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Urgently Needed: Greatly Expanded Roles for Both Science and Scientists in the 21st Century

Bruce Alberts, President
National Academy of Sciences, Washington, DC.

Introduction and welcome from Dr. Sarah Lea McGuire:

Welcome to the 75th Annual Meeting of the Mississippi Academy of Sciences. Our lecturer this year is Dr. Bruce Alberts, President of the National Academy of Sciences in Washington D.C. He is known for his work both in Biochemistry and Molecular Biology, and in particular for his extensive study of the protein complexes that allow chromosomes to be replicated. Dr. Alberts graduated from Harvard College and earned a doctorate degree from Harvard University in 1965. He joined the faculty of Princeton University in 1966, and after ten years moved to the Department of Biochemistry and Biophysics at the University of California in San Francisco, where he became chair. He is one of the original authors the *Molecular Biology of the Cell*, through four editions, which we affectionately call the Alberts book at my institution. His most recent text, *Essential Cell Biology*, published in 2003, is intended to present this subject matter to a wider audience. Dr. Alberts has long been committed to improving science education, dedicating much of his time to educational projects such as City Science, a program that seeks to improve science teaching in San Francisco elementary schools. For the period 2000-2005 Dr. Alberts is the co-chair of the Inter-Academy Council, a new advisory institution in Amsterdam governed by the presidents of the science academies of 15 different nations. I'm honored to introduce to you Dr. Alberts, and the title of his presentation is "Urgently needed: greatly expanded roles for both science and scientists in the 21st century." Welcome, Dr. Alberts.

Dr. Bruce Alberts:

Thank you.

First, let me congratulate the Mississippi Academy for surviving for 75 years, while wishing you an even greater future. My lecture will present a challenge to the Mississippi Academy and to all scientists, because I'm going to try to convince you that—in this ever-more complicated and dangerous world – science needs a much higher profile if we're going to be successful in creating the type of world we would like for our grandchildren.

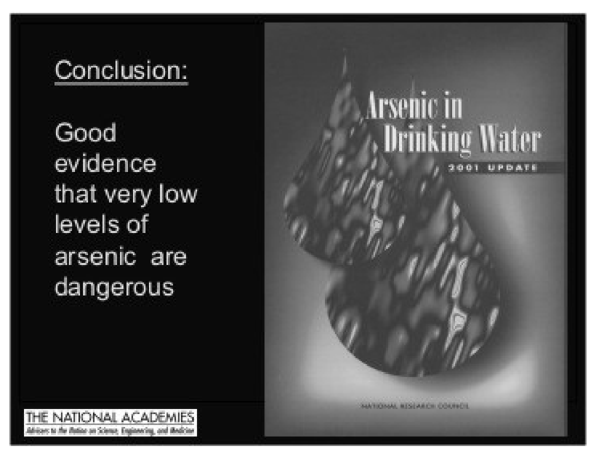
The image we want to create for science can be represented by a pictorial analogy: our Einstein statue, covered by children. This wonderful statue is located in the front yard of the Academy in Washington, very near the Lincoln and Vietnam memorials. The school groups that come a week-long tour of Washington often pose for their last group picture here, sitting on Einsteins very large lap. We need to convince our children that, like this statue, science is something accessible, so that they welcome science into their lives. But we are not doing anything like this in most places. I spent two weeks in India in early January. That nation still benefits from the wisdom of its first prime minister, Jawaharalal Nehru, who deeply respected science and understood its benefits for India. Nehru wanted a "scientific temper" for his nation. Today we badly need the same scientific temper for the United States and the world. I will try to explain what I mean by that in this talk.

Let me start by saying a few words about the National Academy of Sciences. It's an old organization, even older than the Mississippi Academy. It was chartered by Abraham Lincoln in 1863. The academy was being established as an honorary organization of 50 of the best US scientists. At that time, private organizations like ours required a charter from the government. The critical part of our charter that has determined the entire character of the Academy stated that, in order to exist, "The Academy shall whenever called upon by any department of the government, investigate, examine, and report upon any subject of science or art" (art at that time meant technology), but that "the Academy shall receive no compensation whatsoever for any services to the government of the United States." Because of this unfunded mandate, we are very much a service organization: some 6000 volunteers are working at any one time on various committees providing their advice to the government.

We call ourselves today the National Academies—why? Because from the same charter two other honorary organizations were subsequently incorporated – the National Academy of Engineering and the Institute of Medicine. These three honorary organizations now have some 5000 members. And the active, "operating arm" of these academies, established during World War I, is called the National Research Council. It was founded so that we could bring onto our study committee lawyers, teachers, business people – whatever we needed, not only scientists or Academy members. Today there are three presidents—I'm only one of them—who sit next to each other in that building behind the Einstein statue and run the National Academies. This has the great benefit of bringing together all of the talent needed to answer the hard questions we're asked, because it's not enough – as we saw this morning in the talk on earthquakes – to have just scientists, you've got to have engineering for many issues, and of course the medical profession.

The critical thing is that when we're asked by the government to do something, they pay us for the cost of the study; that is, they pay us for the staff work and for flying the members of the committee to Washington who don't get any stipend. Through hundreds of different individual contracts, we obtain the resources we need to produce an average of more than one report every working day – each one in response to a different request from some part of government. It is critical that, even when the government is paying for the full cost of a study, they can't control its outcome. Our charter and legal framework allows the government to come to committee meetings to give us information they think is important for answering their questions, but when they do that, the meeting must be open to the public. The committee meets in private in preparing its report, which is not negotiated with the government in any way. The government gets the final result at the same time that it is released to the public and the press on our website. We insist on telling what we believe to be the truth. I don't remember any report that has made the government completely happy. Usually, they're pleased with part of what we say, but there's always something they wish we had not said. It is our independence and integrity that's central, because otherwise we wouldn't really be useful in our goal of "bringing the truth to Washington."

To explain how we work to promote the use of science for wise decision-making, I'll present four quick examples of what we call our "science for policy" reports. In 1996 or so, there was a lot of worry in the press about the health effects of refrigerator motors, power lines, hair dryers, and other electromagnetic fields in the home. Many people seemed to be fearful, so we were asked to study whether these fields are really dangerous. After looking at 500 reports going back 17 years, we concluded that there's no evidence that they are dangerous. An opposite type of conclusion was reached shortly after President George W. Bush came into office. You may remember the stir created when the president announced that his Administration would not accept the lowered maximum for arsenic in drinking water that Clinton had put forward in an executive order near the end of his term. Former New Jersey Governor Christine Whitman, who was then the Administrator of the Environmental Protection Agency, may have been embarrassed by this decision. But for whatever reason she did a very good thing, when she quietly asked the Academy to do a study that would tell the government how dangerous arsenic actually is for human consumption. Our study, completed in about 6 months, found that arsenic is even more dangerous than had been



thought earlier; as a result, the Bush Administration accepted the Clinton standards as soon as the report was released.

My third example concerns climate change. Just before President Bush went to Europe for the first time, in June 2001, the White House wrote us a letter asking fourteen questions about the science of climate change. We gave them a short report in a month stating that a strong scientific consensus exists that human-induced increases in greenhouse gases are likely to cause serious global warming, and in a nice speech the President accepted that conclusion as he left for his trip.

My final example is an unusual report for two reasons. One is that it was prepared in an emergency right after 9-11. Our aim was to tell the government how our nation's strength in science and technology might best be harnessed to increase homeland security. The work was done so urgently that there was no time to get money from the government, so we took a million dollars of the income from our endowment raised from private sources and spent it to do this study. Secondly, this was a massive effort that involved a huge number of people; we used 160 volunteers, with a different subpanel for each chapter. The result was a large report, released in June 2002, called *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism*. This has become a "bible" for the Department of Homeland Security, guiding the Undersecretary for Science and Technology there.

So why does this all work? First of all, our government, and I think we're very lucky in this respect, prides itself on making decisions on the best science. Both sides of an argument usually claim to have science supporting them. They just use different science. That's not true everywhere in the world. Science doesn't have as much respect in many other nations as it seems to have in our political system. Second, the National Academies have a rigorous report review process, which makes sure that our study committees base all of their conclusions on evidence and don't get into the political aspects of a decision – the kind of judgments that the government should make. Instead we focus on the science: we carefully state how dangerous arsenic is at different levels in drinking water and what the evidence is for these conclusions, but we don't say what limit to set the arsenic level at—that requires a cost-benefit analysis that the government is best suited to carry out. Third, of course, it's very important that the US press pays attention to what we say, because that puts pressure on the US government to respond. Here's a first page from a very famous day, this is actually *The Washington Post* on 9-11, when the two headlines were both ours. EPA Administrator Whitman accepted our report and urged tighter rules for arsenic in drinking water that day, and our stem cell report came out at the same time, urging support for stem cell research.


The Washington Post

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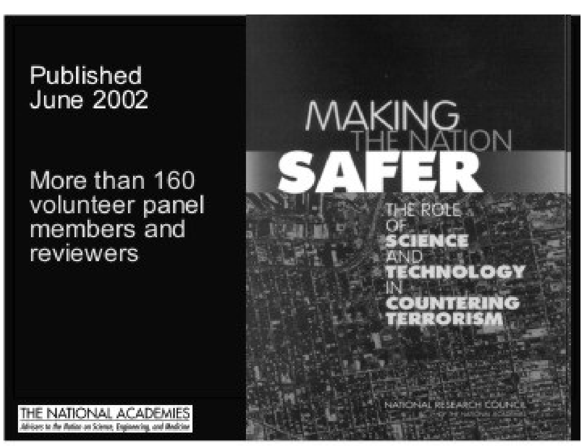
THE DISTRICT'S LOST CHILDREN | Babies at Risk

EPA to Urge Tighter Rules For Arsenic

Report Raises Agency Concerns About Drinking Water Limits

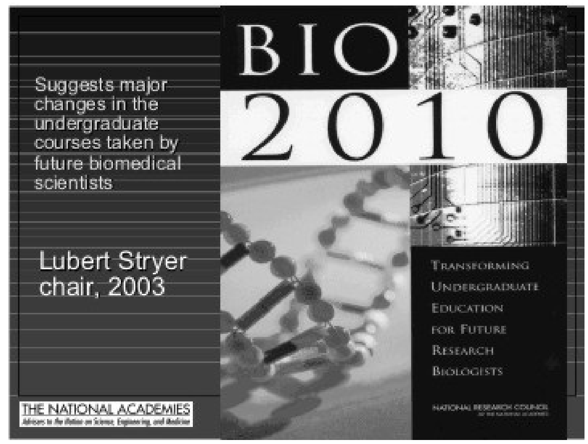


My next slide lists three important broad goals for the Academies, dealing with central issues for scientists. (1) To improve science education for all Americans, in a way that maintains the curiosity and thirst for knowledge of our young people throughout their schooling and their adult lives. (2) To enable all children to acquire the problem-solving, thinking, and communication skills of scientists – so that they can be productive and competitive in the new world economy. (3) To help the US remain the world leader in the generation of new scientific knowledge and technology through a vigorous scientific and engineering enterprise. This last one I'll talk about in more detail later; it's becoming increasingly difficult because the world is changing rapidly.

To address the above goals, we produce "policy for science" reports, where we provide advice on how the scientific enterprise itself can be improved. This is a much smaller fraction of what we do. My path to becoming the president of the National Academy of Sciences began in 1987, when I was a Professor of Biochemistry and Biophysics at UCSF in San Francisco, very happy running a laboratory. The Academy called me to say that it had set up a committee to study whether there should be a special project in the United States to map and sequence the human genome. This committee had several Nobel Prize winners on it, including Jim Watson, with distinguished scientists on both sides who had already taken public positions. The scientific community on the whole was against the idea, because it threatened to bring big science to biology, which many thought would ruin the enterprise.

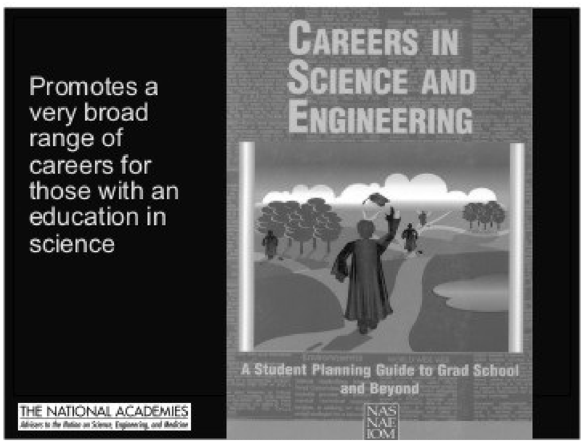
The Academy wanted me to serve as chair in part because I hadn't ever said anything about the proposed project and didn't have any position. As chair, I had to act as a referee, to get this group of diverse characters to reach a consensus. And of course we did reach a consensus; in 1988, we published a road map for a specific project that was immediately adopted by the government. This was very unusual, inasmuch as our reports often take years to have effect. And of course our predictions—and I don't know how it happened, it was sort of magical—our predictions of how long it would take, and how much it would cost were almost exactly right.

Another type of policy for science study focuses on maintaining high standards in the scientific enterprises. The booklet *On Being A Scientist: Responsible Conduct in Research*, is the second edition of an important guide used in graduate school to help make sure that science works. Another report, *Bio 2010*, looked at the future of biological and biomedical research, and recommended change in the college undergraduate curriculum to make sure that the next generation of researchers has the quantitative skills that they will need to be successful. Some places like Princeton have already developed a major new curriculum around these ideas. This committee was chaired by Lubert Stryer, who for decades wrote the best-selling biochemistry textbook used at medical schools and colleges.

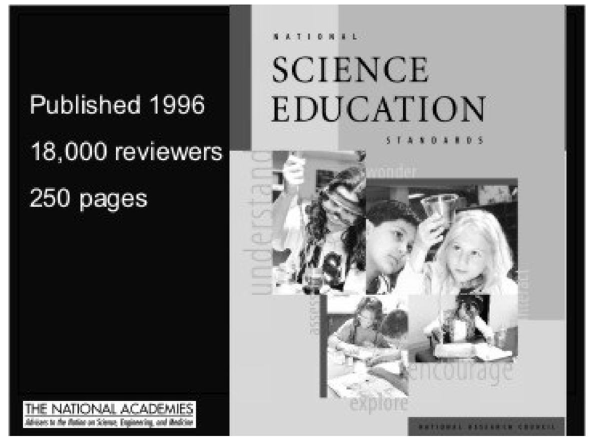


An issue even bigger than any of these is what our aims are in educating undergraduates in our introductory college science classes. Are we trying to produce only professors, which is one way of looking of looking at it, or do we want to encourage as many students to be science majors as we can, with the aim of their entering many different careers with those skills? The Academy has been pushing the latter view, that we need scientists in many different professions. Pre-college teaching is an obvious one. But I learned only after I moved to Washington that our Congress only functions because of the many Congressional aides who work for 100 hours a week, and that having a staff member with scientific training on every committee makes a huge difference for connecting Congress to scientific issues. And I propose to you that there are lots of other places in our society where we badly need scientifically trained people. It's crucial that the academic community recognize and respond to this enormous need.

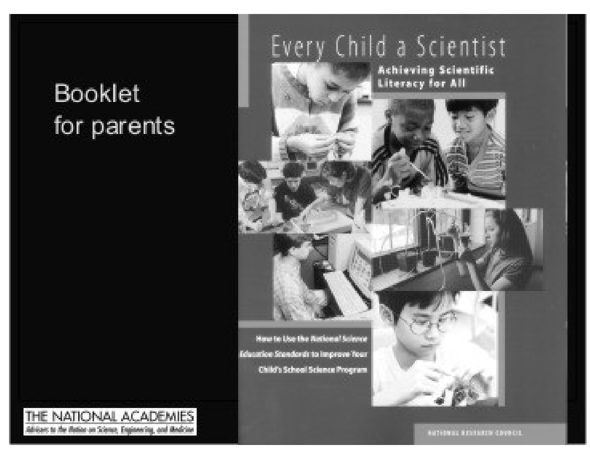
We've produced several different booklets to help. The first was *Careers in Science and Engineering: A Student Planning Guide for Grad School and Beyond*, which promotes a very broad range of careers for those with an education in science. After we produced this booklet, I got invited to several Saturday graduate student retreats, where students would walk up to me after my talk and say that this booklet is fine, but I want to be a teacher or whatever, but I can't tell my professor because as soon as I do, he or she won't pay any attention to me. From such interactions came a second companion booklet for professors, called *Advisor, Teacher, Role Model, Friend: On Being A Mentor To Students in Science and Engineering.* We know a professor is not going to go to the Web to read this mentoring guide, so we suggest to students that they go to the Web and order the booklet for a few dollars. If they leave it on the chair of their professor in the middle of the night, maybe he or she will get the hint and read it.



