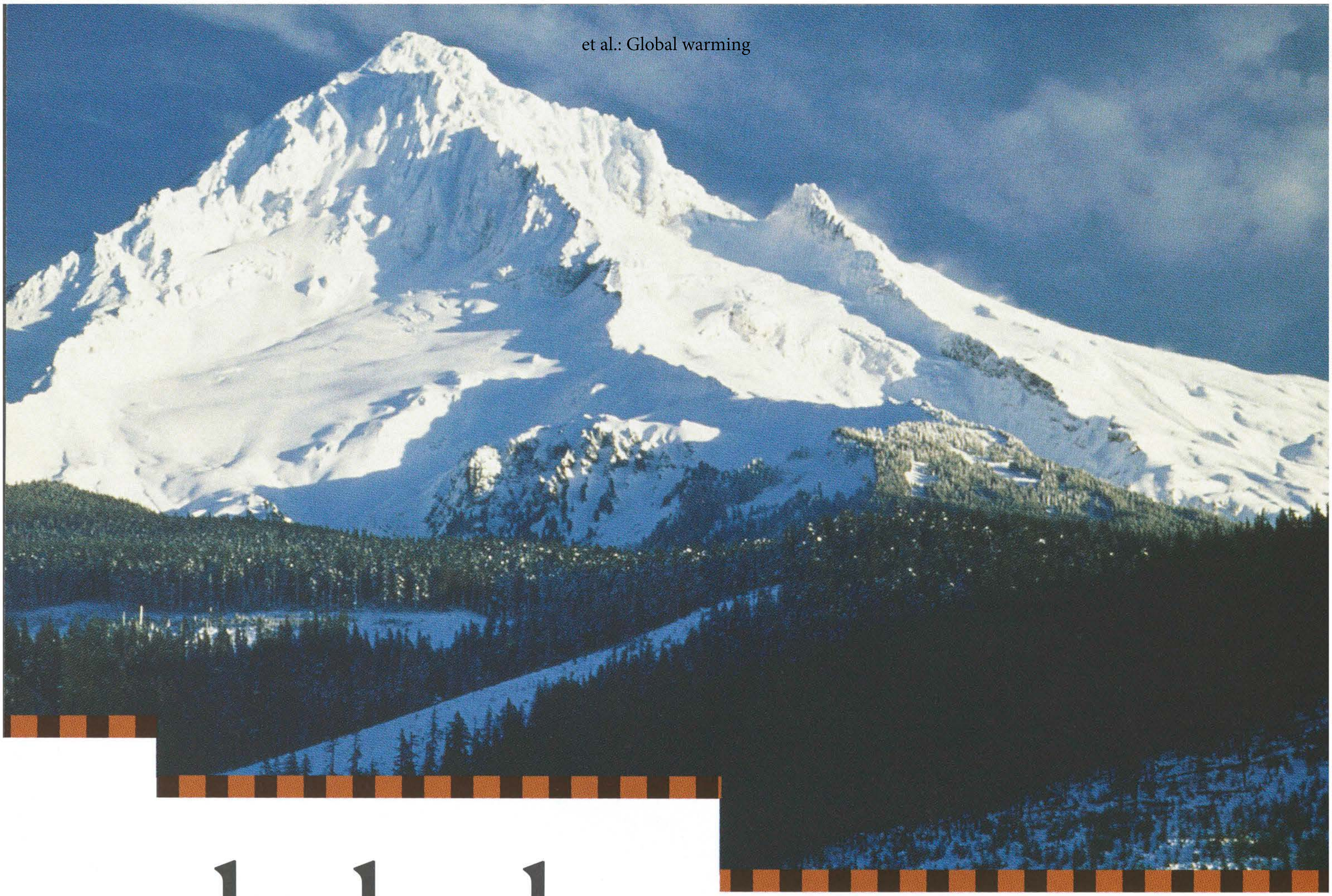


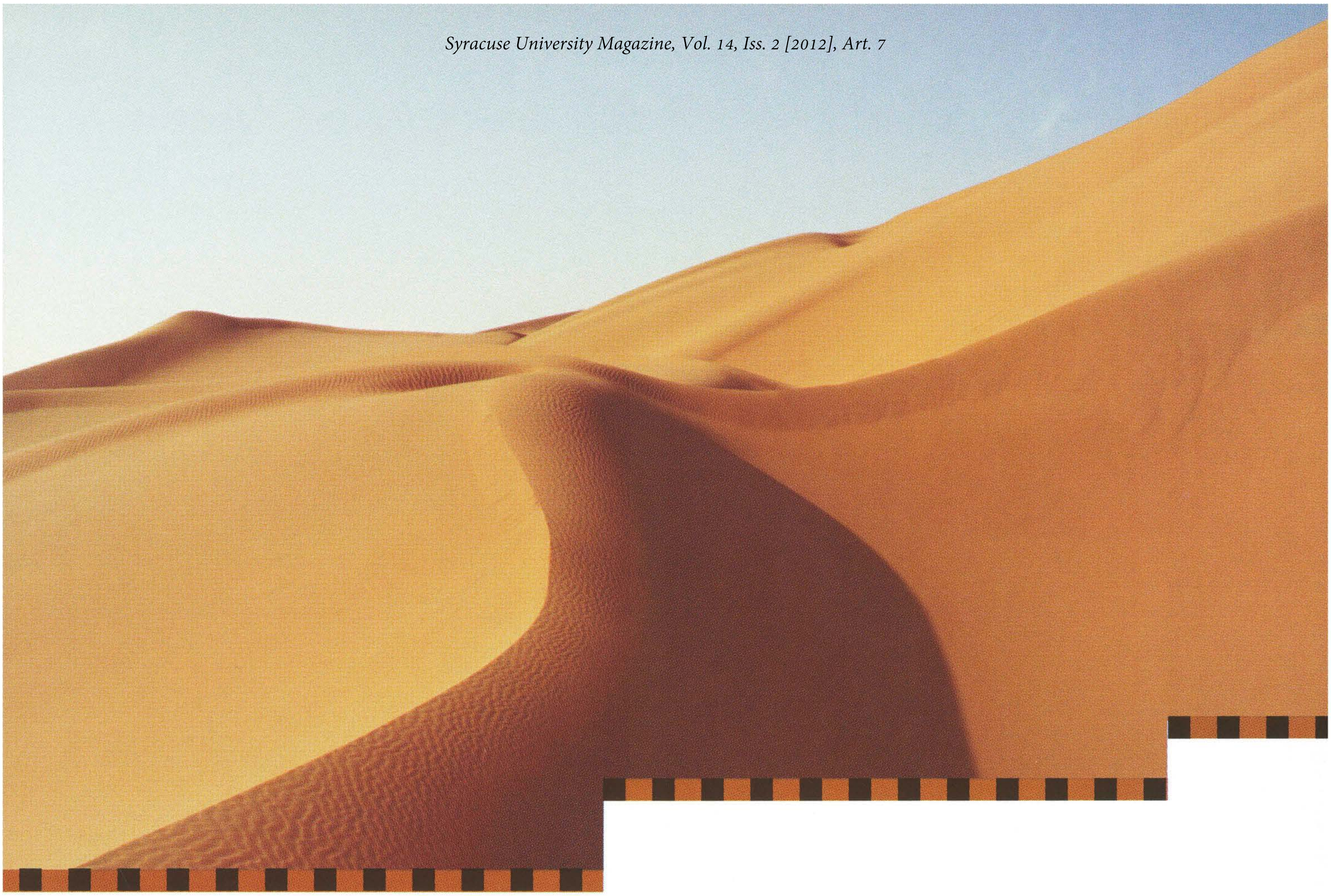
global warming

by jay cox

Hurl a mega-billion-dollar natural disaster at humanity and it's noticed. Mention global warming and hardly anybody breaks a sweat. In a society that often thrives on immediacy, global warming is the epitome of the slow burn. Its potential wrath—if scientific predictions pan out—could be decades down the road, making it seem like a car crash unfolding in super-slow motion.

To avoid such an outcome, a majority in the scientific community has served notice: Global warming is happening, and society had better act before future generations inherit one big mess to mop up. "Global warming is the most pressing scientific issue of our time," says Syracuse University professor Henry T. Mullins of the Department of Earth Sciences in The College of Arts and Sciences.

Mullins is among a handful of scientists at Syracuse University and the State University of New York College of Environmental Science and Forestry (ESF) engaged in research directly or peripherally connected to this topic. Their fieldwork stretches from the White Mountains of New Hampshire to the glaciers of the Andes, and covers everything from the paleoclimatic history of New York's Finger Lakes region to the effects of soil warming. While their opinions on global warming range from extremely cautious to dead certain, their probing questions and research demonstrate the enormous complexity of the issue and tremendous consequences should we ignore the warning signs. "We're entering a realm the Earth has never seen," says Charles A.S. Hall,



through research and other initiatives, syracuse faculty and alumni help unravel the mystery behind our slowly simmering earth

professor of environmental and forest biology at ESF. "If the greenhouse warming increases in any way relative to the increase in carbon dioxide, something big is going to happen."

Big may well be an understatement. What other issue rolls the intricate interactions of air, land, water, and humankind into one colossal conundrum that could turn large portions of real estate into ocean flooring, shift entire agricultural zones, launch assaults on human health, and generally wreak environmental, economic, and social havoc? While it may be hard to envision dealing with such devastation, consider the damage of one deadly hurricane, quake, or season of El Niño. According to the federal National Climatic Data Center, 21 national weather disasters between August 1992 and May 1997 resulted in more than $90 billion in damage and claimed more than 900 lives. Most scientists believe global warming will raise sea level; increase the frequency of extreme weather events and natural catastrophes like cyclones, hurricanes, droughts, floods, and heat waves; alter precipitation patterns; and change ecosystems worldwide. Of course, while raising a ruckus for humans in some regions, it could bless others. But what conscientious global citizen wants to see the biosphere roughed up in such a radical manner just to see who wins and loses?

