satellites and successfully proposed the Gamma-Ray Monitor for the Seventh Orbiting Solar Observatory or OSO-7 mission launched in 1971.

OSO-7, and Chupp's instrument specifically, made history when on August 4, 1972, the very first measurements of gamma-ray lines from a solar flare were recorded.

Says Mark McConnell, Chupp's former Ph.D. student and now associate professor in the Space Science Center, "The presence of gamma-ray lines in solar flare spectra had been predicted but no one had been able to actually identify them until Ed." Chupp received the NASA Medal for Exceptional Scientific Achievement for the discovery.

McConnell notes that he came to UNH in 1980 as a graduate student in part because of Chupp's work. "Ed was known in the field at the time and had even written a book on the nuclear transition region of gamma-ray astronomy. He was a pioneer, he helped pave the way for future investigations in this field."



Gamma-ray lines are created when the nuclei within atoms transfer from an excited energy level to a lower level. Being able to detect and measure the intensity of gamma-ray lines from solar flares allows scientists to probe the composition and energy of accelerated particles involved in the process. The measurements also provide a window on the material with which those particles interact—the solar atmospheric composition. Says McConnell, "It allows you to really probe the heart and guts of the solar flare phenomenon."

The successful, 18-month-long OSO-7 mission was followed by the SMM satellite, which launched on Valentine's Day in 1980. In 1981, malfunctions in some instruments on the satellite reduced the original mission objectives. But the Gamma-Ray Spectrometer, developed and operated by Chupp, David Forrest, and Jim Ryan of SSC, and colleagues from the Max Planck Institute and the Naval Research Laboratory, continued full operations.

In 1984, SMM was taken on board the space shuttle Challenger and repaired. The spacecraft was then boosted into a higher orbit thereby extending its lifetime until December 1989. Among other things, it is the wealth of data from that mission that Chupp is peering at with hindsight and the illumination provided by subsequent missions.

"It's like archeology, somebody will dig up some new fossil somewhere and it will extend the knowledge about a certain era of history," he says of post-SMM missions that looked deeper into gamma-ray emissions. These include the Compton Gamma-Ray Observatory, which carried the Imaging Comptel Instrument

Photo courtesy of Edward Chupp

Graduate student Ed Chupp in 1953 at the University of California, Berkeley.

partially built at UNH, and the Reuven Ramaty High Energy Solar Spectroscopic Imager, RHESSI for short.

RHESSI opened a window on where exactly gamma-ray emissions on the Sun come from —something SMM couldn't do (although the SMM Gamma-Ray Spectrometer covered a wider energy range and was a more sensitive instrument).

"So using information from the newer missions will help us understand some of the more complex events we saw back in the 1980s or 90s," Chupp says.

Although alarmed by the direction NASA is currently headed and what its long-term implications for space science and astrophysics might be, Chupp is pleased with how successful and robust the Space Science Center has become.

"In the early days it was basically Roger Arnoldy, Jack Lockwood, Bill Webber, and myself. It was small then, now it's one of the strongest centers in the country, in my opinion. We have a strong experimental program headed by Roy Torbert and, now, having the Paul Chair with Amitava Bhattacharjee and a team of theoreticians complementing our Space Science Theory Group, that's a real asset," he says. (See related story page 5.)

In early May, to kick off a celebration of Chupp's long career, Gerald Share, SMM collaborator and a close colleague of Chupp's from the University of Maryland and the Naval Research Laboratory, gave a colloquium lecture reviewing the field of gamma-ray astronomy.

Afterwards, at a reception held at the New England Center, Chupp was praised and roasted as the "grand old man of the Space Science Center" by EOS professors and colleagues Berrien Moore, Roy Torbert, and Jim Ryan.

After listening to them spin their yarns, Chupp closed the celebration and officially began retirement from teaching by saying, "I look forward to still being around when some of my colleagues retire, like Berrien, Roy, and Jim, so I can make a few appropriate comments."-DS

Clearing the Air

Researchers from two EOS centers are using sophisticated new robotic instruments to sharpen their respective views of the atmosphere and ocean

IMAGINE SHINING A FLASHLIGHT down a deep, bubbling well to identify the bacterium that has spoiled your water. Imagine further that 90 percent of the light gets reflected back from the air in the well making it very hard to see the water surface.