I'd now like to talk about how the National Academies work to spread science and scientific values throughout society through a focus on science and mathematics education for children. This is actually what I came to the Academy to do. When I was offered the job, I took it mainly because I wanted to be the "education president." But it is clear that education is such a long-term issue that we will need many education presidents in succession. In my first two years at the Academy, 1993-1995, I must have spent nearly half my time on the production of *National Scientific Education Standards*. This was the hardest report we've ever written. For one, we had to get the scientists to agree on what could be left out; in the end, the biologists had to choose the physics and the physicists to choose the biology, because every scientist seemed to feel that way too much of his field is essential for every student to know by the end of high school. When I got to the Academy they had already been at work on the Standards for two years, but they were in pretty disastrous shape. For example, one thing that caught my eye was that it was proposed that every student by the time they graduate should know nine types of soil. Since I didn't know more than two types of soil and I was president of the Academy, I thought this might be overreaching. There was a lot of that kind of thing in all fields.



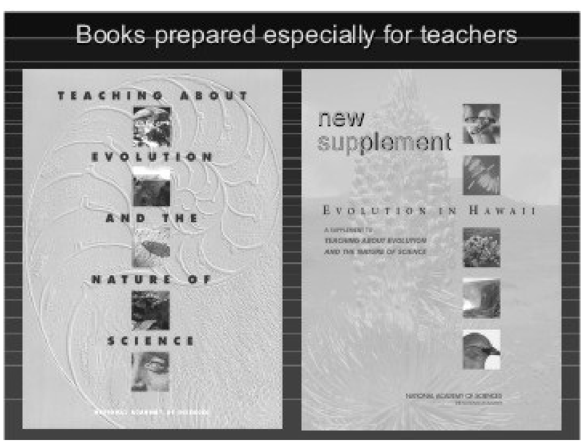
And it was also hard to get the scientists to understand the value of pedagogy, the whole issue of what inquiry means for science teaching, and how important it is to produce tests that drive good teaching. By the end, we had developed a great learning community between teachers, science educators, and scientists that persists to this day. We distributed 40,000 free copies of a full draft report a year before the final report was published. Because we had 18,000 reviewers of this draft, it took a whole year to produce the 250-page final version. To me, the major points are that science should become a core subject in every year of school, starting in kindergarten; that science is for everybody, not just those who view themselves as pre-professionals; and most importantly, that science must be taught through inquiry based learning, not as word definitions and memorization of what scientists have



learned abut the world. The booklet for parents, entitled *Every Child a Scientist*—expresses the sense of this moment— implying that everyone needs to acquire the skills of a scientist to investigate and respond rationally to their world.

We've also been heavily involved, even more so lately, in the creationist-evolution debate. The Academy traditionally has published short booklets on science and creationism, but after I arrived it became clear that we needed to produce tools for the teachers who are under attack at all times. The first book we published is called *Teaching About Evolution and the Nature of Science*, and it makes clear that religion and science are two different ways of knowing about the world, both valid, that don't contradict each other. But you must not mix them in science class. Recently the creationist dogma has reappeared as something called Intelligent Design, which pretends not to be religious but in fact invokes supernatural explanations for biological evolution. This is an energetic movement that has already been successful in affecting how science is taught in some states. Our teachers are under siege, and many of them don't teach evolution at all because they're afraid to be attacked by parents and others.

A new supplement to *Teaching About Evolution and the Nature of Science*, called *Evolution in Hawaii*, presents a wonderful scientific story. The Hawaiian islands rose above the sea at different times, and we can trace how different species of fruit flies evolved by skipping form one island to the other.



Despite such threats to science teaching, there is some very good news. Inquiry based science education precisely fits the needs for workforce skills that have been widely expressed by US business and industry. The Academy has been trying to work with industry leaders to make them more aware of this fact. These leaders advocate for more science education and more math education in general, but they often don't differentiate between more memorization of facts versus imparting more scientific abilities and more understanding of how science works. Here's a quote from a famous business leader, Bob Galvin, who was CEO of Motorola when it was at its prime. While most descriptions of necessary skills for children do not list "learning to learn," this should be the capstone skill upon which all others depend. Memorized facts, which are the basis for most testing done in schools today, are of little use in the age in which information is doubling every two or three years. We have expert systems in computers and the Internet that can provide the facts we need when we need them. Our workforce needs to utilize facts to assist in developing solutions to problems."

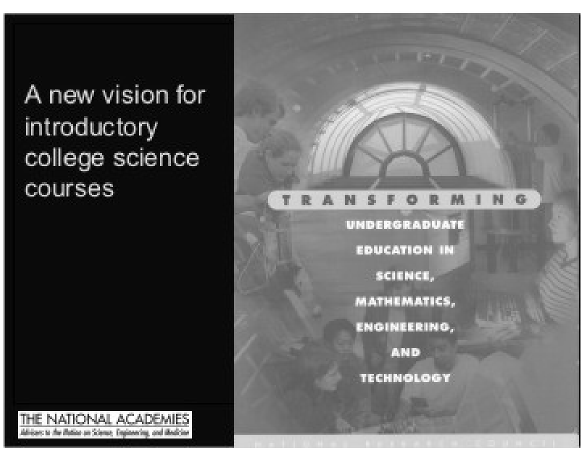
The kind of science education advocated in the *National Science Education Standards* takes kids through guided inquiries, with teachers serving as coaches, teaching them how to think for themselves so that they learn how to learn.

The bad news is "inertia," a term that applies to so many aspects of our society. Social systems show more inertia than physical systems, because if I push on something in the physical world, even if it's very heavy it's likely to move a little. Through special programs we have put a lot of energy into school systems to get them to start doing inquiry science, for example. But continuing this form of teaching takes more energy than teaching for memorization of science facts, passing out ditto sheets with fill-in-the-blanks as a test. And far too often after one stops an intervention, the system declines to the free energy minimum again, and the science teaching returns to where it was before. This is not an easy problem to solve. So we have to explore many strategies for changing the system in a lasting way.

After years of pushing on other aspects, I have concluded that the real rate-limiting step for improving science teaching at all levels occurs in our first-year science courses at the university. The college Biology 1 course, for example, will define what biology teaching should be like for both future parents and future teachers. Often it is based on a fat book that attempts to cover all of biology in one year, which becomes more and more impossible every year. And of course our colleges have the prestige that allows them to set the standard that teachers and parents then expect at lower levels. So we need really to work on our introductory courses, make them inquiry based, with a focus on the teaching of science and its relation to society, for all students. I actually feel guilty because when I was at Princeton for ten years teaching, I didn't ever think carefully about what I was trying to accomplish with undergraduates. I thought I was mainly trying to figure out who could become professors. There was nothing wrong with discouraging the other students from going on to take upper-level classes, because it was only those with obvious promise whom we wanted to teach. We also didn't want large classes. This type of attitude by science faculty will leave most adults ignorant of science, which is very destructive for the future of our society.

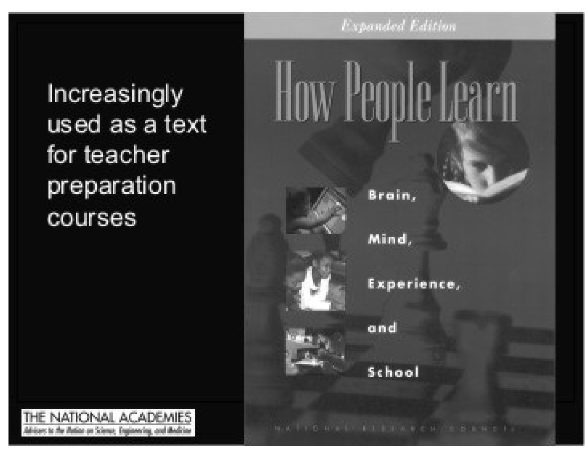
And of course there are those boring lab exercises that we still put students through. I hated lab in college. I was a pre-med, which is the only reason I put up with it. The labs were like cooking, they had nothing to do with science. And today, that's still true for many labs that I think are a complete waste of resources.

To attempt to stimulate changes, the Academy published a report, *Transforming Undergraduate Education in Science, Mathematics, Engineering, and Technology*, with a vision for a new kind of science teaching in the undergraduate years. The National Science Foundation put out a similar report about the same time. But not much has changed. The places that are doing a great job are the small liberal arts colleges. I'm an Overseer at Harvard; getting our major universities to change is much much harder. So what the Academies decided to do is try a new experiment. Last summer was the first example—we'll run it again this summer—of a workshop run at the University of Wisconsin for teams of Biology 1 teachers from research universities. The aim is to get them to rethink their Biology 1 teaching. If this actually starts to work, we'll try to get the resources needed to run similar workshops in other science subjects as well.



We have also published a detailed report on the high school Advanced Placement Courses in Biology, Chemistry, Physics, and Calculus. For the first three, we concluded that, because the AP courses were modeled after the average college course, they weren't good courses. For one, they covered too much and were a mile wide and an inch deep—not teaching for understanding. In response, the College Board is working on revising these three courses and their exams. Hopefully this will inspire universities to rethink their own teaching.

A new mission for the National Academies, besides the specific projects that I've talked about, is what we call "making a science out of education." The goal is to use knowledge of what increases student learning—based on scientifically obtained evidence—to create a continuously improving education system at all levels. The one example I'll show you distilled knowledge from the field of psychology about how people learn, dissecting out what that should mean for schooling. The result, a book called *How People Learn: Brain, Mind, Experience, School*, has been a big success, and it is now used as a text for teacher preparation courses. Recently, we published three supplements for teachers, entitled *How Students Learn Science*, *How Students Learn Mathematics* and *How Students Learn History*, with examples of actual curricula that match the "How People Learn" recommendations.

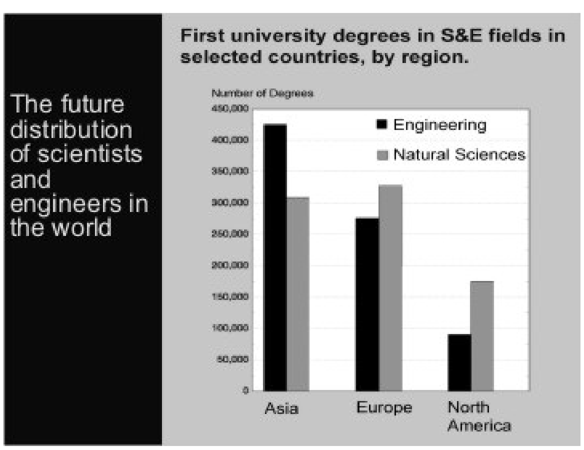


But there are still big gaps in our knowledge. To fill them, we will need a more effective system of education research, one that focuses on real classroom settings. A report we published a couple of years ago called *Scientific Research in Education* tries to set standards for good research in education.

Believe it or not, this is a hot political topic in Washington, with some people claiming that the only valid education research is research is research that is done through randomized trials. Our report argues otherwise; it says that we need multiple kinds of research; we can't yet carry out randomized trials on some issues that are very important.

I want to end my discussion of education by talking about one of the most recent experiments for the National Academies. In general, doing science policy, which I've been doing now for eleven and a half years, is just like doing a science; you do experiments, and you try to see if you can find a way forward that increases what we know. You push here and push there and a lot of things don't work, but you try to learn from them. After many experiments in improving science education; one thing I concluded is that we have to focus on the first few years of college, as I said earlier. Another major conclusion, or at least my hypothesis now, is that our system could be moved strongly in the right direction if we give a much more prominent voice to our best science and mathematics teachers; they need to have more control over the system by bringing their wisdom of the classroom directly to policy makers. For this reason, we have established a Teacher Advisory Council for the past three years at the Academies, composed of twelve of the best science and math teachers in the United States. These teachers have been very carefully selected – some from the elementary, some from the middle school, and some from the high school level – and all are active in classrooms. The committee is run by a former star teacher, Barbara Schulz from Seattle. This terrific group is having a major effect on all of our work in education by giving the teacher's perspectives a major role.

The teachers tell us that a national Teacher Advisory Council is not enough; most education policy is state-based, and therefore every state also needs one. We have thus far been successful in helping to form one such state-based Teacher Advisory Council that was recently established in California. California has a crazy policy-making system for education, with three different centers of power that result in nearly complete chaos. Can this Teacher Advisory Council in California connect to state policy makers, working with the leaders of business and industry in California who can greater amplify their voice? We don't know the answer, so this is all an experiment. I understand there is a similar organization about to be formed in the state of Washington. In both cases, the state Teacher Advisory Council is not connected to us, it is instead connected to a state organization; in California it's the California Council on Science and Technology, which is the closest analog to the National Academies that exists there. I think it's very important that these teacher groups be connected to a state powerbase: those of us in Washington are often viewed as carpet-baggers when we try to affect a state's policy.



I want to now change my topic from science education to science itself. The world is rapidly changing, as other nations are increasingly developing an outstanding capacity in science and technology. Our dominant position in the world of science is an artificial one—it's based on the complete destruction of everyone else during World War II, and a mass movement of the best scientists to the United States from abroad. So we're living in a situation that can't last.

As a clear signal that major changes are under way, US industry, which formerly outsourced only manufacturing, is now also outsourcing its research and development laboratories—to India and China, most notably. And of course increasing numbers of the best international students in the US will be returning to positions in their home nations. That's good for their nations, but our system of science and technology has come to depend on them. The future distribution of scientists and engineers in the world is very sobering. The number of scientists and engineers in Asia dwarfs what's happening in North America, and likewise Europe outnumbers us, so there are going to be many more scientists and engineers in other parts of the world.

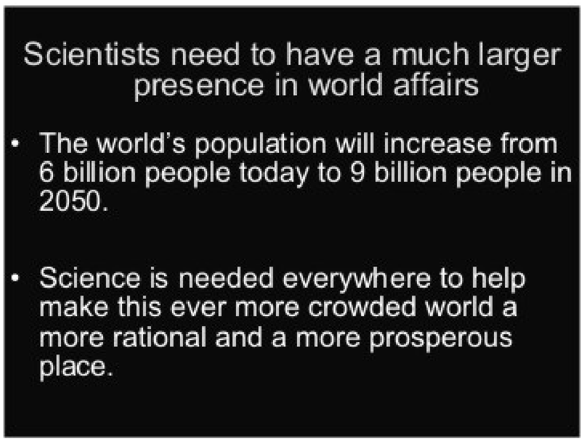
How can we expect to be the leading nation in science and engineering forever? We can't, really. Here's a photograph of me at the Great Hall of the People at a meeting of scientists in China. The president of China, Hu Jintao, came to a scientific meeting with 3000 people in the audience, including about 2000 students,. He came and sat for about an hour and listened to other people's speeches. And then he gave his own speech, in which he made the point that science and technology must form the main basis for China's future development. China's leaders are almost all people trained as engineers, so this vision of the future comes naturally to them. But we still have a big job to do in this country to create a correspondingly clear recognition of the source of US world strength by our leadership.

Is there a way to remain the world leader in science and technology throughout this century? The only option we have is to be the continual source of the most innovative new ideas and technologies. As soon as a technology ages, it's going to move abroad. We must therefore focus much more intensely than we do now on stimulating and rewarding innovation and risk taking. What will this require? Of course, it will require recruiting the most talented young people to science and engineering careers. The people in this room will have a great deal to do with that. Secondly, we must provide these people with the best possible undergraduate and graduate training. Third, we must do more to provide merit-based, strong government and foundation funding for risk-taking research and education. And, last but not least, we must structure our scientific institutions to maximize innovation. We must eliminate environments in our universities where the faculty and students mainly interact with the eight or so professors in their department. I see around the United States a lot of change in this respect, with many interdisciplinary and multidisciplinary interactions taking place.