The problem isn't that we're intentionally creating climate change. But we are active participants in the process, thanks to our proclivity for combusting fossil fuels like coal, oil, and natural gas. At the root of global warming is an unprecedented rise in the atmospheric concentration of carbon dioxide and other greenhouse gases—which trap heat and foster warming—and their long-term accumulation. Since the Industrial Revolution kicked into gear, the atmospheric carbon dioxide concentration has shot up 30 percent to 360 parts per million, the highest in 150,000 years. The concentration of methane, another greenhouse gas, has leaped a stunning 145 percent. Then there's water vapor, the real wild card among greenhouse gases. The potential impact of change in water vapor in combination with cloud cover continues to baffle scientists. "Changes in water content of the atmosphere would have huge effects and, in my opinion, are very difficult to predict," says Charles Driscoll Jr., Distinguished Professor of Civil and Environmental Engineering at the L.C. Smith College of Engineering and Computer Science.

The increased level of carbon dioxide causes what scientists call an "enhanced greenhouse effect," which could jack up the Earth's temperature from 1.6 to 6.3 degrees Fahrenheit by 2100, some studies show. During the last century, the global average surface temperature has increased 1.1 degrees Fahrenheit to about 58 degrees. In *The Encyclopedia of the Environment*, contributor Hall explains that Earth's temperature is "a result of the balance between incoming short-wave solar radiation and the long-wave radiation that is reflected back to space." Atmospheric carbon dioxide and water vapor capture a small portion of reflected long-wave radiation, changing energy to heat, Hall notes. "As the concentration of carbon dioxide in the atmosphere increases, more long-wave radiation is absorbed and converted to heat, leading at least in theory to a global warming."

Much of the scientific community appears to have reached a consensus that human activities are, indeed, cranking up the thermostat. However, as SU earth sciences professor William Patterson says, "it's not so easy to ascribe a culprit." Skeptics can point to the climate's natural variability, question the validity of sophisticated computer modeling forecasts, and argue that equating rising carbon dioxide concentrations with rising temperatures is not a simple cause-effect relationship. For such reasons, the politics of global warming certainly hasn't subsided. Many auto and energy industry officials, for example, believe instituting stringent emissions controls and energy regulations to curb global warming could devastate economies. Many also believe that any measures should be voluntary and emphasize improving the efficiency of energy-related technology. "We are opposed to binding targets and timetables," says Linda Schoumacher, spokeswoman for the Edison Electric Institute, a trade association for more than 100 investor-owned electric companies. "We believe they are overly prescriptive and not, at this point, necessary. There is time to take reasonable action."

The trade association participates in Climate Challenge, a joint, voluntary effort between the U.S. Department of Energy and the electric utility industry aimed at reducing greenhouse gas emissions. Such efforts, which allow for flexible, voluntary initiatives and the advancement of technology, should be the course of action, Schoumacher says. "Our position is there is no scientific consensus about what action needs to be taken right now. For us to go through top-down, binding targets and timetables is not suggested by the science."

The Earth's atmosphere is composed of:

79% nitrogen

20.9% oxygen

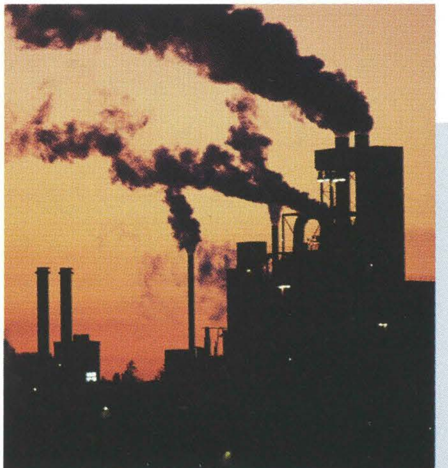
0.036% greenhouse or trace gases (such as water vapor, carbon dioxide, nitrous oxide, methane, and chlorofluorocarbons)

W. Henry Lambright, director of SU's Center for Environmental Policy and Administration at the Maxwell School of Citizenship and Public Affairs, sees global warming as the kind of scientific issue that will never be resolved 100 percent. "So the question is how much you need to know before you make public policy," says the professor of political science and public administration. "The answer is, if the consequences are sufficiently negative, then you better make public policy before all the facts are in."