Welcome to the world of ocean color remote sensing, a field of research that uses satellites orbiting hundreds of miles above Earth to analyze in detail the complex, ever-changing waters of the world's oceans through an equally complex and dynamic atmosphere. All that air, and the minute particles known as aerosols in particular, gets in the way and the ocean color data get obscured or "lost" in the signal.

This is particularly true over coastal ocean waters in the Gulf of Maine due to the dirty continental air that travels from the west and up the Eastern Seaboard by prevailing winds. For this reason the New England region is often referred to as the "tailpipe" of the U.S.

Further complicating matters is the fact that coastal ocean water is vastly more complex to "read" by satellite than the open ocean because it's a mixture of many substances—sediments and pollution from the land, phytoplankton in the water, for example.

"There's a complex mixture of aerosols in the atmosphere in addition to a complex mixture of what's in the water, and this makes it very difficult," says Janet Campbell, director of the Ocean Process Analysis Laboratory. The lab studies the waters of the Gulf of Maine through both remote sensing and monthly cruises, the latter which gather an array of in-water chemical and biological data. (The "color" in ocean color remote sensing represents the biological, chemical, and physical signals a satellite sees in the water.)

So how does one take that aggregated satellite signal and "deconvolve" or untangle it into its various components so that it can be understood?

"That's one of the big challenges remaining in the field of ocean color remote sensing research. Just interpreting the water mixture is difficult, and this has been the subject of my research and that of my graduate students for years now," Campbell says.

Campbell, who leads the Bio-optical Oceanography Group within OPAL, notes that while colleagues at other institutions have been working on the problem of estimating what's going on in the atmosphere with aerosols—a process known as "atmospheric correction"—and have created a computer algorithm used to make that correction, her group has only tried to interpret the complex water signal itself.

One good reason for ignoring the problem of "removing" the atmosphere is that very little hard data has been available on the type and amount of "tailpipe" aerosols that muck up satellite imagery for ocean color remote sensing in the coastal region. But that's about to change.

OPAL research scientist Hui Feng, in collaboration with research associate professor Doug Vandemark, is currently addressing one possible method of estimating the atmospheric aerosols over the coastal ocean and plans to apply the method in conjunction with recently acquired ground-based instruments that measure aerosol properties.

Through a NOAA-UNH program called the Joint Center for Ocean Observing Technology, which involves OPAL and the Climate Change Research Center's AIRMAP program, four state-of-the-art instruments will soon automatically scan the sky at regular intervals to give an extremely accurate portrait of aerosol properties, size, and structure. The derived data should make the atmospheric correction for the New Hampshire coastal/Gulf of Maine region much more accurate.

Photo courtesy of Feldman, G.C., C. R. McClain, NASA Goddard Space Flight Center

A true-color image, i.e., without "atmospheric correction," of the Gulf of Maine, March 24, 2000, captured by the SeaWiFS sensor aboard the SeaStar satellite.

The instruments, two sunphotometers and two micropulse lidars, will be part of AIRMAP observatories on Appledore Island, located 10 miles offshore from Portsmouth, and another at Thompson Farm in Durham.

Says AIRMAP project manager Kevan Carpenter, who is in charge of the observatory instrumentation, "These instruments really bring us to another level with issues critical to climate change—aerosol formation, change, and structure in the atmosphere—and they will help tremendously to validate our models."

For ocean color work the much-needed aerosol information will also improve modeling efforts but, notes Feng, not before he and others determine why current atmospheric correction algorithms often fail in this region.

"First we have to characterize what's causing the problem, why we're losing so much data in coastal waters, before we can precisely remove the aerosol contribution and make the atmospheric correction," Feng says. The data from the new instruments will be compared with satellite data to better make that characterization.

Sunphotometer

While all this represents a big step forward for both camps—atmospheric scientists and oceanographers—Campbell and Vandemark note that until satellites are built expressly for making coastal ocean observations their work will remain challenging.