Will any of this happen automatically? I would say no, because in many cases there are forces taking us in the wrong direction. Both national and state academies are going to need to pay attention, we will require a great deal of active management and creative leadership from the scientific community in the years ahead. Some evidence for my claim is that over a period in which the National Institutes of Health (NIH) budget has doubled, the number of young independent investigators has dropped precipitously. At present, the average age for an independent investigator getting a grant for the first time from the NIH is now 42 years old —isn't that amazing? In my generation, many of us had our own labs as assistant professors with research support before we were 30. In the last two decades, the NIH data shows a big drop in the number of young people with a chance to start their own careers with their own ideas.

As an urgent challenge to universities and funding agencies, we might develop special mechanisms to select our very best young scientists at an early age and provide them with the resources they need to pursue new lines of research, without requiring "preliminary results." Preliminary results are the death of creativity. To require preliminary results from someone starting a new lab means that they must, of course, do what they were doing before in their post-doctoral research. As a result, we force our scientists to do the same thing as their mentors. It's about the worst thing you could imagine for creating new science. A new report from the National Academies, called *Bridges to Independence*, was requested by NIH director Elias Zerhouni, who is very disturbed by the same things I've been talking about. This committee was chaired by Tom Cech, the Nobel-prize winning scientist who is now president of the Howard Hughes Biomedical Institute, and their report recommends that Zerhouni try some bold experiments to try to reverse this trend

I would like to end my presentation today by talking about how the National Academies work to spread science, and scientific values, throughout the world. The bottom line is that scientists will need to have a much larger presence in world affairs in the years ahead. The world's population will increase from 6 billion people today to 9 billion people in 2050, hopefully leveling out thereafter. Already, billions of people are living in poverty. Science is needed everywhere to help make this ever more crowded world a more rational and a more prosperous place.



International science is something I knew nothing about when I became president of the U.S. National Academy of Sciences. My whole view of international science was jaded by international biochemistry congresses in faraway places, where I heard people speak whose papers I could have simply read in the library. I wanted to have nothing to do with it. However, in September 1993, soon after I became president of our Academy, the first-ever meeting of the academies of the world was held in New Delhi. The goal was to inject scientific input into the major U.N. population meeting to be held in Cairo in 1994. Otherwise, we feared that the Cairo meeting would proceed without any scientific input.

The New Delhi meeting was something completely different for me. It wasn't about DNA replication research, it was about how science can do something important for the world and for societies everywhere. It was a different kind of science. For example, how much does educating women contribute to population control? There was scientific data on this issue. In this and other areas, we could tell from scientific evidence what works. That meeting was very successful; and its major statement, presented by the president of the Indian National Academy of Sciences at Cairo, was indeed the only science at that Cairo conference.

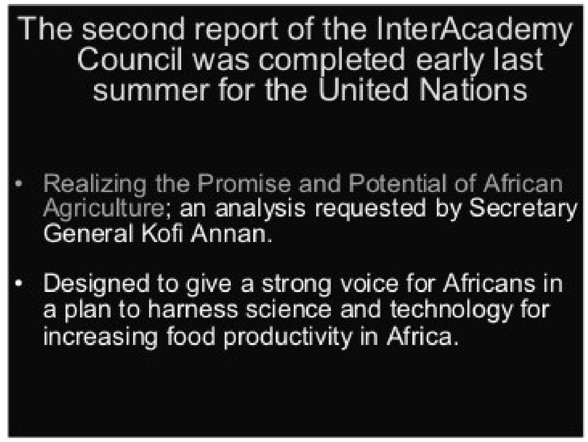
On our last day in New Delhi, someone organized a special meeting of all seventy academy representatives to ask whether there shouldn't be more regular meetings of this kind. As a young, somewhat naïve, new academy president, I doubted the need for yet another organization. We already had ICSU (the International Council of Scientific Unions). Why did we need anything else? Then Dr. M.G.K. Menon from India, a former president of ICSU, presented some very articulate reasons why we did need this new organization, and everybody—including myself—became enthusiastic about the idea.

The InterAcademy Panel (IAP) on International Issues was basically established at that meeting. The IAP Secretariat is now located at the Third World Academy of Sciences in Trieste, and it recently received a permanent endowment from the Italian government. It recognizes that every nation, no matter how poor, needs its own scientists and engineers to enable it to harness the worlds great store of scientific and technical knowledge to meet the needs of its society. However, these people are unlikely to be effective in either their work or in guiding the decisions made by their nations without strong institutions to support and harness their efforts. Therefore, in every nation, building and supporting effective institutions for science and engineering must become a key goal for development. Strong merit-based universities are of course key. But also important are academies (or academy like organizations) that represent the best in science and engineering in the nation and have a focus on integrating and strengthening these capacities in the national interest. One of their critical missions must be telling truth to power. The fact is that politicians everywhere tend to cater to those with special interests, focusing on short term gains that will get them re-elected or re-appointed to their positions. Only a strong, respected voice for local scientists is likely to provide the countervailing power needed for a nation to make wise long-run decisions on many issues that effect health, agriculture, the economy, and the environment. Thus, the major goal of the InterAcademy Panel is to help the member academies in each nation develop a larger role in their own societies, including becoming a respected independent advisor to their own governments. It does so in part by promoting a sharing of information and resources between them to strengthen world science.

In 2000, the InterAcademy Council (IAC) was formed as a creation of the more than 90 IAP academies. An organization specifically established "mobilize the world's best science for policymakers," it is governed by a Board of 15 academy presidents and headquartered at the Royal Netherlands Academy of Sciences in Amsterdam. I have had the privilege of serving as a co-chair of the IAC since its inception—first with the president of the Indian National Science Academy, and now until 2009 with the president of the Chinese Academy of Sciences.

The first major report of the IAC, *Inventing a Better Future: A Strategy for Building Worldwide Capacities in Science and Technology*, was released at a special meeting of the U.N. General Assembly hosted by Secretary General Kofi Annan in February 2004. This report emphasizes the critical importance of building high quality institutions for science and technology in every nation, and it offers practical advice on exactly how to do this – with specific roles identified for both developing nations and for nations like our own who have important catalytic roles to play.

The second IAC report, called *Realizing the Promise and Potential of African Agriculture* was directly requested by the UN Secretary General. Released at the UN and in Africa in the summer of 2004, it was specifically designed to give a strong voice for Africans in a plan to harness science and technology for increasing food productivity in Africa. (Africa is the only continent where food productivity per person is declining). The committee that produced the report was half African, and a great deal of the advice relied on the experience in other developing countries. In the United States, we are sometimes too far removed from the development experience for our solutions to be useful.



All that I have described represents only the very beginning of a newly energized attempt to spread science and its benefits around the globe, because it is critically important that science, and scientists, achieve a much higher degree of influence throughout both their nations and the world. As we pursue this aim, we must not forget, that as we spread the practical benefits of science, we also spread the scientific spirit, and the scientific values of openness and honesty that are so critical for the future. To reinforce this point, I shall end with two of my favorite quotes. The first is from a book called *Science and Human Values* by Jacob Bronowski (1956).

> "The society of scientists is simple because it has a directing purpose: to explore the truth. Nevertheless, it has to solve the problem of every society, which is to find a compromise between the individual and the group. It must encourage the single scientist to be independent, and the body of scientists to be tolerant. From these basic conditions, which form the prime values, there follows step by step a range of values: dissent, freedom of thought and speech, justice, honor, human dignity and self respect. …Science has humanized our values. Men have asked for freedom, justice and respect precisely as the scientific spirit has spread among them."

And finally, a recent statement from a distinguished South African leader, Mamphela Ramphele, who was an important member of the IAC's *Inventing a Better Future* committee.

"The insights, methods, and ways of thinking attendant on scientific inquiry hold, I believe, the key to personal and national development in much of the developing world. The characterization of science as "Western" by some social scientists is unfortunate: it serves to delegitimize scientific inquiry and the application of science to everyday problems. It finds resonance among elites in the developing world who see the entrenchment of a science culture as a threat to their power over the poor and marginal."

The 2006 Annual Meeting of the Mississippi Academy of Sciences will be held on 23 and 24 February at the Convention Center in Vicksburg, Mississippi

A Descriptive Survey of Meteorological Observing Systems in Mississippi[1]

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An extensive survey is given of the wide range of weather data collected by various agencies and private interests within the state of Mississippi. Routine surface weather observations are collected in Mississippi by the National Weather Service, Federal Aviation Administration, military bases, individual airports, U.S. Forest Service, National Park Service, U.S. Fish and Wildlife Service, Mississippi Forestry Commission, U.S. Department of Agriculture Natural Resources Conservation Service, U.S. Geological Survey, Army Corps of Engineers, National Data Buoy Center, and specialized research programs. Both Jackson State University and Louisiana State University operate networks of weather stations. Privately owned stations are managed by AWS WeatherBug, the APRSWXNET/Citizen Weather Observer Program, and wunderground.com. The National Weather Service also has responsibility for "upper air" observations and the publicly owned Doppler radar network. Data from these publicly available networks are appropriate for various research and operations-oriented applications. The types of weather data represented are either in situ or ground-based remotely-sensed data (i.e., excluding satellite data). Significant aspects of the network-specific operational constraints and communications paradigms are briefly documented. In those cases of meteorological data that are publicly available through a website, the URLs for data access are referenced. Emphasis is particularly placed on data that are available in near real-time.

1. INTRODUCTION AND OBJECTIVES

Meteorological data are valuable to a wide variety of scientific disciplines and related applications. However, lack of awareness among potential users in academia, government, agriculture, and industry of the various data sources and their relative merits is often an obstacle to full and appropriate utilization of these resources. The purpose of this document is to provide an exhaustive survey and description of meteorological data sources within Mississippi, including procedures for data access. Much of the impetus for providing such documentation to a general audience came from a workshop held at Jackson State University on Oct. 29–30, 2002, to discuss the possibility of building a new state-level "mesonet" of automated meteorological observing stations that would vastly improve the spatial and temporal availability of surface weather data (White, 2002; Alonso et al., 2003). Although there have been meaningful steps taken toward that goal, the intent of this paper is to serve as a benchmark of what data are currently available within the state.

The data sources vary in their use of metric or English units, and in terms of timekeeping conventions. These issues will be addressed only in general terms for each observing system. Meteorologists most commonly use UTC time (Universal Time Coordinate; also known as "Z" or "Zulu" time), i.e. the standard time at Greenwich, England (0° longitude). However, some observing networks in Mississippi report in terms of Central Standard Time, usually without changing to Daylight Saving Time (DST) during the warm season. Central Standard Time is six hours earlier than UTC, and Central DST is five hour earlier.

2. SURFACE OBSERVING SYSTEMS

For purposes of this survey, we will define surface observing systems to be those systems of sensors which are primarily used to describe the state of the atmosphere within 100 m of the earth's sur-

[1]See appendix at the end of this article for a list of acronyms.

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face, as well as related sensors to describe temporal variations in the surface itself. These data are most commonly of interest to a typical user, and are usually the most easily accessible. Emphasis will be given to permanent sites that typically record data at least once per hour. The availability of such data within at most one hour of the observation time will be referred to as "real-time" access.

2.1 ASOS/AWOS systems. The most widely distributed real-time data are those observed by the system of automated weather stations operated jointly by the National Weather Service (NWS) and the Federal Aviation Administration (FAA). Typically these sites are located at airports and have their strongest mandate for aviation safety requirements during take-off and landing (http://www.faa.gov/asos). The Automated Surface Observing System (ASOS) takes observations every minute, twenty-four hours a day (U.S. EPA, 1997). The current one-minute data are normally only available via dedicated phone line or through VHF radio. The routinely available (and archived) data are transmitted at least once per hour. The standardized hourly observation (referred to as "synoptic") normally occurs during the ten minutes before the top of the hour, and is transmitted through the Global Telecommunications System (GTS) of the World Meteorological Organization (WMO) for use by NWS and other users. These are the data reports most often referred to in the news media. Under certain circumstances data may be provided more than once per hour, either due to significant changes in weather at the station (e.g. wind shifts or beginning of rain) or at the discretion of the local airport operations. These "special" reports are also transmitted through GTS, but are not as routinely accessed due to their temporal inconsistency.

A similar type of observing system, known as the Automated Weather Observing System (AWOS), is basically the predecessor to ASOS (Harder and Dunlap, 1999). AWOS has been replaced at most commercial airports by ASOS since 1992. But there are still AWOS systems operating at some smaller airports. In most respects the differences will not be noticeable to the casual user. However, there are some AWOS sites that do not supply data through GTS, significantly limiting data access.

Manual observing sites report through GTS in the same format as ASOS/AWOS, with similar procedures. Practically all manual sites have been replaced by automated systems. The most important distinction for most users is that manual sites do not generally report 24 hours a day. The three remaining "manual" sites in Mississippi are all at military installations. Automated instrumentation is actually on-site, but the sensors differ from NWS equipment and observations are only reported when a human being is on duty since they are manually entered for transmission.

The data for both synoptic and special observations are normally provided in "METAR" format. This compact text format reports all observed parameters (which may vary slightly according to location) along with various automated or manually entered remarks (e.g. thunderstorms visible to the southwest). The authoritative description of how to read a METAR report is the Federal Meteorological Handbook "FMH-1" (OFCM, 1998), which may be accessed at http://www.ofcm.gov/fmh-1/pdf/ch12a.pdf or at http://metar.noaa.gov. Various tutorials on METAR may be found by searching the World Wide Web. For many users, there is no need to deal with actual METAR reports since many websites provide decoded observations. Only the most routine elements of an observation are typically decoded however.

A synoptic METAR report will normally include: station identification, UTC time, wind at 10 m above the ground, visibility, "present weather", temperature and dewpoint at 2 m, sea level pressure, cloud cover amount, cloud base heights, and precipitation. A typical ASOS site is shown in Fig. 1. Unfortunately the mixture of English and metric units in the U.S. version of METAR can lead to confusion. Operational limitations of ASOS preclude visibility being reported beyond 10 statute miles or clouds detected more than 12,000 feet above ground level. The latter may result in reports of "clear skies" even when the sky is overcast if the clouds are higher than 12,000 feet. "Present weather" refers to types of precipitation, causes of visibility obscuration, and other standardized qualitative observations.

Locations of ASOS and AWOS sites in Mississippi (or within 20 km of the state line) are shown in Fig. 2. The official location for current METAR data reported through GTS is http://weather.noaa.gov/weather/metar.shtml. More convenient access is available through http://weather.noaa.gov/weather/MS_cc_us.html or the University Corporation for Atmospheric Research's (UCAR) Research Applications Program (RAP) http://www.rap.ucar.edu/weather/surface. The official repository for all NWS data is at the National Climatic Data Center (NCDC) (http://www.ncdc.noaa.gov/oa/ncdc.html). Since most of NCDC's data are not available for free, some users may also find the "Detailed History" feature (after selecting a location) at http://www.wunderground.com to be useful for data from the last few years. Other offices worth checking with are the Office of the State Climatologist (http://www.msstate.edu/dept/GeoSciences/climate) and the Southern Regional Climate Center (http://www.srcc.lsu.edu). The current list of phone numbers for direct access to current ASOS/AWOS observations is available at http://www.faa.gov/asos/map/ms.cfm. Toll-free access is currently available through the privately operated service described at http://www.anyawos.com.

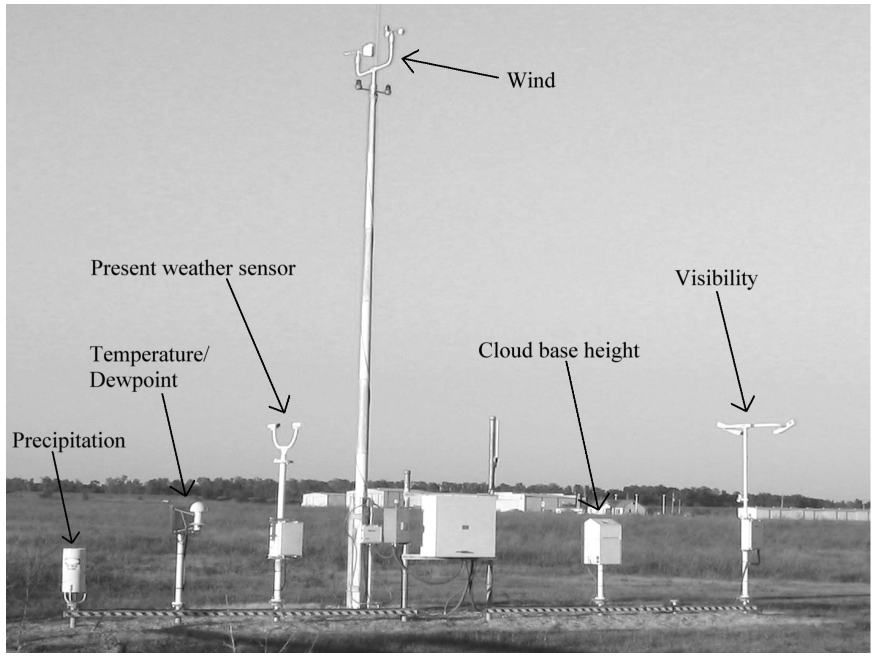

Figure 1. KTVR ASOS site.