The controversial international climate change conference in Kyoto, Japan, in December was one step in that direction. Representatives from nations around the world gathered to hammer out binding agreements on reducing emissions to 1990 levels and below, and by what year these cutbacks should be achieved. The Clinton administration entered negotiations with a proposal to reach 1990 levels between 2008 and 2012, but agreed to slice emissions an average of 7 percent below 1990 levels in those years. When President Clinton announced his plan in October, he noted that while the United States makes up less than 5 percent of the world's population, it is responsible for more than 25 percent of the globe's greenhouse gas emissions. The Clinton initiative also called for "an international system of emissions trading," allowing companies to invest in foreign emissions-reductions projects and receive credit for the cutbacks at home; and universal participation among industrialized and developing countries. The president also emphasized providing financial incentives to spark research and development undertakings "to encourage energy efficiency and the use of cleaner energy sources."

The success of any deal, however, is likely to encounter challenges. Here in the United States, any implementation would need congressional approval and, given the current political atmosphere, that seems unlikely. "Congress," Lambright says, "has made it clear that it is not in the mood for any policy that would lead to expensive emissions controls."

The Intergovernmental Panel on Climate Change (IPCC), an advisory body organized by the United Nations Environment Programme and the World Meteorological Organization in 1988 to analyze scientific, technical, and



Industry accounts for about 45 percent of the world's carbon dioxide emissions. Improving energy-related technology could help reduce such emissions.

Tropical forests play an important part in the global carbon cycle. The Costa Rican forest, right, could be considered a carbon storehouse. When forests like the one in Mexico, above, are cleared and burned, carbon is released.

socioeconomic information on the topic, concluded in *Climate Change 1995: IPCC Second Assessment Report* that "the balance of evidence suggests a discernible human influence on global climate." The report also pointed out that even if carbon dioxide emissions were stabilized at 1994 levels, a cumulative effect would push the concentration to 500 parts per million by the end of the next century, nearly double pre-industrial levels. Levels after that could climb much higher.

So, what to do? Turn off the car engine, click off the lights, and relegate coal to holiday stocking-stuffer? "If we are going to stop the climate change from occurring, then we have to stop fossil fuel emissions, and that's going to be extremely difficult," says SU earth sciences professor Donald I. Siegel. "In some sense, maybe the problem can't be solved and we, as a society, will have to learn to cope with it. If any of the global climate models are correct, it won't be a fun ride."

tracking carbon

Before a classroom of ESF and SU students last fall, Hall laid out the dilemma and posed three choices for action: Ignore the problem; greatly increase use of nuclear power; or become poorer. "There really are no other important alternatives," the systems ecologist says.

An increasing human population and economic growth inevitably lead to more energy consumption. But burning through a tank of gasoline or firing up a coal furnace aren't the only ways to release carbon dioxide into the atmosphere. Forests, for example, store vast amounts of carbon in their vegetation and soil. During plant respiration or decay, stored carbon is released as carbon dioxide. Likewise, plant photosynthesis draws carbon dioxide out of the atmosphere, creating a carbon storehouse in the plant. This process is part of the global carbon cycle that involves storage and movement of life's main element in its various forms around the Earth. As carbon moves through the cycle, the balance between release and storage amounts can have an impact on climate change. In one form or another, this omnipresent and multidimensional player can be stashed away for centuries in an ocean or forest floor, and sprung from storage in a flash of wildfire. The oceans, for instance, hold the largest reservoir of carbon, much of it stored in deep-sea sediments of the discarded shells and skeletons of marine organisms and as dissolved bicarbonate. Fats, carbohydrates, and proteins contain carbon. It can be found in sedimentary rocks like limestone, and in ocean corals. That wooden chair you're fidgeting in is stored carbon; ignite it and you're shifting the balance between carbon storage and release. Hall, who's studied changing land-use patterns in the tropics and their impact on the global carbon cycle, points out that as tropical forests are cleared and burned to make way for pasturelands, more carbon dioxide is released back into the atmosphere. Such a fluctuation in the global carbon cycle can potentially spark warming and climate change.

Atmospheric carbon dioxide concentrations have been monitored hourly for four decades at Mauna Loa, Hawaii, providing scientists with crucial evidence tracking the unprecedented increase. An analysis of the data, Hall says, also reveals the effects of the seasonal interaction between photosynthesis and respiration. During the growing season, carbon dioxide in the atmosphere declines as it is pulled into plants by photosynthesis and enters the biota. When respiration exceeds photosynthesis in the fall and winter months, more carbon dioxide is released. And thanks to the human contribution to the carbon dioxide equation, it appears that the Earth's metabolism has sped up as well.

"Until 1975, human activities appeared not to have an influence on the net functioning of ecosystems," Hall says. "Now, human activities appear large enough to start encouraging both photosynthesis and respiration."