Says Vandemark, "Current satellites weren't designed to do coastal work, they're open ocean systems, so it's always pushing a satellite's capabilities when you bring it into the coast" due to the complexity of the signal from both the water and the atmosphere.

Campbell adds that one of the recommendations made by the recent National Academy of Sciences "Decadal Survey," for which EOS director Berrien Moore was co-author, was that a satellite dedicated to coastal ocean observation be launched within the next decade.

"The coastal ocean has generally been beyond the capability of existing missions, it's always sort of fallen through the cracks," Campbell says. "The land people have their satellite technology and the ocean people have theirs, but the interface between the land and sea presents problems. It has not received the attention it deserves, until now."-DS

Space Science

Reconnection, Magnetic and Otherwise

The Paul Chair of Space Physics four years on

IT'S A SMALL WORLD AFTER ALL. When Amitava Bhattacharjee left the University of Iowa to occupy the newly established Peter T. Paul Chair in Space Science at UNH, little did he know that his partner, Melissa Deem, who would also swap university jobs, had her own Peter Paul connection; Paul's physician-father of Troy, N.H. once saved the life of Deem's grandmother.

"Doctor Paul saved her with a direct blood transfusion," Deem says. She adds, "My grandparents were quite poor. My grandfather was a welder and he'd do work in exchange for some medical services. He built the swing set Peter Paul used as a child." That child grew up, headed west, did very well for himself and, recently, became a philanthropist.

"Between 1940 and 1969 my father was for much of the time the only general practitioner for the town of Troy," notes Paul, who graduated from the UNH Whittemore School of Business and Economics in 1967 and later founded and was president and CEO of Headlands Mortgage Company. In 2001 he gave the university $10 million to establish chairs in space science and developmental psychology. The Dr. Samuel E. Paul Chair in Developmental Psychology was established in memory of his father.

Photo: K. Donahue, UNH-EOS

Amitava Bhattacharjee

Of his investment in space science at UNH, Paul believes the endowment might be called a "poster child" of success in that a host of scientists joined Bhattacharjee in coming to the UNH Space Science Center and Department of Physics to further strengthen work being done in theoretical plasma physics—including investigations into two fundamental physical processes that occur in the universe, magnetic reconnection and turbulence.

"It's bolstered and broadened a strong group that can definitely compete in the first tier nationwide in this area," Paul says.

Plasma is the hot, ionized gas that makes up 99 percent of the visible mass of the universe. Magnetic reconnection is a process where the plasma within magnetic fields—like that in the Sun's corona or Earth's magnetosphere—breaks apart, reconnects, and liberates vast amounts of energy. This same process occurs in experimental controlled thermonuclear fusion reactors.

Bhattacharjee (pronounced "bah-tah-CHAR-jee") notes the Paul endowment provides leverage for supporting high-risk, high-gain research and has paved the way for grant writing to external agencies, which "I think, like to see seed money put forward by institutions," he says.

Indeed, the SSC plasma theory and computer simulation group led by Bhattacharjee was recently awarded a $1.7 million grant from the Federal Department of Energy for a new center that will use advanced, high-performance, parallel computing techniques to better understand magnetic reconnection and turbulence.

Called the Center for Integrated Computation and Analysis of Reconnection and Turbulence, the new center is a collaborative effort with Dartmouth College. In addition to federal money, the center will receive matching funds up to 50 percent from UNH and Dartmouth as required by the award. Approximately one-sixth of the matching funds from UNH were committed from the Paul Chair endowment by Bhattacharjee.

The establishment of the new center is particularly satisfying for Bhattacharjee because, when he arrived at UNH four years ago, he brought with him a similar DOE-funded center he directed—the multi-institutional Center for Magnetic Reconnection Studies. But as DOE shifted gears that center "came to a natural end programmatically," Bhattacharjee says.

"So for the last four years, as a group, we have painstakingly taken advantage of every opportunity large and small, and I think with the establishment of CICART the circle is closed and we now have in place a center with greater resources and an enhanced research mission than the center I came with from Iowa," he says.

Co-investigators of the new center are Naoki Bessho, Ben Chandran, Kai Germaschewski, Phil Isenberg, Chung-Sang Ng, and Bernie Vasquez of the SSC, Joe Klewicki, dean and professor of mechanical engineering at the UNH College of Engineering and Physical Sciences, and Barrett Rogers of Dartmouth.