2.2 RAWS. The major federal land management agencies (U.S. Forest Service, Bureau of Land Management, National Park Service, and U.S. Fish and Wildlife Service) have for the last several years operated their own network of automated weather observing sites known as RAWS (Remote Automated Weather Stations) (http://www. fs.fed.us/raws). The primary purpose has been fire management (Zeller et al., 2001). Hourly observations are reported of temperature, dewpoint (or relative humidity), wind, precipitation, and solar radiation. Fuel moisture and temperature are also observed, in order to better describe the combustibility of the local vegetation. Due to communications constraints of the GOES (Geostationary Operational Environmental Satellite) satellite through which data are transmitted, different sites may report at a different number of minutes after the hour (although many report on the hour). There are also a few RAWS sites that still only upload their data once a day via phone line. Observation times are reported in UTC.

In Mississippi, RAWS observing sites are located on National Forest, National Park, and National Wildlife Refuge lands (Fig. 4). There are also several sites recently installed by the Mississippi Forestry Commission to give better coverage of the state. Since sites are typically collocated with work centers or agency communications infrastructure, the data may be more representative of forested environments than of the large clearings in which ASOS/AWOS stations tend to be sited (e.g., Fig. 3). Data from the last 24 hours may be obtained from

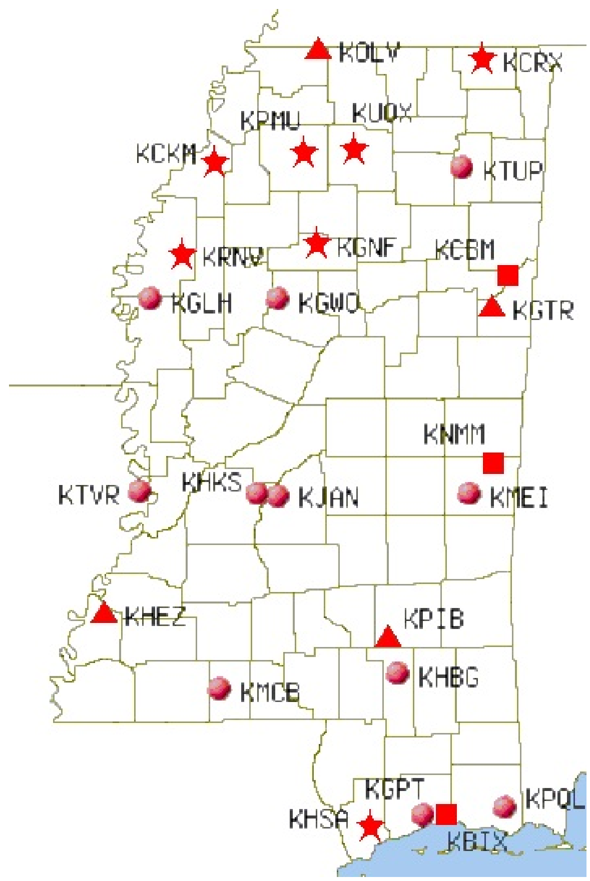

Figure 2. Locations of ASOS sites (balls), AWOS sites (triangles), manual GTS sites (squares), and non-GTS AWOS sites (stars), as of early 2004.

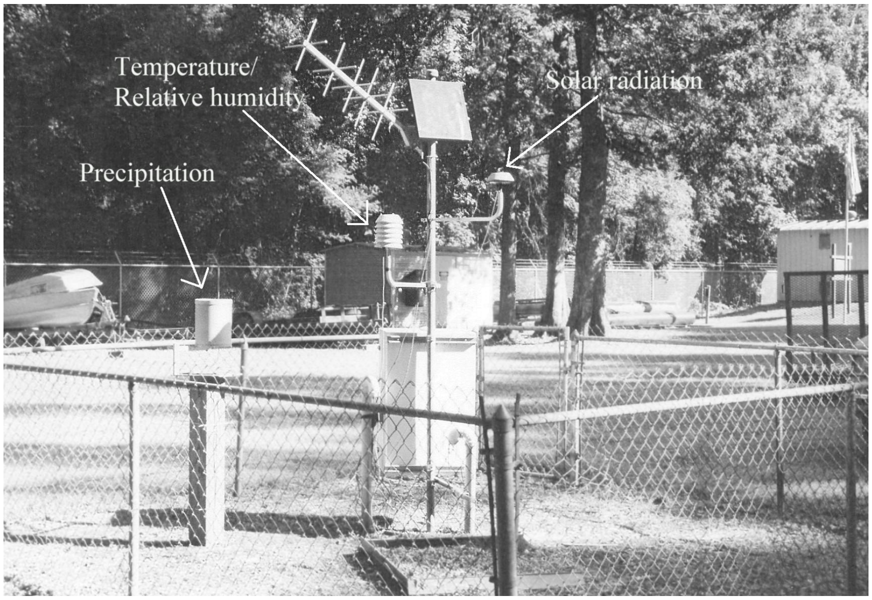

Figure 3. Delta RD RAWS site (wind sensors on taller tower out of view).

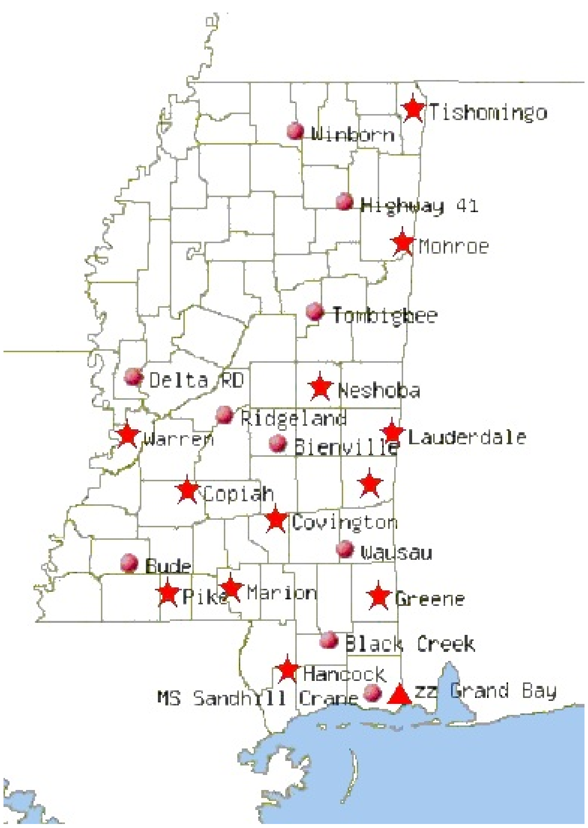

Figure 4. Locations of RAWS sites: real-time federal sites (balls), real-time non-federal sites (stars), and non-realtime sites (triangles), as of Spring 2004.

http://raws.wrh. noaa.gov/roman. Limited access to archived data is available at http://www.wrcc.dri.edu/wraws/al_msF.html. The HADS system (described below in Section 2.4) also provides access to RAWS data.

2.3 SCAN. The Soil Climate Analysis Network (SCAN) of the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) was developed primarily for agriculture. Currently Mississippi has the most SCAN sites of any state. Hourly observations include temperature, relative humidity, wind, precipitation, and solar radiation. Additionally, measurements of soil temperature and soil moisture are made at various depths under bare soil. Data are transmitted via meteor burst telemetry (Puterbaugh et al., 2003) to a central processing center for real-time access via the internet: http://www.wcc.nrcs.usda.gov/scan/Mississippi/ mississippi.html. All measurements are reported in metric units, and observation times are referenced to Central Standard Time. A typical site is shown in Fig. 5, and locations of observation sites in Mississippi are shown in Fig. 6.

2.4 Hydrological Networks (HADS). There are several sites in Mississippi (mostly in Jackson County) where the U.S. Geological Survey (USGS) and Army Corps of Engineers measure temperature and/or wind to complement a larger network of precipitation and streamflow observations. These data are accessed by NWS for flood forecasting using the Hydrometeorological Automated Data System (HADS) (Glaudemans et al., 2002). Typically instrumentation (e.g., a rain gauge) is mounted on the side of a bridge over a major stream where river stage and discharge are being observed. Reporting intervals and times vary from station to station, with transmission via GOES satellite. Observation times are reported in Central Standard Time. Direct access to data through HADS is possible through http://www.nws.noaa.gov/oh/hads, though the user interface is relatively inconvenient. Data may also be obtained from http://ms.waterdata.usgs.gov/nwis/rt or http://ms.water.usgs.gov/rt/biloxi/imap.html (for coastal counties). A USGS observing site that measures temperature, wind, and precipitation is shown in Fig. 7. All stations in Mississippi currently reporting

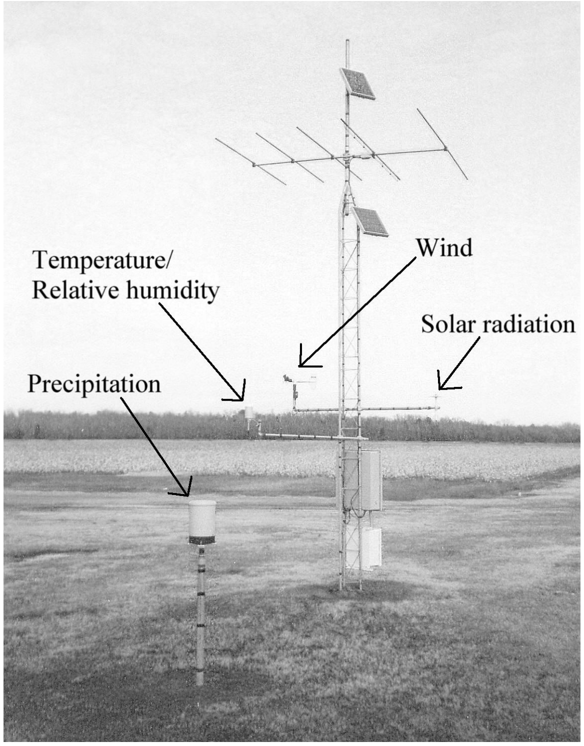

Figure 5. Starkville SCAN site.

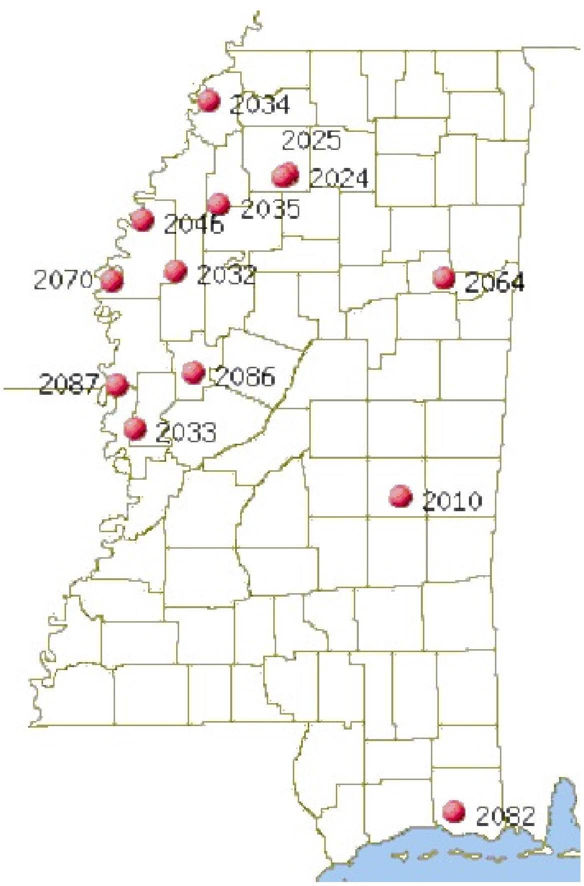

Figure 6. Locations of SCAN sites.

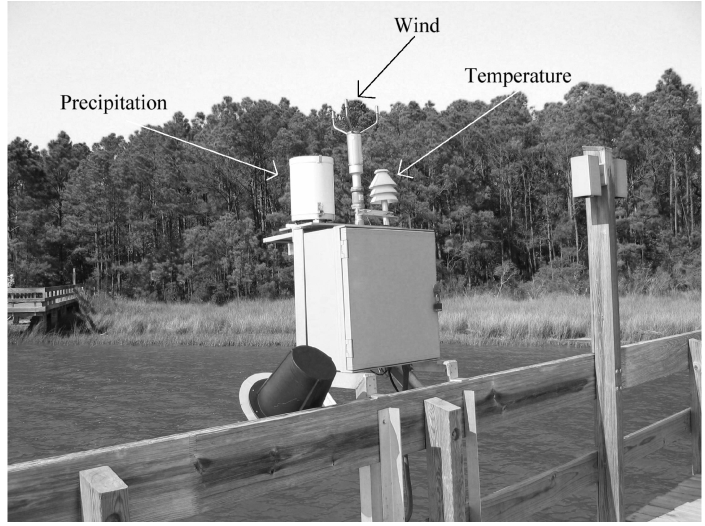

Figure 7. A meteorological observing station (OFBM6) installed by USGS on a bridge near Ocean Springs.

meteorological data through HADS are shown in Fig. 8.

2.5 Other Publicly Owned Real-time Sites. There are at least two marine weather sites relevant to Mississippi. Although technically within the waters of Louisiana, the buoy operated by the National Data Buoy Center (NDBC) south of Biloxi (Fig. 9) provides hourly data (on the hour) for temperature, dewpoint, wind, and pressure. Additional data include winds every 10 minutes, and wave statistics and water temperature every hour. Data are transmitted via GOES satellite. Current and archived data may be accessed through http://www.ndbc.noaa.gov/Maps/WestGulf.shtml. Another marine buoy site located near the Mississippi barrier islands is part of the Wave-Current-Surge Information System (WAVCIS) operated by Louisiana State University's Coastal Studies Institute (http://www.wavcis.lsu.edu). It observes temperature, wind, and pressure hourly on the hour, but data are only transmitted once every three hours. Additional marine observations describe waves, currents, and sea surface temperature. Transmission is by cellular phone to a Coastal Studies Institute lab.

Temperature, relative humidity, and pressure are reported for diagnostic purposes at three sites in Mississippi of the Ground-Based GPS Meteorology (GPS-MET) demonstration network operated by NOAA's Forecast Systems Lab (FSL) (Wolfe and Gutman, 2000). Data are available every five minutes relative to UTC time from http://www.gpsmet.noaa.gov. The surface meteorological conditions are primarily monitored for use in calibration of ground-

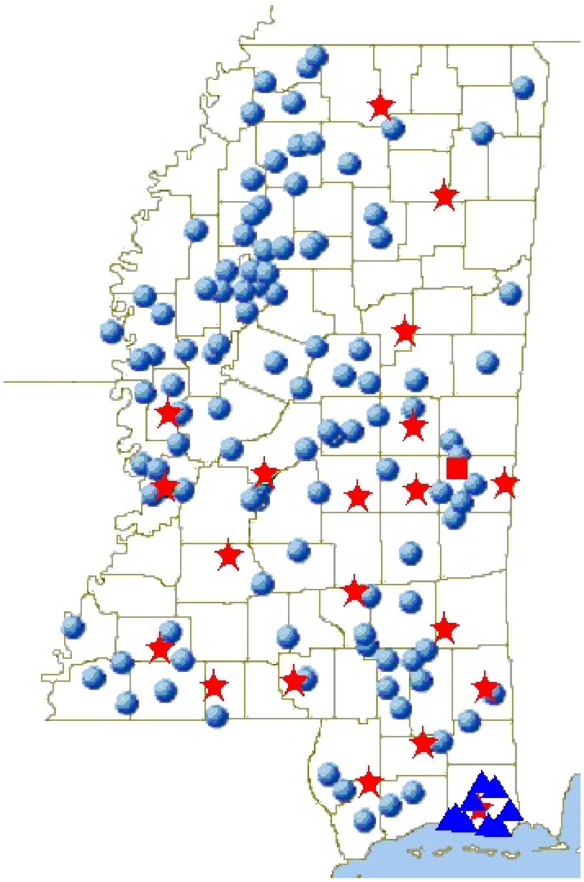

Figure 8. Observing sites available through HADS: precipitation only (balls); temperature, wind, and precipitation (triangles); temperature and precipitation (squares); RAWS and CRN sites (stars).