Mullins will vouch for that. While examining climate changes during the past 10,000 years in New York's Finger Lakes, he and colleagues found evidence of increased photosynthetic activity reflected in the calcium carbonate concentrations of lake sediments. During photosynthetic activity on a lake's surface, microscopic plants precipitate calcium carbonate that settles on the lake bottom, releasing more carbon dioxide in the process. The percentage of calcium carbonate reflects how much photosynthesis is going on at various times, Mullins says, citing changing climatic conditions during warming and cooling periods. During a cooling period about 3,500 years ago, the calcium carbonate content, taken from a Cayuga Lake sediment core, dropped off and stayed low for thousands of years. Around 1860, however, the amount of calcium carbonate started increasing, and beginning in 1940, it really jumped, Mullins says. This change correlates closely with the rise in atmospheric carbon dioxide, and supports theories about the biosphere's response to the surge—increased photosynthesis and

HERB WRIGHT

socking away more organic carbon in storage. "We're putting more carbon dioxide into the atmosphere and it's very well known that carbon dioxide is a fertilizer for photosynthesis in plant growth," Mullins says. "This leads me to believe that what we're seeing in Cayuga Lake is really due to global environmental change."

Tracking carbon also leads scientists to another perplexing issue—namely, missing carbon. In attempting to balance a multibillion-ton carbon budget, which reflects the element's release and absorption throughout the biosphere, upward of 20 percent would be unaccounted for. One place to look could be the oceans, with their carbonate-rich corals and white sands, Patterson says. "Increased dissolution of these shallow-water deposits may be removing a significant amount of carbon dioxide." Recent research also points to the role of improved forest management, which can enhance the sequestering of carbon dioxide, and of all things—peat, organic soil that is loaded with carbon.

If there's anyone who knows peat, it's Siegel, an expert in wetlands biogeochemistry and hydrogeology. For nearly 20 years, he's ventured to remote northern Minnesota and Canada to study vast peatlands there. Accessible only by helicopter, the landscape features fens, which look like a wet meadow with grasses growing in standing water; and bogs, accumulations of organic soil that form gentle domes covered with spruce trees and sphagnum moss. These peatlands contain different communities of plants, including rare and endangered species. As part of the global carbon

DONALD SIEGEL

Andrew Reeve G'96, above left, of the University of Maine and SU earth sciences professor Donald I. Siegel take a water sample from a fen in Minnesota. At left, methane, found in pockets beneath the surface of bogs, blasts out of a groundwater sampling tube, expelling a ball of peat.

cycle, they also produce large amounts of carbon dioxide through plant decomposition, and methane through the subsurface decomposition of peat. "Many scientists feel that a significant portion of the world's carbon budget is tied into these terrestrial peatlands," Siegel says. "The amount of carbon dioxide and methane is tightly coupled to climate change, so the research we're doing is to try to determine what chemical and physical processes control the release and production of these greenhouse gases, and to what extent peatlands moderate climate or accentuate climate change."

Siegel, Paul Glaser of the University of Minnesota, and their associates have made several significant discoveries during their research, including a recent one related to what's called "bog breathing." Last summer, the scientists installed global-positioning equipment that measures elevational changes of the bogs as minute as a quarter of an inch. "We discovered, much to our surprise, that the whole landscape rises and falls every day as much as 20 centimeters relative to sea level. It's breathing," he says. "It's been known that bog landscapes rise and fall, but up until now it's never been recognized that it's done on a daily basis."

Although the discovery requires more research, team members speculate that the breathing could be connected to atmospheric pressure changes that may cause the methane, located in large pockets several feet beneath the surface, to expand or contract. Another hypothesis, Siegel says, is since the vast peatlands are about 90 percent water, there could be a lunar tide influence. "What's interesting with the methane is if a big cold front comes through that's at very low atmospheric pressure, it's low enough to allow the bog methane to expand to where it bursts out—and that might be how it's lost," he says. "We'll have an answer to this in a year, and it may be that we have discovered a brand new physical phenomena."

The project involves scientists from a variety of disciplines and the more they learn about how peatlands function, the more they may understand the potential role of these huge carbon storage tanks in a changing climate. For instance, Siegel says, if peatlands begin drying out, the result could be large emissions of carbon dioxide. On the other hand, if the climate becomes wetter, more peat will accumulate, removing more carbon from the atmosphere. "These peatlands may be important buffers to climate change, like thermostats," says Siegel, whose project assistants are graduate students Jennifer Rivers, Jeff McKenzie, and Susannah Kitchens.

At Huntington Forest in the Adirondack Mountains this past summer, ESF environmental and forest biology professor Myron Mitchell studied another component of the carbon cycle—how soil warming affects such soil processes as respiration. By burying heating cable in the soil, Mitchell induced higher temperatures that increased the loss of certain trace gases,

DONALD SIEGEL

Fens, which feature meadows and standing water, are part of the landscape where SU's Siegel does wetlands research.

such as carbon dioxide, and also sped up the loss of unstable, fluctuating pools of carbon. "Over the long term you may have a warmer temperature, which stimulates respiration, but its effect doesn't continue because the carbon pools are removed sooner," he says. "Therefore, the temperature effect is a bit transient."