In addition to the new center, Bhattacharjee notes, UNH is now also part of a National Science Foundation Physics Frontier Center called the Center for Magnetic Self-Organization led by the University of Wisconsin-Madison. "Next year, when the center goes up for renewal, we'll be going in as a core part of the CMSO team."

Leading one center and partnering with another in this area of plasma physics positions UNH and the SSC very well in years ahead, particularly in light of NASA's budgetary strains, Bhattacharjee asserts. "It's really good to have this mandate to do basic science supported by DOE and NSF."

Bhattacharjee is also hopeful that the SSC theory and simulation group will be able to play an active role in the Magnetospheric Multiscale Mission as part of the MMS Interdisciplinary Science Team. Two years ago, UNH was awarded $38 million from NASA to build a suite of instruments for the MMS mission.

Reflecting on his four years as Paul Chair, Bhattacharjee says he is grateful to have found "instant community" with colleagues in the institute in general and the Space Science Center and the Department of Physics in particular. "The relationship is really a model for how a department and center can work together," he says.

The only dark clouds on an otherwise sunny horizon, Bhattacharjee notes, are the growing pains the university continues to experience as it evolves into a full-fledged research institution. "It is vital that UNH preserve the incentives for research—research that is aligned with its educational mission," he says.

On a more personal level, Bhattacharjee says that having had the chance to get to know his benefactor has been a rare pleasure. "You often don't have that opportunity," he says adding, "and, conversely I think Peter Paul, too, has enjoyed learning about the science that is being done by the money he has given."

Says Paul, "I follow it, but the physics is a little tough." He notes, however, that Bhattacharjee's 2005 textbook, *Introduction to Plasma Physics with Space and Laboratory Applications*, co-authored with a colleague from the University of Iowa, "did prompt quite a bit of interest as a coffee table item."

Adds Paul, "Let's just say I've got a *Reader's Digest* understanding of his work, but I do look forward to following Amitava's career for quite a while."
-DS

Getting at the Root of the Problem

The complex, intertwined world of roots and fungi proves elusive to scientific investigation

SCIENTISTS MODEL THE CIRCULATION OF OCEANS, the transport of air masses around the world, and global climate change scenarios well into the future. Even the complexities of an entire forest ecosystem can be modeled top to bottom, almost.

"Ecosystem models currently stop at the roots, they don't really consider the functioning of soil fungi at all," says Erik Hobbie, a Complex Systems Research Center terrestrial ecologist.

Not that the fungi don't matter. On the contrary, the relationship between mycorrhizal fungi and tree roots is one of the classic give-and-take relationships in nature.

Trees produce sugars during photosynthesis and send them belowground as food for the fungi whose hairy filaments or "hyphae" are woven around the fabric of the tree roots. In return for the meal, the symbiotic fungi, which are more skilled than roots at extracting nutrients from the soil, pass these along to the trees. The fungi also protect tree roots against pathogens and filter out potentially toxic metals such as aluminum. Not bad for the oft-maligned fungus.

A mushroom, in this case Amanita muscaria, *is the fruiting body of mycorrhizal fungi. Below ground the filamentous hyphae are woven around fine root tips.*

Indeed, says Hobbie in ecologist lingo, "Trees are essentially obligate symbionts, meaning they will not survive without their fungal partners."

Hobbie is particularly interested in understanding the importance of mycorrhizal (meaning "fungus root") fungi in forests as a carbon sink (storage) and as a source for nitrogen—the latter being the nutrient that most commonly limits plant growth.

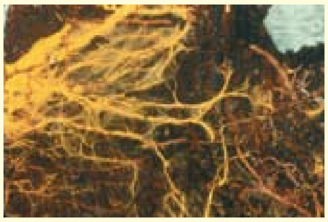
"The fungi might be getting 10 to 20 percent of the plant net primary productivity that is shunted belowground to support them in their symbiotic relationship with roots. So that's a very important component of the budget that right now is just being lumped into the roots," he says.

All of which means that a standard tool in today's scientific toolbox—computer modeling—is missing a gear.