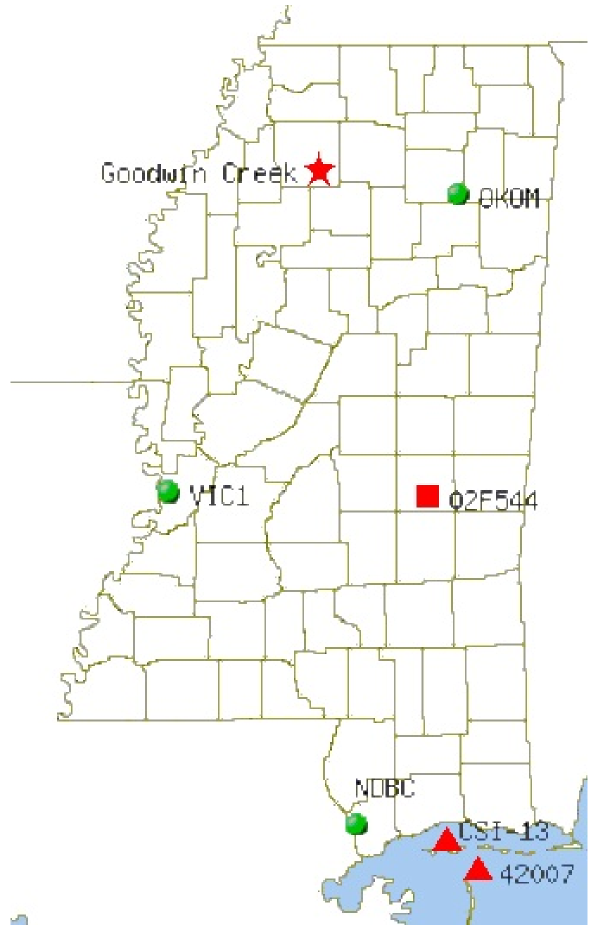

Figure 9. Other publicly owned observing sites: NDBC and WAVCIS (triangles), GPS-MET (circles), Climate Reference Network (square), and SURFRAD (star).

based integrated (i.e., total column) precipitable water retrievals using differential GPS technology.

The NOAA Climate Reference Network (http://www.ncdc.noaa.gov/servlets/crnmap) is designed to provide very reliable long-term climate measurements at select sites around the United States (Baker, 2002). Data collected via GOES satellite upload include air temperature, radiative surface temperature, precipitation, wind speed, and solar radiation every hour. There is one station located in Mississippi near Newton.

The SURFRAD network (DeLuisi et al., 2000) exists primarily "to support climate research with accurate, continuous, long-term measurements of the surface radiation budget over the United States." These sites provide ground truth surface radiation budgets for validation and calibration of satellite-based estimates. Temperature, relative humidity, wind, pressure, and various radiation measurements are stored every three minutes in UTC time. The data are uploaded to http://www.srrb.noaa.gov/surfrad once a day. There is one site in Mississippi, near Batesville.

2.6 AWS. The largest single network of privately owned weather stations is operated by "AWS WeatherBug." Many of the observing sites are located at schools. AWS works with a local television station to manage sites within a given television market. Significant limitations are imposed on data access and redistribution due to the commercial nature of the observing network. Observations are available of temperature, dewpoint (or relative humidity), wind, pressure, precipitation, and (in some cases) "light" (as a percentage of potential). Scientific integrity of data may be compromised in some cases by placement on the tops of buildings (Fig. 10). The network as of April 2004 is shown in Figure 11.

At many locations observations are available every minute, although some sites report only sporadically. Time is either Central Standard Time or

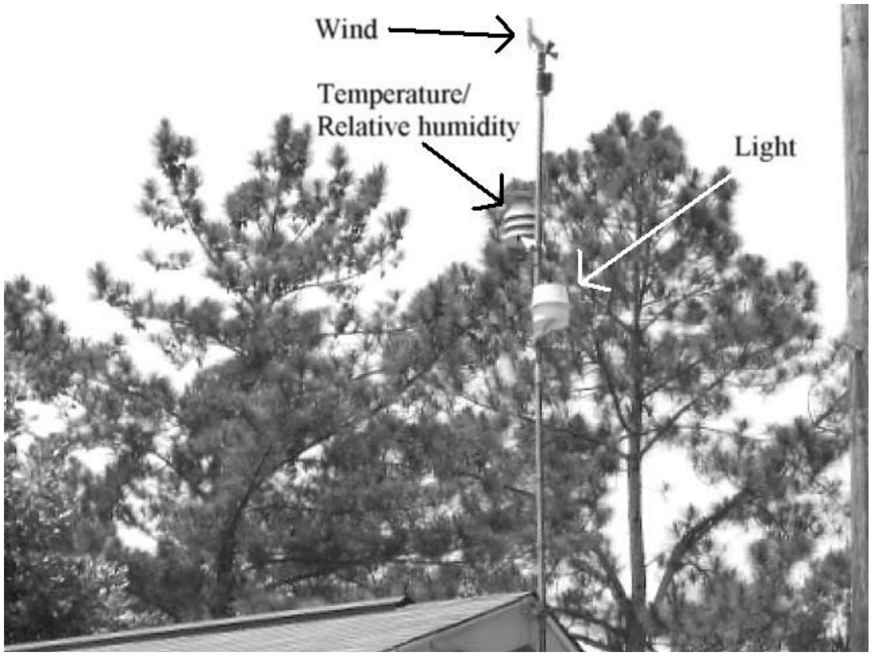

Figure 10. AWS WeatherBug station at Coast EPA in Poplarville.

DST, according to time of year. Northern Mississippi stations may be accessed at http://www.instaweather. com/WREG; central Mississippi stations at http:// www.aws.com/wlbt; and coastal Mississippi stations at http://www.aws.com/wlox. For stations in northern Mississippi, archived hourly data can also be obtained freely from the website. As a reflection of the complexity of partnerships between multiple schools, businesses, and television stations, there is a wide variety of consistency in sensor calibration and communications reliability. As a consequence, data reliability and availability may range from fairly good to practically useless depending on the site.

2.7 APRS and "wunderground." Automated weather stations owned by individuals exist at various locations with the state. There are two primary places to look for these data. The APRSWXNET/Citizen Weather Observer Program (CWOP) has grown out of efforts to collect weather data observed by ham radio operators. Parameters reported can include temperature, humidity/dewpoint, wind, precipitation, and pressure. Data are available essentially instantaneously, although frequency of reports varies by station. Times are reported in UTC. As with AWS, there is a fair amount of flux from day to day of which stations are actually reporting. Since individual "observers" may purchase observing systems from several commer-

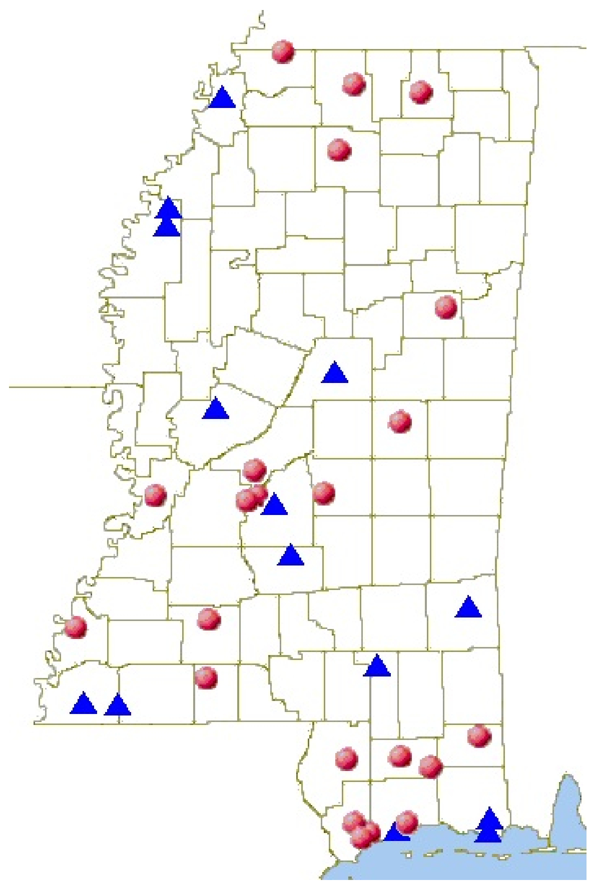

Figure 11. AWS WeatherBug stations: with data available on 8 April 2004 (balls) and inactive or not reporting on 8 April 2004 (triangles).

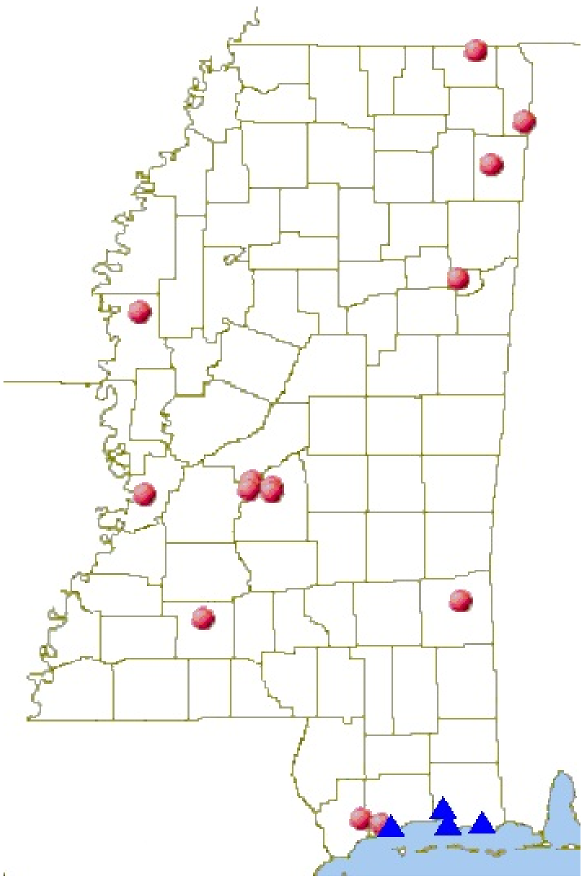

Figure 12. APRS/CWOP sites (balls) and wunderground.com sites (triangles), as of 8 April 2004.

cial vendors and maintain the equipment differently, there is no guarantee of consistency between sites. A list of sites with current observations may be found at http://www.wxqa.com/states/MS.html. Sites reporting on 8 April 2004 are shown in Fig. 12.

Another source for data from privately operated weather stations is "wunderground.com" ("Weather Underground"). Variables observed include temperature, humidity/dewpoint, wind, pressure, and precipitation. Observation frequency varies, with times reported in Central Standard Time or DST. In many cases, individually owned websites exist that provide additional data, though not in a standardized format. Sites reporting in Mississippi are listed at http://www.wunderground.com/weatherstation/ListStations.asp. In a few cases, the sites also report data through APRS. Archived data are available through the website, both for the private sites and for ASOS observations.

2.8 NWS "COOP" sites. The backbone of NWS climatic observations for more than a hundred years has been the Cooperative Observer Program (http://www.nws.noaa.gov/om/coop). Relying primarily on manual observations by "cooperative observers," observations are normally made at over 100 sites in Mississippi once a day of maximum/minimum temperature, 7 am temperature, and daily precipitation. Temperatures may either be from manual liquid-in-glass thermometers or from an electronic Maximum-Minimum Temperature System

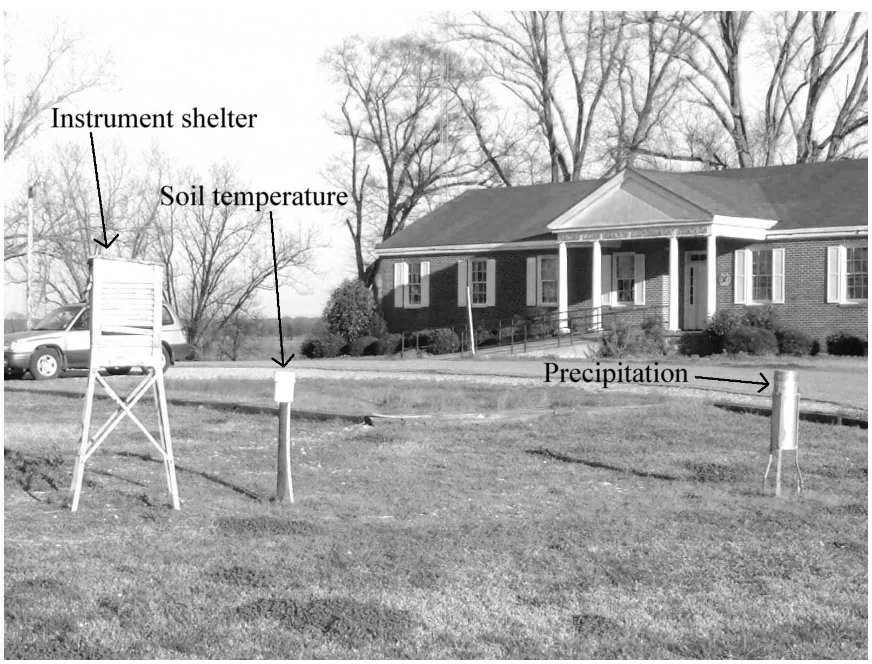

Figure 13. Manual COOP observing site at Oakley Experiment Station (OES).

(MMTS). In the manual case, the thermometers are shielded from sunlight within a white wooden instrument shelter (also known as a "cotton region shelter") (Fig. 13). The COOP network is the primary climate observing system in the United States and is used to generate most NWS official climate statistics. Approximately 40 stations also record hourly precipitation, and about 15 have supplemental observations of evaporation or soil temperature. Data are not routinely available to the general public in real time. In some cases, recent observations may be obtained from the closest NWS Weather Forecast Office. All data are eventually archived at NCDC, from whom they may be purchased. They may also be obtained from the state climatologist (http://www.msstate.edu/dept/GeoSciences/climate) or from the Southern Regional Climate Center (http://www.srcc.lsu.edu).

2.9 Sources of multiple datastreams. NOAA's Forecast Systems Lab (FSL) maintains an interactive website (http://www-frd.fsl.noaa.gov/mesonet) for graphical access to real-time quality-controlled data from several observing systems. They store the full observational database in the Meteorological Assimilation Data Ingest System (MADIS) (Barth et al., 2002). Recent data from several networks are provided by AnythingWeather at http://www.anythingweather.com/state.aspx?id=ms. Other online resources dedicated to Mississippi weather data have been developed by Jackson State University, and may be accessed via links from http://weather.jsums.edu.

3. UPPER AIR OBSERVING SYSTEMS

Most knowledge of the state of the atmosphere above 10 m is from radiosondes. Commonly referred to as "weather balloons", radiosondes are typically launched by the National Weather Service at locations near their Weather Forecast Offices (WFOs) (Peterson and Durre, 2004). As the balloon rises, temperature, relative humidity, and pressure are measured and sent back to a base station by radio. Winds at the different heights are determined from radar tracking of the balloon. Data are gathered from several mandatory pressure levels, as well as additional "significant" levels where atmospheric changes are noted. Usually it is possible to get data from throughout the troposphere and lower stratosphere, in some cases as high as 30 km (about 10 hPa). Radiosondes are launched twice a day at 00 and 12 UTC (approximately sunrise and sunset in Mississippi), with additional launches during special circumstances. One of the most comprehensive online sources for radiosonde data is maintained by FSL at http://raob.fsl.noaa.gov. There are many websites that present most recent radiosonde data in "skew-T ln p" graphical form or spatial analyses of mandatory level data from across the North America, such as UCAR RAP (University Corporation for Atmospheric Research's Research Applications Program): http://www.rap.ucar.edu/weather/upper. Although the only radiosonde site in Mississippi is at Jackson, others within surrounding states are close enough to be useful for some parts of the state. Locations are shown in Fig. 14.