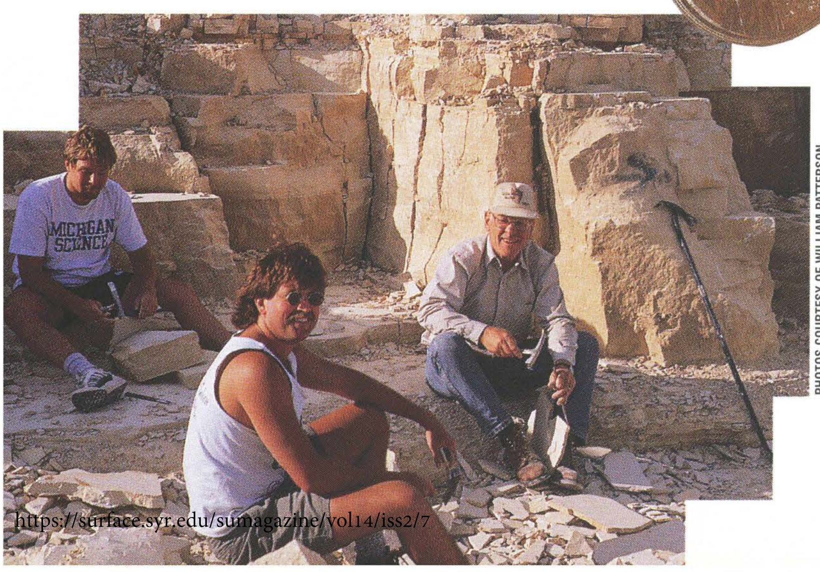
Although the experiment deals with only a small part of the carbon cycle, Mitchell says it's like most things in science: "It seems like a very simple story, but when you start looking at the interactions and complexities, things become much more complicated."

evidence for the future

When scientists consider the complexity of climate change, the more they learn about the past, the more they can help predict the future—especially in improving the accuracy of computer modeling forecasts. Through various procedures, such as examining sediment cores, paleoclimatologists can add valuable information to regional historic records. SU earth sciences professor Patterson may be the only scientist around today who collects climate information through fish fossils. Specifically, he examines fish otoliths, which range from recent times to the Jurassic period 172 million years ago. These ear stones, located in the inner ear of most bony fish, are composed of aragonite and form annual bands, much like tree rings. By examining minute samples of these bands, Patterson reconstructs daily to three-day temperature records throughout the fish's water-cruising days and, through identifying different oxygen isotopes, can peg the origin of the water they inhabited. "We get a permanent record out of their heads—it's like a lifelong recording thermometer, functioning like an airplane's 'black box' flight-data recorder. It tells you what they're doing metabolically and thermally through their entire lives," he says. When used on extinct species, this forensic paleothermometry may help determine what led to their demise and, in turn, assist scientists in predicting which species may be more sensitive to impending climate change.

This technique has also helped Patterson reconstruct climate and seasonal variation of Idaho's Snake River Plain from about five million to two million years ago. Major shifts in seasonality, he says, can be stressful on animals. "It's not so much the mean annual temperature that controls what lives where, but the seasonal range," he says. "This change in seasonality is probably responsible for a lot of the extinction events during that period of time."

With help from graduate students Jesse Coburn and Chris Wurster, Patterson is currently examining fossil records from basins in the western United States over the past 10 million years, and an area in Tennessee over the last 10,000 years. "It's bone dry in Washington today, but you can find abundant evidence for tropical rain forest vegetation and animals in these dry sediments and volcanic rock," says Patterson. "As a geologist, it's the most clear-cut evidence you've ever imagined for catastrophic volcanic activity."



PHOTOS COURTESY OF WILLIAM PATTERSON

SU's William Patterson, front, with colleagues Jerry Smith and Shane Webb of the University of Michigan, works on a dig in Wyoming. Patterson uses otoliths (compared with a penny, above) in reconstructing past climates.

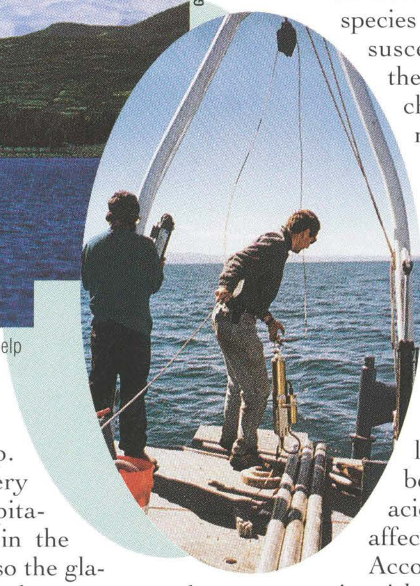
Whereas drastic elevational changes may have affected western interior climate, the Tennessee project, he believes, will be more reflective of a stable region influenced by the weather changing over it. "The paleoclimatological record is critical for modeling, so modelers can accurately recount the fossil and/or isotopic record," he says. "Modelers have to tune their models to the paleontological record, and records like those from Tennessee that look in great detail at specific regions are exactly what models need to be finely tuned."