"Models are about quantifying the interconnected processes that make up a system," says CSRC forest ecologist Scott Ollinger who, among others, is currently working with Hobbie on a project at the Bartlett Experimental Forest in New Hampshire's White Mountains. Adds Ollinger, "So if we can't quantify a process it's very difficult to include in a model."

Without a clearer picture of this subsurface world, scientists cannot effectively piece together just how much carbon and nitrogen are passing through or being held in these systems.

"We're trying to at least put a high-low range on how much of the carbon and nitrogen cycle gets processed through the fungal system. Even just knowing if it's a small, medium or large number will help," Ollinger says.



Mycorrhizal mat

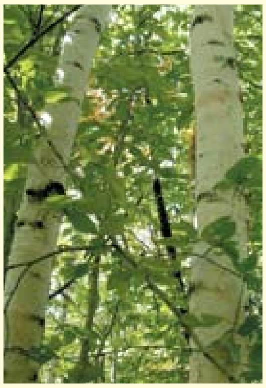
But figuring out which pathway—directly through roots or through roots via the fungi—these essential elements are traveling is tricky.

"Trying to do this requires a number of different methods," Ollinger notes adding, "all of which are far from perfect." In other words there's virtually no way for scientists to observe fine roots and mycorrhizal fungi on their home turf, as it were, without disturbing them and altering their environment.

One promising, indirect method is to measure isotopes—forms of the same element differing in atomic weight—to trace the pathways through which elements travel. Different isotopes will move at different rates through biological processes within an ecosystem and leave a distinctive "fingerprint" of that passage. In his work, for example, Hobbie uses different isotopes of carbon and nitrogen to infer what gets processed by fungi or roots.

Hobbie's work has been made easier by the recent arrival on campus of a mass spectrometer that can measure isotopic concentrations of various elements. (The isotopic method is just one aspect of the team's Bartlett Forest project.)

Made possible with a grant from the National Science Foundation and matching funds from UNH (including money from EOS, the Marine Program, the Office of the Vice President for Research, and the College of Life Sciences and Agriculture), the half-million-dollar instrument is being used by researchers across campus doing a diversity of environmental science-related work. (See related story on page 7.)



Birch trees in the Bartlett Experimental Forest

Further complicating an already complex situation, Ollinger notes, is a recent hypothesis that takes the age-old understanding of how elemental nitrogen is actually made available to plants and turns it on its head.

In a nutshell, it has long been thought that before nitrogen could be taken up by a plant the process of mineralization needed to occur; leaves and twigs fall to the ground, are decomposed by microbes, and nitrogen in its inorganic form, ammonium, is released into the soil. But notes Ollinger, "There is some evidence suggesting organic nitrogen in soil, which is what it is before it's mineralized, can be taken up directly and made useful to the plant if done by mycorrhizal fungi."

If this proved to be the case, it would be a short circuit of the mineralization process and provide a competitive advantage to certain trees. Hobbie and Ollinger are working to incorporate such direct uptake of organic nitrogen by mycorrhizal fungi into their models.

Making things even more interesting, in the soil and for researchers, is the fact that when nitrogen rains down from above in the form of acid precipitation, Mother Nature's intricate design gets a jolt. Specifically, there is some evidence that trees getting more nitrogen via the atmosphere lose their incentive to "play nice" with the fungi and, in turn, the relationship falls apart.

"We see declines in diversity and abundance of mycorrhizal fungi in areas with higher nitrogen pollution and deposition," Ollinger says. This in turn may make the trees more vulnerable to root pathogens and other environmental stresses.

Adds Hobbie, "Through our fieldwork and modeling, we will help forest managers to predict how trees and their associated mycorrhizal fungi will interact to control forest functioning in the future." -DS

Student Profile

Two's the Charm

MASTER'S STUDENT RICH MACLEAN was awarded a NASA-New Hampshire Space Grant Consortium Fellowship for the academic year 2006-07 and the funds helped him defray some costs of thesis work he's doing in the Complex Systems Research Center's Forest Ecosystems Research Lab.