To provide temporal resolution between radiosonde launches, ground-based radar wind profilers have been developed. For the most part these are part of FSL's National Profiler Demonstration Network (http://www.profiler.noaa.gov) (Benjamin et al., 2004). Wind speed and direction are sampled at regularly spaced vertical levels, and displayed as a time-height cross-section with a time increment of one hour. In Mississippi there is one site, at Okolona (Fig. 14).

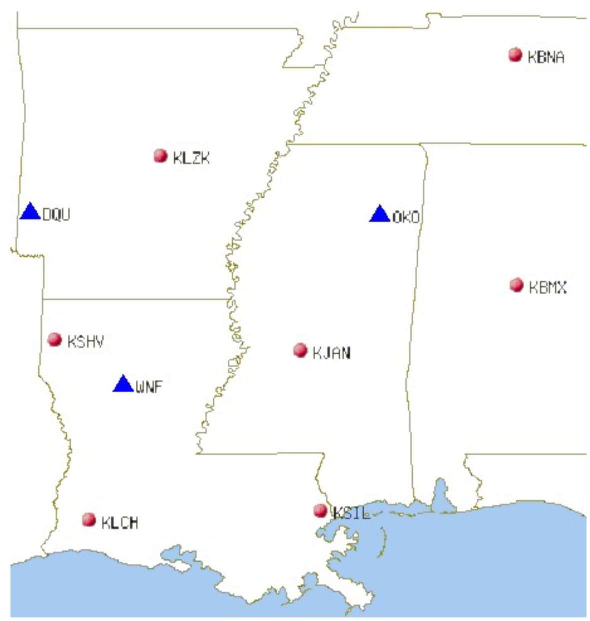

Figure 14. Upper air observing sites in Mississippi and surrounding states: radiosondes (balls); and wind profilers (triangles).

4. RADAR

The National Weather Service's "NEXRAD" Doppler radar network serves a dual purpose of estimating rainfall rates and winds within storms. Based on radar reflectivity, rain rates can be determined. However, this relationship varies with the size distribution of droplets, which in turn depends somewhat on the character of the weather system. Accuracy of radar-derived rainfall estimates also depends on distance from the radar site. Very close to the site useful data are difficult to retrieve due to electromagnetic interference effects and the "ground clutter" of nearby buildings, trees, and topography. At distances too far away, the curvature of the earth results in the radar beam sampling too high above the ground to give a reliable representation of surface precipitation rates. In general, comparison with surface measurements of precipitation should be used to ensure calibration of radar estimates when quantitative precipitation is required. Radar backscatter may also occur due to non-precipitation effects such as migrating birds, dust clouds, or atmospheric ducting. The major value of radar lies in its high spatial and temporal resolution.

The Doppler effect makes it possible to detect variations in the component of the wind radially toward or away from the radar site. This is dependent though on there being sufficient scatterers in the atmosphere. The most common application is for severe storm detection in association with lines of strong wind shear. NWS Doppler wind data are not routinely available to the general public.

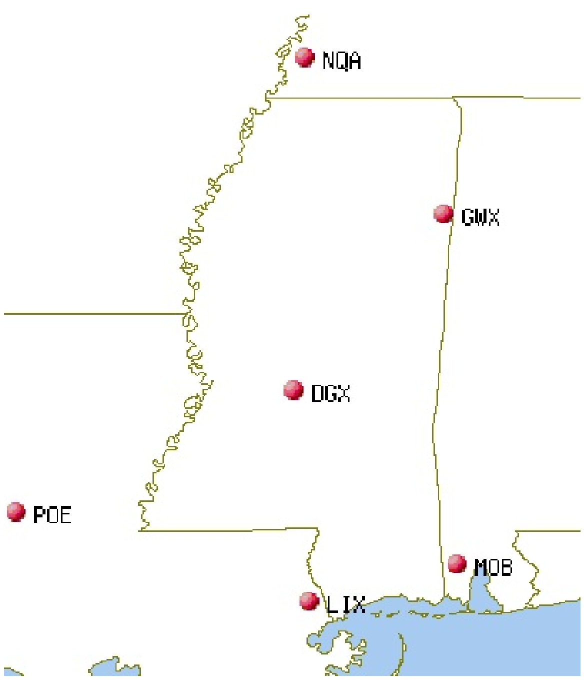

Figure 15. NWS NEXRAD radar sites.

NEXRAD radar sites serving Mississippi are shown in Fig. 15. In addition, several television stations operate their own radars. Real-time displays of NEXRAD data are available through the web pages of the individual NWS WFOs, which are linked from http://www.rap.ucar.edu/weather/radar.

5. SUMMARY AND FUTURE DIRECTIONS

The various meteorological data sources relevant to Mississippi each have their own strengths and weaknesses. This paper has attempted to give a comprehensive snapshot of the current state of these data sources. Spreadsheets of basic station metadata on each of the networks in Mississippi are available to the public by following the appropriate links from http://weather.jsums.edu. Although large amounts of data are available, it remains that there are many situations in which the desired data simply do not exist or can not be accessed in a satisfactory manner. In many cases this reflects the spatial and temporal gaps in the observing networks. As mentioned earlier, there is currently an effort to significantly improve the meteorological data availability by building a Mississippi Mesonet. Having been designed to meet the needs of a wide user constituency, the mesonet is planned to have at least one station in each county and to provide real-time access to one-minute research-quality data.

ACKNOWLEDGMENTS

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APPENDIX OF ACRONYMS

APRS: Automatic Position Reporting System
APRSWXNET: APRS Weather Network
ASOS: Automated Surface Observing System
AWOS: Automated Weather Observing System
BLM: Bureau of Land Management
COE: Corps of Engineers
COOP: Cooperative Observer Program
CRN: Climate Reference Network
CSI: Coastal Studies Institute
CWOP: Citizen Weather Observer Program
DST: Daylight Savings Time
FAA: Federal Aviation Administration
FMH: Federal Meteorological Handbook
FSL: Forecast Systems Lab
GOES: Geostationary Operational Environmental Satellite
GPS: Global Positioning System
GPS-MET: Ground-Based GPS Meteorology
GTS: Global Telecommunications System
HADS: Hydrometeorological Automated Data System
JSU: Jackson State University
LSU: Louisiana State University
MADIS: Meteorological Assimilation Data Ingest System
METAR: Routine Surface Weather Report
MFC: Mississippi Forestry Commission
MMTS: Maximum-Minimum Temperature System
NCAS: NOAA Center for Atmospheric Science
NCDC: National Climatic Data Center
NDBC: National Data Buoy Center
NEXRAD: Next Generation Doppler Radar
NOAA: National Oceanic and Atmospheric Administration
NPDN: National Profiler Demonstration Network
NPS: National Park Service
NRCS: Natural Resources Conservation Service
NWS: National Weather Service
RAP: Research Applications Program
RAWS: Remote Automated Weather Station
SCAN: Soil Climate Analysis Network
SRCC: Southern Regional Climate Center
SURFRAD: Surface Radiation network
UCAR: University Corporation for Atmospheric Research
URL: Uniform Resource Locator
USDA: U. S. Department of Agriculture
USFS: U. S. Forest Service
USFWS: U. S. Fish & Wildlife Service
USGS: U. S. Geological Survey
UTC: Universal Time Coordinate
WAVCIS: Wave-Current-Surge Information System
WFO: Weather Forecast Office
WMO: World Meteorological Organization

The Effect of Natural Sunlight on Ciprofloxacin Ophthalmic Solution[1]

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Ciprofloxacin (0.3% preparation) is available on the market for topical ophthalmic use. The marketed eye drop samples, as well as reference ciprofloxacin in aqueous solution were found to degrade to an ethylenediamine derivative of ciprofloxacin when exposed to natural sunlight. The degradation product was identified by comparison to a reference standard as well as by LC–MS, MS^2 and MS^3. A model compound, phenylpiperazine, was found to decompose to a N-phenylethylenediamine after sunlight exposure at a much slower rate compared to ciprofloxacin. When tested against *Bacillus pumillus*, the sunlight exposed ophthalmic solution of ciprofloxacin showed reduction by 2.6% of antimicrobial potency in 24 hrs compared to properly stored solution. However, ciprofloxacin ophthalmic drop containers stored in original cartons, showed no HPLC detectable photolytic degradation.

Keywords: Ciprofloxacin ophthalmic solution, sunlight, photodegradation, phenylpiperazine, electrospray mass spectrometry

Ciprofloxacin is the generic international name for the most common and widely used fluoroquinolone antibacterial agent originally introduced by Bayer Pharmaceuticals. In general, ciprofloxacin has good activity against both gram-negative and gram-positive bacteria. It is effective against a number of different types of bacteria that cause severe infections in humans, including *Streptococcus pneumoniae*, *Staphylococcus aureus*, *Escherichia coli*, *Proteus mirabillis*, *Klebsiella pneumoniae* and *Pseudomonas aeruginosa*. This antibiotic has now been released as ophthalmic drops and is useful against eye infections. When used topically, corneal toxicity and retinal toxicity rarely occur. Corneal precipitation occurs with ciprofloxacin but does not appear to interfere with healing (Smith et al., 2001).

Ciprofloxacin solution (0.3%) is currently available for topical ophthalmic use. Ciprofloxacin and ofloxacin are recognized as being safe to use, but there have been reports of skin reddening and rashes in patients taking these antibiotics after sun exposure, symptoms common to photosensitivity (The Fluoroquinolone Toxicity Research Foundation, Webpage). Research at Southmead Hospital Bristol on the stability of ciprofloxacin and ofloxacin eye drops showed that loss of antibiotic potency occurred when ciprofloxacin was irradiated at 320 nm and then tested against *Escherichia coli* (Tobin, Webpage; Phillips et al., 1990). On the other hand, Sunderland et al. in 1999 reported that the photodegradation products of ofloxacin were effective in killing bacteria. In addition, initial experiments suggest that the photodegradation products may cause toxicity. There is an extensive report (Sunderland et al., 2001) on the antibiotic activity of photodecomposed products of ofloxacin, levofloxacin, ciprofloxacin and moxifloxacin. The antibiotic activities were compared by parallel-line bioassays using *Escherichia coli*, *Enterobacter cloacae* and *Klebsiella oxytoca*. With ofloxacin and levofloxacin, the zone size for the control solution was significantly less than that of the irradiated solutions. More than 15% photodegradation in at least two of the indicator organisms indicated that the photodegradation products possess antimicrobial activity.

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[1]Presented as a poster in MAS 69th Annual Meeting, Feb 17, 2005 Oxford, Mississippi.

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There is, however, no difference seen with ciprofloxacin at any level of photodegradation with any of the indicator organisms, nor with moxifloxacin at 30 and 54% photodegradation. This conflicts with the earlier findings (Phillips et al.,1990). A significant difference was observed with *E. cloacae* only, at 83% photodegradation. On the other hand, the main degradation product of ciprofloxacin, after both artificial and daylight exposure, was reported as 7-amino-1-cyclopropyl-6-fluroro-1,4-dihydro-4-oxo-3-quinolone carboxylic acid, commonly known as ethylenediamine derivative of ciprofloxacin (Torniainen et al., 1997). Although the antimicrobial activity of photodegradation products of some fluoroquinolones including ciprofloxacin has been investigated, the general pathways in forming the degradation products have not been evaluated.

The objective of this investigation is to identify the major degradation products of ciprofloxacin in eye drop preparations when placed in natural sunlight. The antibiotic activity was investigated using different samples including controlled, photodecomposed and reference samples. In addition, experiments were performed using a simple model compound to obtain preliminary information on the mechanism of this photodegradation.

MATERIALS AND METHODS

Ciprofloxacin ophthalmic solutions. Ciprofloxacin ophthalmic solution manufactured in Bangladesh (Ciprocin, trade name, manufactured by Square Pharmaceuticals Ltd.) and a commercially available ophthalmic solution manufactured in USA (Ciloxan, trade name, manufactured by Alcon Manufacturing Ltd. and ciprofloxacin eye drop manufactured by Falcon Pharmaceuticals) were used in this study. The natural sunlight-stability experiments were conducted by keeping samples in an original container as well as in different plastic containers such as translucent (light can interact with the contents of these type of containers), amber- colored (usually used to protect the contents of the container from exposure of light), and with carton or without carton in sunlight exposure from 10 AM to 4 PM. The reference samples for ciprofloxacin and the ethylenediamine derivative of ciprofloxacin [1-cyclopropyl-6-fluoro-1,4-dihydro-4-oxo-7-(1-ethylenedimino)-3-quinoline carboxylic acid or desethylene ciprofloxacin] were USP Reference Standards having catalogue no. 13433 and catalogue no. 13432, respectively.

High Performance Liquid Chromatographic (HPLC) analysis. Reversed phase high performance liquid chromatography analysis of ciprofloxacin and its different ophthalmic solutions including sunlight-exposed samples of eye drops were carried out using a Shimadzu LC-10 as pump, a Shimadzu SPD-10A UV detector, a Shimadzu C-R 6A integrator, and a Rhedyne-7125 injector. A reversed phase column (Zorbax ODS, 4.6mm id X 250 mm) was used for analysis. The mobile phase consisted of 0.025 M phosphoric acid solution (pH 3 $\pm$ 0.1 adjusted with triethylamine) and acetonitrile in the ratio of 87:13 v/v (United States Pharmacopoeia, XXV). The chromatographic conditions are mentioned in Figure 1.

Electrospray MS and Liquid Chromatography-Mass Spectrometric (LC-MS) analysis. The electrospray mass spectrometric analysis was carried out on a Finnigan LCQ ion trap mass spectrometer using direct injection of samples in 0.1% formic acid in acetonitrile. LC-MS was carried out on a BAS HPLC interfaced with the mass spectrometer with 5% of the effluent flowing to the mass spectrometer. A reverse phase C-18 column (Econosphere) and conditions of HPLC analysis described above were used in the separation of degraded products of ciprofloxacin ophthalmic solution.

Bioassay. The sunlight exposed samples as well as the unexposed samples of ophthalmic solutions were bioassayed with USP agar 1. *Bacillus pumillus* (NCTC 8241) was used (2 mcg/ml suspension) as the indicator organism. The diameter of the zones of growth inhibition around the wells were measured and plotted against the logarithm of parent ciprofloxacin concentration.

RESULTS

The opthalmic solutions kept in direct sunlight for 3 months were analyzed by HPLC. The identification as well as quantification of the major degradation product, the ethylenediamine derivative of ciprofloxacin, was done using HPLC by comparison with the properties of a reference compound. Typical HPLC chromatograms representing both sunlight unexposed and exposed samples of ciprofloxacin ophthalmic solution are shown in Figure 1. The percent loss of potency resulting from exposure of ciprofloxacin ophthalmic solution to sunlight in different packaging conditions is shown in Table 1.

Table 1. Natural sunlight induced (3 months) loss of potency of ciprofloxacin in different packaging conditions.

Products	Packaging conditions	Loss of potency of ciprofloxacin (%) N = 3
Sample A: (Ciprofloxacin eye drop manufactured in Bangladesh)	Translucent plastic container without carton	28.5 ± 1.4
Sample B: (Ciprofloxacin eye drop manufactured in USA)	Translucent plastic container without carton	19.2 ± 1.1
Sample A	Amber colored plastic container without carton	8.4 ± 0.5
Sample A	Translucent plastic container with carton	No loss detected by HPLC
Sample A	Amber colored plastic container with carton	No loss detected by HPLC

The identity of the ethylenediamine derivative of ciprofloxacin was also confirmed by multiple stage mass spectral fragmentation and deuterium exchange followed by mass spectral fragmentation. This electrospray mass spectrometric identification technique can be used where a reference compound representing a ethylenediamine derivative of ciprofloxacin is not available. The electrospray LC-MS of sunlight-exposed ciprofloxacin ophthalmic solution or sunlight-exposed ciprofloxacin in aqueous solution produced a molecular ion $(M + H)^+$ at m/z 306 for the first peak (photodegradation product) in Figure 1(B) which on further fragmentation (MS^2 of m/z 306) yielded ions at m/z 288 by loss of H_2O. The mass fragmentation pattern of this photodegradation product, i.e., an ethylenediamine derivative of ciprofloxacin is shown in Figure 2. The peak representing the ethylenediamine derivative of ciprofloxacin was then collected in a test tube and mixed with D_2O. The deuterated sample, when injected directly into the mass spectrometer, resulted in deuterium scrambling the mass spectrum (Figure 3). On further fragmentation, the individual deuterated ions also showed the loss of D_2O, HDO, or H_2O in a scrambled manner.

