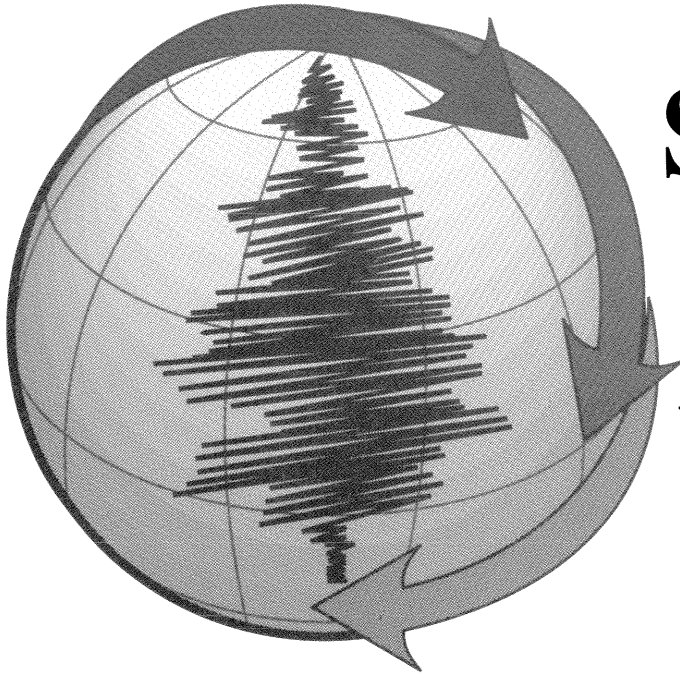
The Southern Global Change Program

United States
Department of
Agriculture

Forest Service

Southeastern Forest
Experiment Station

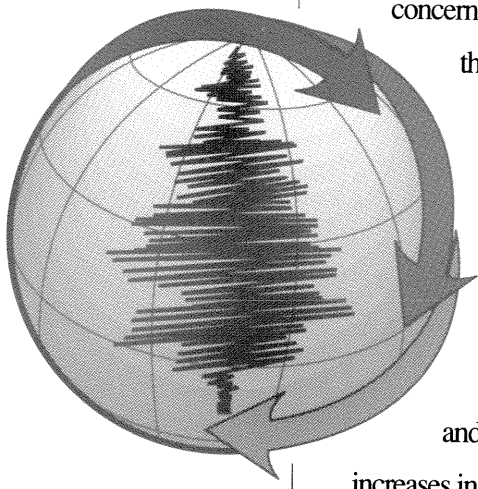
General Technical
Report SE-79



The Southern Global Change Program

Determining the Relationships Between Air Pollutants, Climate Change, and Southern Forests