He was able to purchase the special nitrogen- and oxygen-free polypropylene filters that wouldn't contaminate the results of his experiment. And he secured some of the double-labeled isotopic potassium nitrate that is at the very heart of his project–and costs a mere $1.8 million per pound.

Photo: D. Sims, UNH-EOS

Rich MacLean

Lucky for MacLean he only needed 200 milligrams of the stuff and spent just $801 of his fellowship money. Other supplies he needed were dirt cheap, literally. MacLean went to the Harvard Forest and dug up some soil next to plots where chronic nitrogen deposition experiments began in the late 1980s by CSRC's John Aber.

MacLean's thesis work picks up, in a sense, where some of the Harvard Forest work left off.

While Space Grant very broadly defines the "space-related disciplines" for which it provides graduate students support—including Earth sciences with a "planetary view"—MacLean's project perhaps stretches even that boundary. It certainly is expanding the horizon in his chosen field.

"This project was particularly interesting to me because it's pushing the envelope a little bit," MacLean says of his project.

In an effort to get at one aspect of a question that has confounded ecologists for nearly 20 years —where does all the nitrogen dumped into an ecosystem go?—MacLean is using a tricky isotopic technique he hopes will not only provide an answer but also prove his chosen method. So far, so good.

Says MacLean, "Currently my project is one part investigation of a process—trying to demonstrate, yes or no, this process is occurring, and one part methodological experiment—is this method of using a doubly labeled compound feasible? I only have preliminary data back but they show the patterns I was expecting based on my hypothesis. It seems to be positive for both."

Put simply, MacLean is trying to figure out if nitrogen can be chemically removed from a soil system rather than biologically by plants and animals. The latter method, the process of mineralization, has long been thought to be the primary method.

However, the chronic nitrogen deposition experiments at Harvard Forest first discovered that some other mechanism had to be at work.

Forest plots at Harvard were doused with labeled nitrogen and scientists expected to see the stuff pouring out the other end of the system in short order. Not only did that not happen but also, in some cases, it took just 15 minutes for a good portion of the nitrogen to "vanish" into the soil.

"So the thought was it must be abiotic or chemical because its removal was too rapid," MacLean says. He adds that while experiments have been done on the "abiotic immobilization" of nitrogen in soil, the methodology used—soil sterilization—is incomplete, alters the soil itself, and does not provide adequate answers.

No experimenters have used a single compound with two isotopes to try and settle the matter. (To solve the riddle, MacLean is using the new UNH mass spectrometer. See story page 6.)

By experimentally following the fate of heavy nitrogen (15-Nitrogen) and heavy oxygen (18-Oxygen) on a single compound, MacLean hopes to be able to differentiate between abiotic immobilization (chemical removal) and biotic assimilation (uptake by plants or animals).

This is possible because, after being processed through the soil, the single compound will end up with both isotopes if chemically immobilized but will be heavy with nitrogen only if the pathway was via plants, bacteria, or fungi.

Explains MacLean, "If this process is occurring, if I'm able to demonstrate it, it would be another pool of nitrogen in the soil that would need to be accounted for when you're trying to track the fate of nitrogen—whether or not it's available to microbes, fungi, plants, how long is the residence time of this pool, and how large is the pool?"

It could be, in other words, another important piece in the "where's the nitrogen" puzzle that scientists continue to wrestle with. -DS

Faculty/Student News

As *Spheres* goes to press, **Mark McConnell** reports that the GRAPE detector is poised to hitch a ride aboard a NASA balloon flight from Palestine, Texas. GRAPE, for Gamma-ray Polarimeter Experiment, is an array of detectors developed at EOS for studying polarized X-rays (see spring '07 *Spheres*).

CCRC's **Cameron Wake** was invited to testify at the first field hearing of the new Select Committee on Energy Independence and Global Warming chaired by U.S. Senator Edward Markey. The hearing, held the first week in June on the summit of Cannon Mountain in Franconia, N.H., was entitled "Global Warming Mountaintop 'Summit': Economic Impacts on New England."