In order to gain insight into the mechanism of this photolytic degradation of the ciprofloxacin molecule, a model compound, phenylpiperazine in aqueous solution (0.3%), was exposed to natural sunlight alongside a solution of ciprofloxacin solution (0.3%) in water. The degradation of the model compound occurred at the piperazinyl ring in a similar fashion as observed for ciprofloxacin (Figure 4). The photodegradation product of phenylpiperazine has been identified as N-phenylethylenediamine (or ethylenediaminobenzene) from mass spectrometric data. The mass spectral data showed $[M+H]^+$ at m/z 137, which on further fragmentation yielded m/z 120 by the loss of neutral ammonia (m/z 17). However, the photodegradation of phenylpiperazine is very slow in comparison to that of ciprofloxacin.

The sunlight-exposed ciprofloxacin ophthalmic solution samples at different time intervals were assessed for their antimicrobial activity against *Bacillus pumillus* and the results are shown in Figure 5. The antimicrobial activity of sunlight-exposed samples against *Bacillus pumillus* decreased gradually with the sunlight exposure time. About 3% reduction in antimicrobial activity was found over 24 hours sunlight exposure when compared to that of sunlight-unexposed sample. On 100 hours sunlight exposure, the sample had about 92% antimicrobial activity when compared to the activity of sunlight-unexposed, properly stored sample.

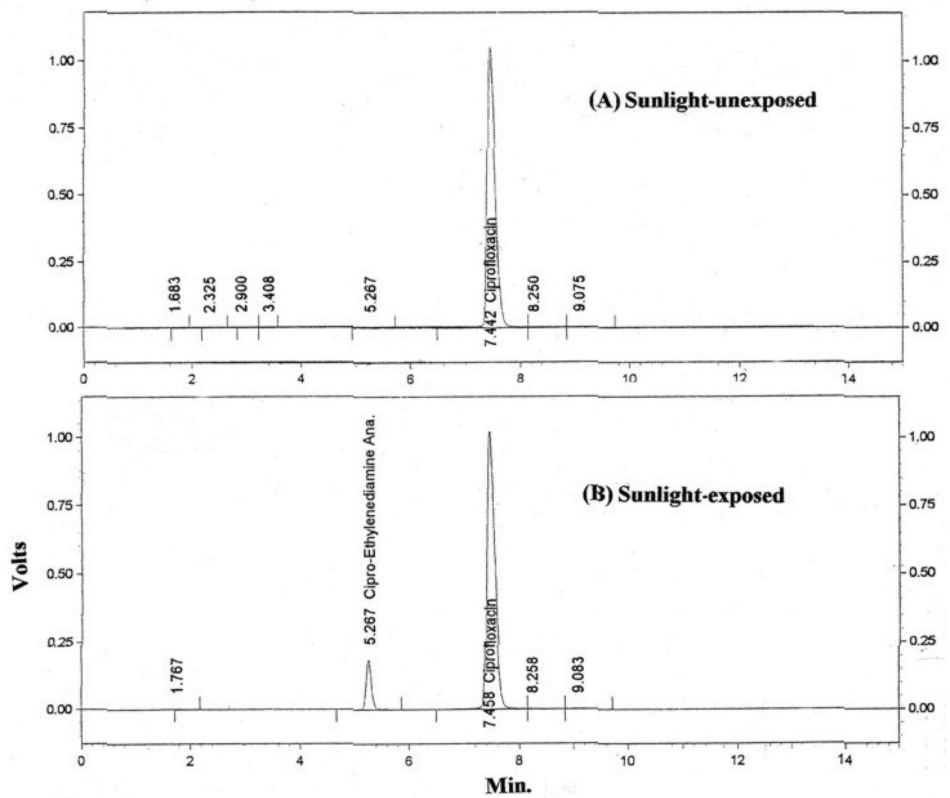

Figure 1. Typical high performance liquid chromatogram of (A) sunlight- unexposed and (B) sunlight-exposed ciprofloxacin ophthalmic solution. Column: C18 SHIMPACK-CLC-ODS(M); 4.6 mm (ID) X 25 cm (L); mobile phase: 0.025 M phosphoric acid solution (pH 3 ± 0.1 adjusted with triethylamine) and acetonitrile in the ratio of 87:13 v/v; flow rate: 1.5 mL/min at UV 278 nm; chart speed: 0.5 cm/min.

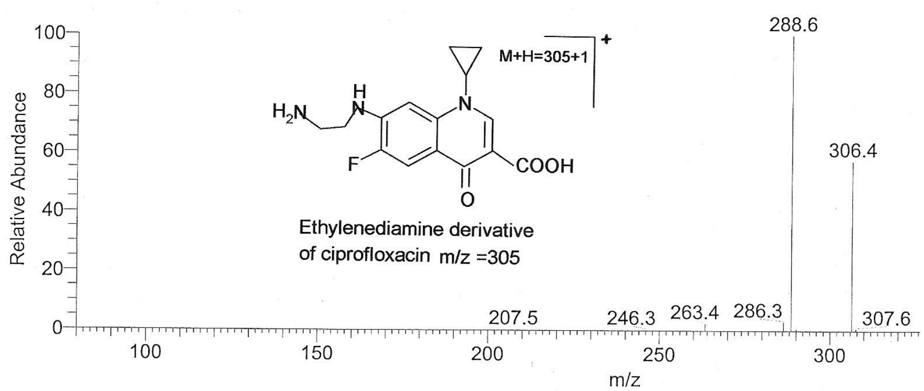

Figure 2. Mass fragmentation of $[M+H]^+$ ion of ethylenediamine derivative of ciprofloxacin.

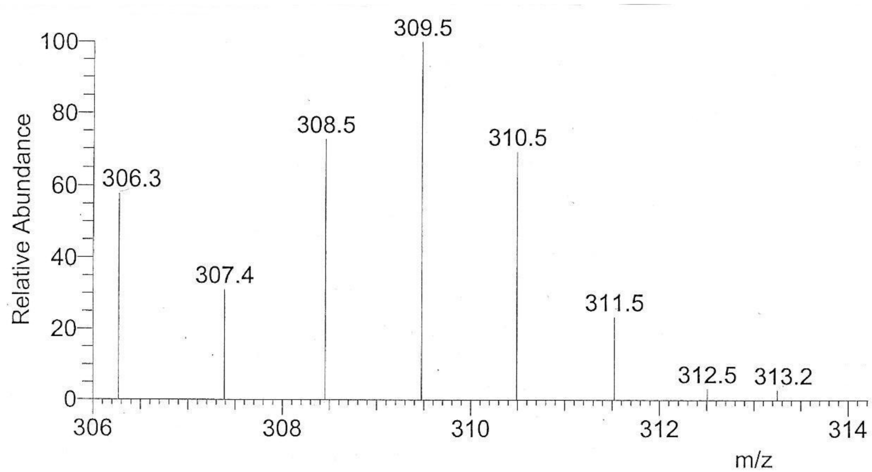

Figure 3. $[M+H]^+$ spectrum of ethylenediamine derivative of ciprofloxacin in deuterium oxide.

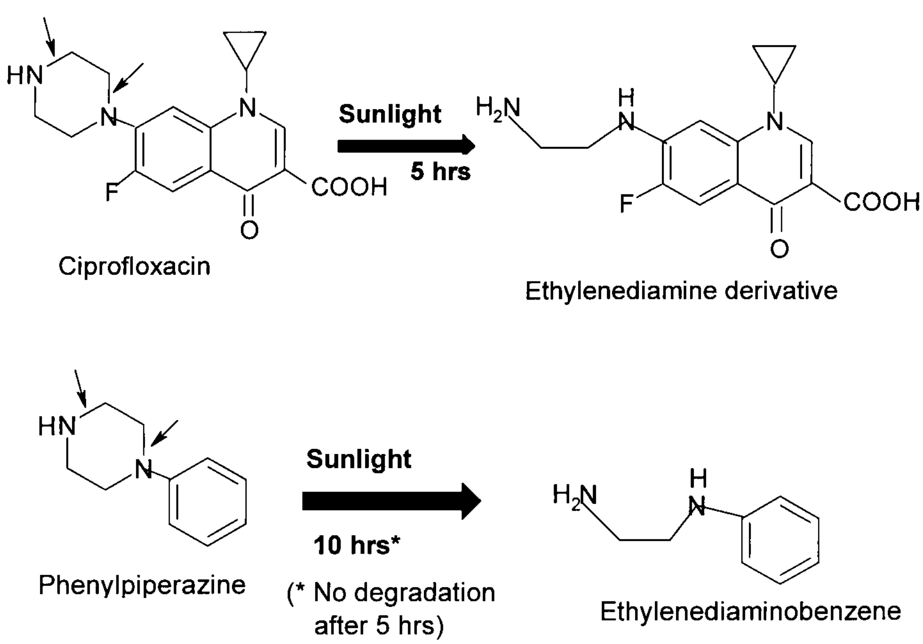

Figure 4. Sunlight induced degradation of ciprofloxacin in ophthalmic solution and phenylpiperazine, a model compound in water (affected bonds are shown by arrows).

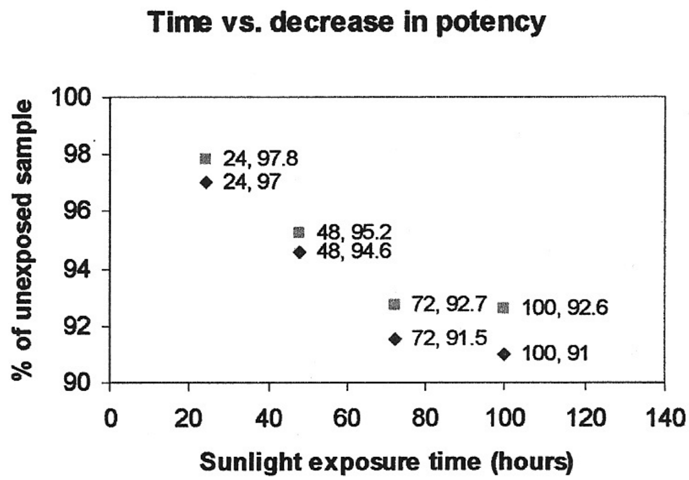

Figure 5. Antimicrobial activity of sunlight-exposed samples against *Bacillus pumillus.*

DISCUSSION

Fluoroquinolones are photodegradable compounds that produce various photodegradation products (Tiefenbacher et al., 1994). However, a systematic qualitative and quantitative evaluation of all the flouoroquinolones has not been published. The British Pharmacopoeia has listed 5 different impurities of ciprofloxacin. The UV irradiation of rufloxacin, a fluoroquinolone antibacterial that shows photosensitizing properties toward biological substrates, leads to formation of two main photoproducts characterized by a decarboxylation process and an opening of the piperazinyl ring, respectively (Condorelli et al., 1999). The photochemical reactivity of four fluoroquinolone antibiotics has been examined (Fasani et al., 1998). For norfloxacin, enoxacin and lomefloxacin, the process occurring is defluorination. Ofloxacin is less light sensitive and undergoes, in part, reactions different from defluorination. Interestingly, photodegradation by natural sunlight of ciprofloxacin in eye drops preparation produces mostly an ethylenediamine derivative of ciprofloxacin by opening of the piperzinyl ring (Figure 4). This impurity is also mentioned in both the British Pharmacopoeia and the United States Pharmacopoeia.

In this study, the structure of the degradation product of ciprofloxacin exposed to natural sunlight was also confirmed by electrospray mass spectrometric analysis. The ciprofloxacin structure contains a piperazine group that is the site of photodegradation. The photolytic breakdown of the piperazine ring in ciprofloxacin produces the ethylenediamine derivative. The model compound, phenylpiperazine, was also found to decompose in a similar fashion producing phenylethylenediamine. However, the breakdown of ciprofloxacin occurred more rapidly compared to that of phenylpiperazine (Figure 4). The strong inductive effect of *ortho*-fluorine in ciprofloxacin may enhance the light-catalyzed cleavage of the piperazine ring, although further studies would be required to establish the actual mechanism of the reaction.

The results from sunlight-exposed samples of ciprofloxacin eye drop kept for a 3 month period indicated 20–30% loss of potency of ciprofloxacin whereas there was no HPLC detectable degradation if the eye drop container were kept inside its carton (Table 1). On the other hand, sunlight-exposed samples showed slightly lesser antimicrobial activity than the control sample against *Bacillus pumillus* (Figure 5).

Pharmaceutical products, especially eye drops are exposed to light while being:

- manufactured as solution.
- held in pharmacy retail shops or in hospitals

pending use.

- held by consumers pending use or while in use over the period of treatment.
- exposed to sunlight if one goes into sun immediately after instillation of drops.

The marketed samples examined by HPLC did not show any degradation at the beginning which means that no degradation had taken place during manufacturing or as long as the product remained in the carton after manufacturing. It was also found that no photodegradation occurred in eye drop products exposed to sunlight while covered by packaging container. Thus, as long as the containers are inside the carton there is little or no photodegradation. However, if the containers are translucent, the eye drop containers should not be exposed to sunlight. It is also advisable not to go out in sun immediately after instillation of ciprofloxacin eye drops without sunglasses. The use of amber colored containers or light-reflecting containers could be an alternative solution for photosensitive eye drop preparations.

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Species of Adult Odonata from Three Natural Areas in Mississippi

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Mississippi was quoted recently as one of the most under-surveyed states for Odonata (Donnelly, 2002). Published updates of species distribution or even point-location data are necessary for official documentation of biodiversity and to provide a baseline for setting conservation priorities. Furthermore, published species lists serve as a reference tool for persons involved with biological inventory. A comprehensive update of Odonata species and county records in Mississippi, complete with statewide distribution maps, is planned for release within a few years (S. Krotzer, pers. comm.). In the meantime, this article presents a compilation of collected or sight records from three locations sampled during the 2003-04 flight seasons: Noxubee National Wildlife Refuge (NNWR), Strawberry Plains Audubon Center (SPAC), and Tombigbee National Forest (TNF). Managers at these locations requested and were promised lists of Odonata species, thus this article will help facilitate the fulfillment of that promise.

The NNWR and TNF are adjacent and spread over four counties in east-central Mississippi. The Noxubee River flows through both areas and supports numerous beaver impoundments. These wetlands are typically less than a meter deep and dominated by soft rush (*Juncus effusus*), bur-reed (*Sparganium americanum*), and tag alder (*Alnus serrulata*). Other lentic sources of odonates in these areas include bottomland swamps, reservoir lakes, and ponds.

The SPAC is a 2,500 acre former plantation near Holly Springs in northern Mississippi. This mixed woodland and fallow pasture landscape is interspersed with farm ponds, moist-soil wetlands, and a *Nuphar* dominated beaver impoundment. Much of the fallow open space is under fire restoration to warm-grass prairie.

Most of the following records were taken from research outings to wetlands, so the lists are weak on lotic breeders, and because most surveys occurred at project sites that I sampled mostly in summer, the coverage is incomplete and the lists really represent a minimum species set for each natural area. In addition, records are based on adults, without exuviae or nymph collections to truly determine residency. Therefore, the possibility exists that at least some species were in transit from a natal site beyond the natural area's boundary.

These species lists were generated during ecological research on wetland-breeding Odonata. Details of some projects and survey methods are given in Bried (2005) and more will become available in forthcoming publications (e.g., Bried and Ervin, 2005).

Altogether, 77 species were caught or seen across all natural areas in 2003-04. This total is nearly 60% of the odonates currently known to occur in Mississippi (Abbott, 2005). Most records include collected specimens of at least one adult; the sight-only records are marked with an asterisk (*). Voucher specimens are stored in the Mississippi Entomological Museum of Mississippi State University.