A continent away, SU earth sciences professor Geoffrey Seltzer is engaged in three paleoclimatic projects centered on examining environmental and climatic change in the Andes of Bolivia, Peru, and Ecuador during the last 10,000 to 20,000 years. It is an area of extremes, ranging from the coastal desert of western Peru to lush tropics in the east. In between is Lake Titicaca and the surrounding altiplano, a dry, flat, grasslands area located at an elevation of 12,000 feet between glacier-covered mountains. "It's a really spectacular environment with very extreme climatic and vegetational gradients," he says. "There's very little information from the tropics about climatic change. By obtaining climate records from low latitudes and comparing them with high latitude areas, we try to get a handle on what could force big changes like causing glaciers to appear or disappear."

Two of Seltzer's projects focus on lakes—small lakes in the Bolivian mountains and Lake Titicaca, "the highest Great Lake in the world," Seltzer says. As a natural border between Peru and Bolivia, it is a vital resource to both countries. By examining sediment cores taken from all of the lakes—as well as using seismic reflection equipment on Titicaca—Seltzer and his fellow researchers can study changes in hydrology and pollen records. Pollen samples, for instance, can reflect the prevalence and types of vegetation in the area through the years. "We can separate the pollen, look at the assemblage, and determine what the vegetation was like 10,000 years ago and how that compares with what it's like today."

In the altiplano region, the glacier-fed Titicaca is a major water resource supporting hydroelectric power, irrigation, and fishing. "There's a lot of concern

GEOFFREY SELTZER



SU's Geoffrey Seltzer does studies on Lake Titicaca (with the Andes in the background) to help determine past climates in South America. At right, Seltzer's colleagues Paul Baker of Duke University, left, and Harry Rowe of Rice University lower coring equipment into the lake.

about whether there is enough water to sustain this lake," Seltzer explains. "It's being used extensively in a primarily agrarian society. We're trying to understand the modern system—how much water flows in, how much evaporates, how much could possibly be diverted. Then we want to extend the record into the past and provide the countries with a longer-term perspective—what sort of maximum changes could be expected and what should be planned for."

Seltzer and a colleague are also collecting evidence from Andean glaciers in Peru and Ecuador to determine whether a period of rapid fluctuation in glaciation and deglaciation happened there at the same time as in parts of North America and northern Europe. Around 11,000 years ago, a very cold period occurred and then rapidly disappeared about 1,000 years later, Seltzer explains. "The whole question is how variable the climate system is; how rapidly can it change and how widespread are those changes."

The glaciers' connection to the past is an important piece not only of the global climate puzzle, but also to the region's future. The Andean glaciers, like glaciers worldwide, are retreating at an acclerating rate, and there is speculation that this change could be tied to global warming, Seltzer says. The result could pose a major dilemma for the region's inhabitants since glacial melt fuels the water supply, particularly during dry winter months. With Seltzer's guidance, SU doctoral student Bryan Mark journeyed to Peru last fall on a prestigious Fulbright scholarship to study this relationship. "There's very little precipitation runoff in the dry season, so the glaciers buffer the water supply. Without glaciers to do this, the big question is how they will get water," Mark says. "The behavior of glaciers is not exactly predictable. We're trying to understand what the natural variation is and then conclude whether humans influence or enhance that. A lot of it has to do with the rates of change, not just the extent of change."

environmental adjustments

In New Hampshire's White Mountains, scientists have been performing studies at the Hubbard Brook Experimental Forest for decades, assessing how ecosytems function, interact, and change. This winter, SU engineering professor Driscoll is examining the impact of reduced snowpack on soil freezing. "We reasoned that if there's global change, there may be changes in snowpack distribution. There may be greater events of freezing, which may affect organisms and plants that have acclimated to current conditions with a lot of snowpack," says Driscoll, who's being assisted on the project by Ross Fitzhugh, a Ph.D. engineering student. "Under the snowpack, the soil doesn't freeze because bacterial activity keeps the temperature slightly above freezing, so the roots don't freeze, and the organisms in the soil don't freeze. However, if there is freezing, there may be a lot of mortality."

One part of the experiment focuses on how freezing will affect such tree species as sugar maples that are highly susceptible to frost damage. "If there's a great deal of distribution change in the snowpack, there may be a decrease in the abundance of sugar maples in this area," he says. "We anticipate there will be a lot of death of the root material and changes in the soil environment that will allow for the release of carbon dioxide and nitrous oxide. We also anticipate there may be some increased leaching of chemicals from the soil, like nitrate, and that's of interest because nitrate contributes to the acidity of lakes and streams, so it affects recovery from acid rain."

According to Dudley Raynal, Distinguished Teaching Professor in the environmental and forest biology department at ESF, climate change must be considered an aspect of changing global conditions because of human influence. Human activities inject all sorts of effluents into the landscape, air, and water, he says, and cause a variety of conditions that affect how organisms respond to an altered climate. Changing temperature and precipitation patterns, for example, could cause one species to expand its territorial range, while another is displaced. "I don't think questions of climate change can be separated from those of global change that involve so many different kinds of interrelationships," he says.