According to **Eberhard Möbius**, following a series of tests conducted on the IBEX mission instruments built at EOS over the past two years, "IBEX is now well on its way towards integration on the satellite this fall, and it is on track for launch next year in June." Möbius also notes that while conducting tests at Bern he took a break to attend a symposium entitled, "The Sun, the Heliosphere, and the Earth" on the occasion of the International Heliophysical Year (IHY) 2007-08, where he gave an invited presentation on IBEX and discussed with colleagues the coordinated investigation programs during the IHY.

In early May, CSRC's **Barry Rock** joined NASA's James Hansen, director of the Goddard Institute for Space Science, as an expert witness in a court case brought against the State of Vermont on behalf of the Automobile Manufacturers of America. The AMA is trying to prevent the enactment of legislation requiring new fuel economy standards.

Ben Chandran was awarded a grant for $353,000 from NASA's Living With a Star Program to study "Stochastic Particle Acceleration in Solar Flares."

Along with colleagues from other institutions, **Pingguo He** of OPAL is organizing an international symposium on haddock conservation, harvesting, and management to be held in Portsmouth next October.

Fernando Espirito-Santo, a Ph.D. student in CSRC working with Michael Keller and Rob Braswell, was awarded a NASA Earth System Science Graduate Fellowship.

Ph.D. candidate **Shane Bradt**, a former Space Grant fellow, received an Outstanding Student Paper award from the American Geophysical Union.

We bid a fond farewell and say "job well done" to **Laurie Lalish**—former *Spheres* Circulation Manager and EOS Director's Office Administrative Assistant extraordinaire—and send her all the best in her new position as Program Assistant for the Coastal Response Research Center at UNH. We will miss you, Laurie!

Laurie Lalish

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Captain Jack and the Halogen Hunters

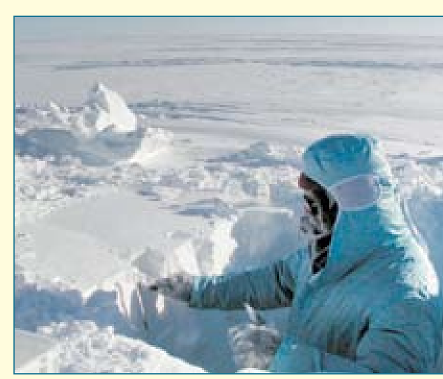
WHEN THESE PAGES LAST REPORTED on atmospheric chemist Jack Dibb's long-term work on the snowfields of Summit, Greenland (*Spheres*, Spring 2004) he was digging further into a surprise finding he and other researchers had stumbled upon in 1998 at both Summit and the South Pole.

That year, the multi-institutional team of 12 researchers Dibb was leading at Summit discovered high levels of nitrogen oxides above the snow and "astronomical" levels right in the snowpack itself. Recalls Dibb, "The whole issue of a lot of reactive gases pouring out of the snow into the atmosphere wasn't even on anybody's radar screen at that point." The finding opened up a new area of investigation—snow photochemistry.

Dibb, of the Climate Change Research Center, along with graduate student Luke Ziemba, project engineer Pieter Beckman, and a team of colleagues from eight institutions returned to Summit in early May to see if another reactive group of chemicals, halogens, are being formed in the snow at Summit or are transported from elsewhere.

"We're trying to determine whether tropospheric chemists have overlooked the importance of halogens on a global scale," Dibb reports from the field. If the halogens are confirmed to be sufficiently abundant at Summit, they will have large impacts on nitrogen, ozone, and radical chemistry above the snow. The work is part of a decades-long effort to understand Earth's past and future climate.

The biggest surprise would be if the halogens—a family of very reactive elements —were found to be mixing down from the free troposphere, confirming a recent hypothesis that they might be ubiquitous in the global atmosphere.



Jack Dibb collects snow samples for ion analysis.

Because their snow photochemistry findings to date have shown that surface snow gets chewed up by photochemical reactions and new compounds that weren't in the atmosphere at the time can get formed, Dibb notes that the work has important implications for ice core records of past atmospheric conditions.

"Ice cores may be the best place to get past atmospheric composition information but there are all these open questions about the accuracy, resolution, and fidelity with which snow records the composition of the air above it," he says.

A two-part podcast about the research can be viewed at http://passporttoknowledge.com/polar-palooza/pp06geos03.php -DS