NOXUBEE NATIONAL WILDLIFE REFUGE

damselflies (Zygoptera, 18 species)

Argia apicalis, *A. tibialis*, *Calopteryx maculata*, *Enallagma basidens*, *E. civile*, *E. divigans*, *E. geminatum*, *E. signatum*, *E. traviatum*, *E. vesperum*, *Ischnura hastata*, *I. kellicotti*, *I. posita*, *I. ramburii*, *Lestes australis*, *L. inaequalis*, *L. rectangularis*, *L. vigilax*

dragonflies (Anisoptera, 40 species)

Anax junius, *Aphylla williamsoni*, *Arigomphus maxwelli*, *Celithemis elisa*, *C. eponina*, *C. fasciata*, *Cordulegaster obliqua*, *Coryphaeschna ingens**, *Dromogomphus spinosus*, *D. spoliatus*, *Epiaeschna heroes*, *Epitheca cynosura*, *E. princeps*, *Erythemis simplicicolis*, *Erythrodiplax minuscula*, *Gomphaeschna furcillata*, *Gomphus exilis*, *G. lividus*, *Hagenius brevistylus*, *Ladona deplanata*, *Libellula cyanea*, *L. incesta*, *L. luctuosa*, *L. lydia*, *L. pulchella*, *L. semifasciata*, *L. vibrans*, *Macromia illinoiensis georgiana*, *M. taeniolata*, *Nasiaeschna pentacantha*,

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Pachydiplax longipennis, *Pantala flavescens*, *P. hymenaea*, *Perithemis tenera*, *Somatochlora linearis*, *Sympetrum ambiguum*, *Tramea carolina*, *T. lacerata*

In addition, Dr. Lloyd Bennett of Mississippi State University captured adult specimens of the dragonflies *Cordulegaster bilineata* and *Gomphus vastus* at NNWR (species verifications made by J. Bried).

STRAWBERRY PLAINS AUDUBON CENTER

damselflies (19 species)
Argia apicalis, *Calopteryx maculata*, *Enallagma aspersum*, *E. basidens*, *E. civile*, *E. daeckii*, *E. divigans*, *E. doubledayi*, *E. dubium*, *E. geminatum*, *E. signatum*, *E. vesperum*, *Ischnura hastata*, *I. posita*, *I. ramburii*, *Lestes australis*, *L. inaequalis*, *L. vigilax*, *Nehalennia integricollis*

dragonflies (32 species)
Anax junius, *A. longipes*, *Arigomphus villosipes*, *Celithemis elisa*, *C. eponina*, *C. fasciata*, *Epiaeschna heroes*, *Epitheca cynosura*, *E. princeps*, *Erythemis simplicicolis*, *Erythrodiplax minuscula*, *Gomphaeschna furcillata*, *Gomphus exilis*, *G. lividus*, *Ladona deplanata*, *Libellula auripennis*, *L. cyanea*, *L. incesta*, *L. luctuosa*, *L. lydia*, *L. pulchella*, *L. vibrans*, *Macromia taeniolata*, *Nasiaeschna pentacantha*, *Pachydiplax longipennis*, *Pantala flavescens*, *P. hymenaea*, *Perithemis tenera*, *Sympetrum ambiguum*, *S. vicinum*, *Tramea carolina*, *T. lacerata*

Several additional species were found nearby around Chewalla Lake in Holly Springs National Forest, including the damselflies *Argia fumipennis*, *A. tibialis*, *Chromagrion conditum*, and *Nehalennia gracilis*. To my knowledge, the only previous Mississippi record of *N. gracilis* is given in Westfall and May (1996). There are no county records of this species in Mississippi (Donnelly, 2004), nor is it currently listed in the Odonata Central database (see Abbott, 2005).

TOMBIGBEE NATIONAL FOREST

damselflies (18 species)
Argia apicalis, *A. fumipennis*, *A. tibialis*, *Calopteryx maculata*, *Enallagma daeckii*, *E. divigans*, *E. dubium*, *E. geminatum*, *E. signatum*, *Ischnura hastata*, *I. kellicotti*, *I. posita*, *I. prognata*, *I. ramburii*, *Lestes forficula*, *L. inaequalis*, *L. vigilax*, *Nehalennia integricollis*

dragonflies (36 species)
Anax junius, *Aphylla williamsoni*, *Boyeria vinosa**, *Celithemis eponina*, *C. fasciata*, *C. verna*, *Cordulegaster erronea**, *Coryphaeschna ingens**, *Dromogomphus spinosus*, *Epiaeschna heroes*, *Epitheca cynosura*, *E. princeps*, *Erythemis simplicicolis*, *Erythrodiplax minuscula*, *Gomphaeschna furcillata*, *Gomphus exilis*, *Ladona deplanata*, *Libellula cyanea*, *L. flavida*, *L. incesta*, *L. luctuosa*, *L. lydia*, *L. pulchella*, *L. semifasciata*, *L. vibrans*, *Macromia illinoiensis georgiana*, *M. taeniolata*, *Nasiaeschna pentacantha*, *Pachydiplax longipennis*, *Pantala flavescens*, *Perithemis tenera*, *Progomphus obscurus*, *Sympetrum vicinum*, *Tachopteryx thoreyi**, *Tramea carolina*, *T. lacerata*

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New Species Records for Mississippi: An Expected Dragonfly and an Unexpected Damselfly

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The list of Odonata for Mississippi expanded from the first published account of 50 species in 1950 (Bick, 1950) to 83 species over thirty years later (Stanford and Lago, 1981). It continued to grow considerably, from 114 species at the start of 2002 (Donnelly, 2002) to 130 species by the end of 2004 (Abbott, 2005). Some of the most recent additions include *Dromogomphus spoliatus*, *Ischnura prognata*, and *Telebasis byersi*. The Mississippi list surpassed Louisiana's (128 spp., Mauffray, 1998; Abbott, 2005) during the last three years, but it still trails behind the other neighbor states; Alabama (176 spp.), Arkansas (136 spp.), and Tennessee (150 spp.) (Abbott, 2005). In this article we report details surrounding the addition of the dragonfly *Arigomphus lentulus* (Stillwater Clubtail) and damselfly *Lestes forficula* (Rainpool Spreadwing) to the Mississippi fauna, which brings the total Anisoptera (dragonflies) to 94 spp. and total Zygoptera (damselflies) to 38 spp.

Previous records for *A. lentulus* are concentrated mostly west of the Mississippi River in eastern Oklahoma and Texas and in western Arkansas. Additional records exist north of Mississippi and stretch into Illinois and Indiana (Donnelly, 2004a). Like other members of the genus, *A. lentulus* often breeds in ponds, lakes and slow areas of streams, often with mud or clay substrate (Abbott, 2005).

The first author collected *A. lentulus* on farm property off Rt. 389 in northern Oktibbeha Co., east-central Mississippi (N 33° 31.008', W 88° 52.167'). Several pond impoundments dot active or former pastures within a 2.5 km radius on the property. Four of these ponds were surveyed for one hour on each of 8–11 dates between mid May and mid September 2004. The *A. lentulus* was observed at only one of these, a small pond (perimeter = 0.28 km) set in a large hay field and cow pasture. The field is mowed yearly and livestock herds trampled the pond margin for over a month during the survey period. Banks are steep and in some places nearly 1 m above water. Forty-six vascular plant species were recorded in 50 plots (mean = 4.2 spp per 0.5 m^2 plot); dominants included *Eleocharis obtusa*, *Hydrolea uniflora*, *Ludwigia peploides*, *Paspalum dilatatum*, and *Polygonum hydropiper*.

Arigomphus lentulus was first seen on 17 May and again on 22 May, 26 May, and 09 June 2004. It was not seen on 04 July. Surveys at the site lasted one hour between 1345–1510 hr on each date. Average air temperature, wind speed, and relative humidity (Kestrel 4000 Pocket Weather Station, Forestry Suppliers Inc., Jackson, Mississippi) were 32.6°C, 1.2 m/s, and 55.2%, respectively, during the four surveys. *Arigomphus lentulus* was rare to moderately abundant (5 to 15 individuals) relative to 24 co-occurring odonate species that were accumulated over ten sample days; the common species included *Enallagma civile*, *E. signatum*, *Erythemis simplicicolis*, *Ischnura posita*, and *Perithemis tenera*. The predominance of these opportunists and agricultural land use around the pond suggest a low quality breeding site for odonates, and may indicate that *A. lentulus* can tolerate such conditions. Six larvae of *A. lentulus* were collected from this pond during two hours of sweep netting on 18 April 2005, confirming residency of the species.

Whereas the dragonfly *A. lentulus* was expected to occur in Mississippi, the damselfly *L. forficula* was not. *L. forficula* was previously documented only in south-central and southeastern Texas (Donnelly, 2004b), and it was not listed in a comprehensive update of Louisiana's Odonata (Mauffray, 1998). As the English name implies, the breeding habitat usually includes pools or small ponds, usually with abundant emergent vegetation (Abbott, 2005).

The first author collected two individuals of *L. forficula* on separate dates in different locations. The first was taken 17 September 2004 on the same farm property but different pond (N 33.5328°, W

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88.8649°) as the *A. lentulus*. This pond was larger (perimeter = 0.64 km) and surrounded by inactive pasture with wooded areas ~100 m from the pond edge. Sixty-three vascular plant species were recorded in 50 plots (mean = 4.3 spp. per 0.5 m^2 plot); dominants included *Diodia virginiana*, *Hydrolea uniflora*, *Panicum rigidulum*, and *Polygonum hydropiperoides*. The following water quality data are averages of three readings taken on one date in July 2004: pH = 6.3, D.O. = 4.5 mg/L, water temp = 29.4°C, conductivity = 28.7 µS. Weather on 17 Sept was sunny (< 5% of survey time with cloud cover) and warm (29.3°C), with 63.4% average humidity and 3.0 m/s maximum wind speed. Two *L. forficula* were spotted at 1125 hr. Both were perched atop *Hydrolea uniflora*, a succulent low emersed forb. Thirty-four additional odonate species were detected at this site, of which 19 were possible or probable residents based on abundance, presence of tenerals, and reproductive behaviors (i.e., tandem flights, guarding behavior oviposition attempts, mating wheels, territoriality); examples include *Celithemis eponina*, *Enallagma traviatum*, *Libellula incesta*, *Tramea carolina*, and those listed above at the *A. lentulus* site.

The second record was taken 24 September 2004 from a beaver wetland complex (N 33°13.814', W 89° 03.726') in the Tombigbee National Forest, Winston Co., east-central Mississippi. This location is about 36 km from the farm site. It was surveyed 20 times during the early (calendar days 1–10), middle (11–20), and late (21–30/31) thirds of each month from late March to early October. Each census lasted 45 min or more. The marsh complex includes a series of impoundments with at least 40 to 50 non-woody vascular species (mean = 4.1 spp per 0.5 m^2 plot; 50 plots). Dry woodland borders the corridor on both sides. The impoundment with *L. forficula* was created at least 30 years ago based on aerial photographs. This site is now blanketed by the tussock rush, *Juncus effusus*, which over time builds a large, raised substratum for other plants to exploit (Ervin, 2005). Mean depth of surface water varied from 55.2 to 72.4 cm over the flight season. Weather at the time of census on 24 September was mostly sunny and 29.7°C, with 52.9% average humidity and 2.0 m/s maximum wind speed. A single mature *L. forficula* was found perched on *Juncus* culms about half a meter above water at ~1410 hr. Thirty additional odonate species were observed in the beaver marsh complex over the six-month study period (e.g., *Enallagma daeckii*, *E. dubium*, *E. geminatum*, *Lestes vigilax*, *Nehalennia integricollis*).

The three encountered individuals of *L. forficula* were probably strays rather than constituents of resident populations, although we can not rule out a substantial range expansion that went unnoticed. It is interesting to note that a major tropical storm, Hurricane Ivan, made landfall near Mobile, Alabama, on 16 September 2004. Sustained winds associated with this storm were measured at over 50 mph at Starkville, Mississippi, with gusts well in excess of 60 mph (National Weather Service, 2004). It is certainly conceivable that winds associated with this system resulted in a few individuals of *L. forficula* being transported beyond their usual range.

ACKNOWLEDGMENTS

Many thanks to Mr. Vernon Moore for permission to sample ponds on his property. An anonymous reviewer provided helpful comments on an earlier draft of this article. This research was supported by funding from the US Geological Survey Water Resources Research Institute to Gary N. Ervin (Mississippi State University, Department of Biological Sciences), grant #01HQGR0088, and a Society of Wetland Scientists Student Research Grant to Jason T. Bried.

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President's Column

It is an honor to serve as President of your Mississippi Academy of Sciences during this year. There are many opportunities and challenges that are before us. Hurricane Katrina has forever changed the landscape of our state and the Academy. This is a time in which we must all pull together to assure that needs of all of our members are fully addressed.

The Academy has a very rich history as was eloquently recalled by Dr. Sarah Lea McGuire, the immediate Past-President, at our annual meeting in Oxford, MS. With all of us working together we can add to that history. In keeping with the trend of changing sites for the annual meeting, the 2006 meeting will be held February 23 and 24 in Vicksburg. Planning is well underway for the meeting. In keeping with another trend of having a national figure as the Dodgen Lecturer, the 2006 lecture will be presented by Dr. John Marburger, the director of the Office of Science and Technology Policy. Dr. Marburger is the scientific advisor to the President of the United States. He is a spirited public scientist-administrator that brings an opened, reasoned approach to contentious issues where science intersects with the needs and concerns of society. He is also a leading advocate for science education.

We hope to continue to build on the progress made by the Academy over the last few years. There are many opportunities for development in Mississippi. Much of the development that has occurred in our state has its foundations in strong academic institutions. We need to continue to develop resources and partnerships at all levels throughout our state. Part of the stated purpose of the Academy is "to improve the effectiveness of science in the promotion of human welfare." To achieve this purpose we must continue to provide strong scientific education and opportunity for all of our state. The Academy plays a vital role in this process and provides many opportunities for young and developing scientist in our state. The annual meeting is a great resource which brings many people together and often provides the first venue for those being educated as scientist our state to present their data. This can be an exciting experience for all involved. The key of course is involvement. That is where you as individual members of the Academy are most important. The Academy is dependent on the involvement of all of us as students, teachers, mentors, and administrators. I urge all of our members to plan to attend the annual meeting, participate, and more importantly, spread the word about the many benefits of being involved in the Academy.

As we regroup from a very trying time in our state, we need to continue to improve ourselves and the Academy by working together to assure that no opportunities are missed and that interactions among all the disciplines are fostered. I look forward to working with you to assure the continued growth and success of our Academy.—Larry S. McDaniel

The 2006 Annual Meeting of the Mississippi Academy of Sciences will be held on 23 and 24 February at the Convention Center in Vicksburg, Mississippi

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- Enclose a personal check, money order, institutional check, or purchase order for $25 publication charge for each abstract to be published, payable to the Mississippi Academy of Sciences. The publication charge will be refunded if the abstract is not accepted.
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Dr. John Boyle
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FORMAT FOR ABSTRACT

- Your abstract should be informative, containing: (a) a sentence statement of the study's specific objectives, unless this is given in the title; (b) brief statement of methods, if pertinent; (c) summary of the results obtained; (d) statement of the conclusions. It is not satisfactory to state, "The results will be discussed."
- Your abstract, including a concise, descriptive title, author(s), location where work was done, text and acknowledgment, may not exceed 250 words. **Excessively long abstracts will be truncated**.
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EXAMPLES OF TITLES AND AUTHORS:

[single author, no ambiguity about designated speaker or affiliation]
AN EXPERIMENTAL MODEL FOR CHEMOTHERAPY ON DORMANT TUBERCULOUS INFECTION WITH PARTICULAR REFERENCE TO RIFAMPICIN
Joe E. Jones, Mississippi State University, Mississippi State, MS 39762
Abstract body starts here . . .

[two authors, both designated as speakers, different affiliations, but no ambiguity]
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[three authors, one designated speaker, different affiliations]
AN EXPERIMENTAL MODEL FOR CHEMOTHERAPY ON DORMANT TUBERCULOUS INFECTION WITH PARTICULAR REFERENCE TO RIFAMPICIN
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