In one experiment, Raynal and then-graduate student Yude Pan used computer modeling to predict plantation conifer tree growth in the Adirondacks in response to climate change. "Under varying scenarios of climate change, we can predict how individual trees might grow and we may gain some insight as well into how species might reproduce and spread, or migrate," he says. "The presumption is that the species, in encountering global change in a short period of time, will have little if any ability to evolve attributes that will enable them to stay in place. So they physically migrate as climate changes. The idea is that we'll see range of distribution changes for organisms, plants, and ani-

CHARLES DRISCOLL

The Hubbard Brook Experimental Forest in New Hampshire, above and below left, is a place where scientists, like SU's Charles Driscoll Jr., study ecosystems.

mals. We know this has happened in the past by looking at fossil evidence, pollen profiles, and similar kinds of indicators."

Raynal has seen a wide variety of responses among species and notes that, in general, while some species may react positively to change, others may be harmed. Another aspect of such change that shouldn't be overlooked, he says, is the role of exotic, invasive species that could displace native species, disrupting the biodiversity of natural communities. "Maintaining biodiversity is important from the ecological standpoint of maintaining the stability of natural systems," he says. "And there's a great deal of interest around the world in maintaining natural systems. The presumption is that we do need to preserve and to conserve natural communities so we can experience and enjoy them, as well as study them to understand relationships between the biota and physical components of the environment and how that knowledge might serve us in the future."

politics of change

With regard to our own future, SU's Lambright points out that many more political forces are arrayed around the notion of economic development than the concept of energy conservation. Americans, after all, lead the world in energy consumption and their collective memory of the oil crisis in the seventies seems to have been erased. According to the Intergovernmental Panel on Climate Change, global energy demand has climbed at an average of about 2 percent annually for nearly two centuries. In 1990, the IPCC reports, the industry sector accounted for the largest amount of carbon dioxide emissions with 45 percent, followed by the residential/commercial sector (29 percent) and transport (21 percent), which has grown the most in the last two decades. The question then is whether government policies can curb our penchant for fossil fuels. "Quite frankly, I think we're probably going to have to institute pricing measures and market mechanisms to get people to drive less, and change land-use and development patterns and lifestyles," says Sarah Siwek '77, G'80, president of Sarah Siwek & Associates, a transportation and environmental consulting firm that provides state and federal policy-oriented work on such issues as air quality, emissions reduction, and fuel technology. "Without some kind of federal tax or increase in the price of fuel, it's going to be on the margins that we get these kinds of reductions by convincing people to drive less."

CHARLES DRISCOLL

Siwek, a Federal Highway Administration consultant, is developing a national campaign on air quality and transportation issues, an effort spawned by the Clean Air Act of 1990. Part of the initiative includes assessing what approaches get public responses. "People have a number of reactions, like saying, 'It's not my problem, somebody else is doing it,' even if that's after they realize there is a problem," Siwek says. "You have to convince them they can do something about it."

As author of *Climate in Crisis: The Greenhouse Effect and What We Can Do*, Albert Bates '69 stresses the importance of developing an individual consciousness aimed at reducing carbon emissions. Be aware of your energy consumption and try to reduce it, he says, look at your electric meter, chart your mileage, plant trees to offset emissions from car and air travel, use alternative energy methods when possible, and shop selectively, supporting environmentally friendly companies. "It might cost a few dollars more, but it's sometimes worth it in the long term," he says.

Bates speaks from experience. He has practiced sustainable living at an alternative community in Tennessee for 25 years, and is currently the regional secretariat for the Global EcoVillage Network, a group of sustainable communities linked through their common interest in living greener lifestyles. "What the United States really needs to do is take leadership instead of just following along and dragging its heels," he says.

In the past several years, many cities have initiated their own policies aimed at corraling potential global warming. One project, Cities for Climate Protection, involves more than 100 cities, including Toronto, considered a model and leader in the field with its own climate policy. These cities, Lambright says, emphasize prevention and mitigation. Toronto implemented an array of policies ranging from improving energy efficiency in buildings to encouraging downtown residential development to reduce suburban commuting. "It's encouraging to realize there are people in the trenches who aren't waiting for Kyoto and consensus," Lambright says.

Still the question remains: Can the right thing be done on a global scale? And does it really matter? Mullins notes that long after we've burned through our finite fossil-fuel reserves, the Earth will have adjusted and will still be spinning around the sun. "It's a momentary blip in Earth's history," he says. "The threat is to the planet's inhabitants. I don't see it as a terminal threat, but one that we inhabitants—from humans down to whatever level of origin you want to consider—must adapt to. And this will include higher carbon dioxide levels, higher global temperatures, and everything that comes with that."

Adaptation, of course, can be a merciless creature. But it will, Lambright says, "be the name of the game." Which leaves us with yet another question: At what cost?