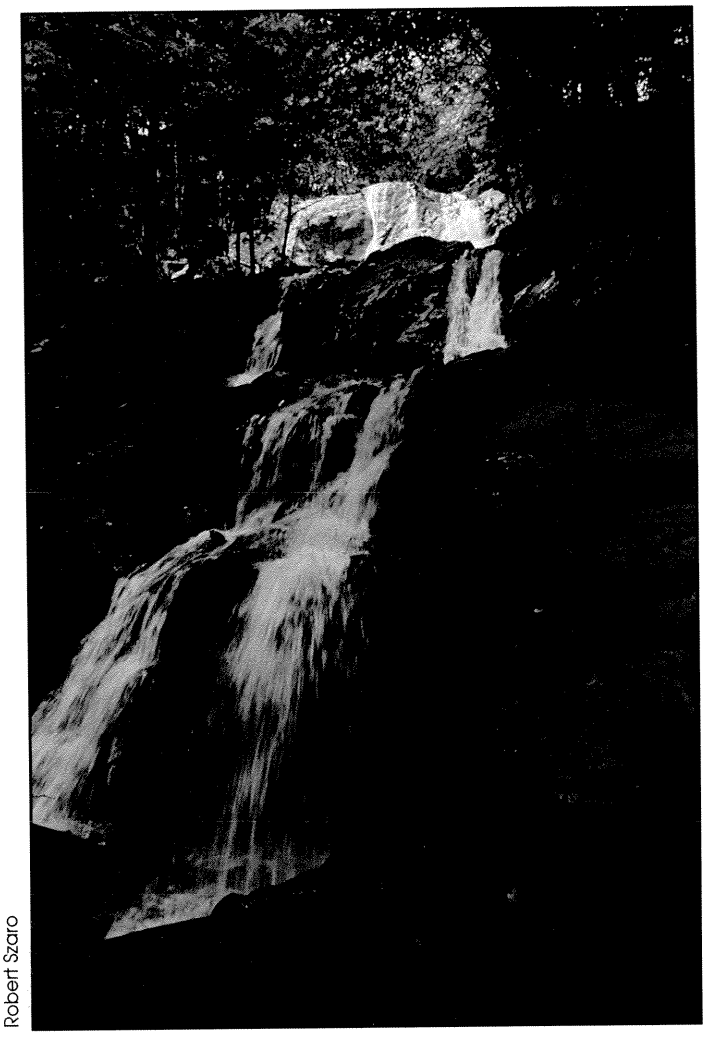
Global Changes



For more than a decade, scientists around the world have expressed concern over observed changes in the Earth's environment that suggest future global environmental problems. They have documented increased levels of air pollutants such as ozone and acid rain, as well as increases in carbon dioxide and other greenhouse gases. Scientists also have noted a 0.5 °F to 1.0 °F rise in mean surface air temperatures over the past 100 years, with the five warmest years on record occurring in the 1980s and '90s. And they have recorded a 4- to 8-inch rise in mean sea level over the same period. The changes in the chemical climate—the increases in carbon dioxide and air pollutants—can be linked to human activities such as fossil fuel combustion. There is concern that chemical climate changes are causing, or will cause, changes in the physical climate. Uncertainties exist about the extent to which human activities can be linked to the recent warming trend. Some members of the scientific community argue that the changes in temperature and sea level are simply natural variations. Long periods of unusually warm weather have been recorded in the past; however it is known that the so-called greenhouse gases contribute to a warming of the Earth and the atmospheric concentrations of these gases are increasing. Predictions from global-scale general circulation models suggest that over the next century the planet's physical climate will change at an unprecedented rate. The growing consensus among scientists is that, because of human activities, global conditions are changing in ways, and at rates, that will have profound effects on humans and on natural ecosystems.

A Threat to Southern Forests?

Southern forests are vitally important resources for the region and the Nation. Forests are of major economic importance, supporting the South's timber, paper, and recreation industries. In addition, they protect water quality; provide habitat for wildlife, including threatened and endangered species; and provide recreational opportunities for the public. Among the diverse forest ecosystems in the South are upland pine



Robert Szaro

Protection of water quality is an important function of forests. Shenandoah National Park, Virginia.

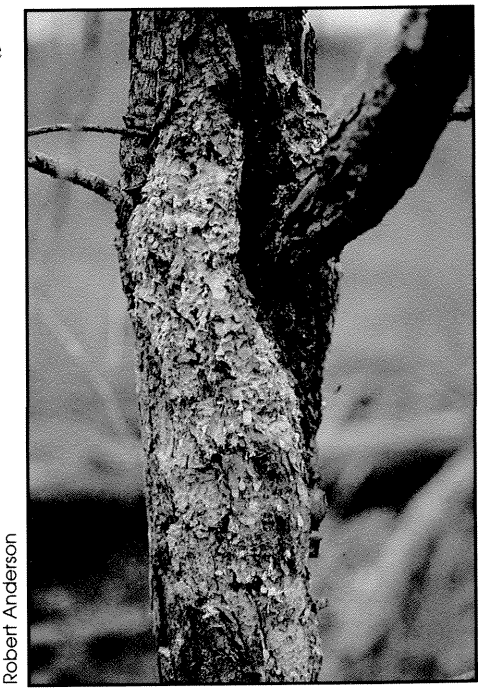
and mixed pine-hardwood forests, pine flatwoods and savannahs; coastal maritime forests, pocosins, cypress-tupelo swamps and mangrove forests; bottomland hardwoods; upland hardwoods; and Southern Appalachian spruce-fir forests. Forests cover approximately 60% of the land in the 12 southeastern and south-central states.

Southern forests are subject to numerous physical and chemical stresses. Currently, weather conditions play a major role in determining stand growth, insect and disease outbreaks, protection costs, regeneration success, and accessibility of forests for management or recreation. Throughout the South, drought, nutrition, and high temperature are three major factors that limit forest health and productivity.

Factors making up the chemical climate also affect southern forests. Ozone, for example, occurs at levels that have been shown to cause foliar injury, physiological alterations, and reductions in growth of several forest species. Also, preliminary modeling suggests that the fertility of some southern soils may be at risk from the combination of short rotations and acidic deposition.

If the scientific consensus on global change is in any measure correct, the socially and

Insects and diseases cause extensive injury. Fusiform rust, shown here on loblolly pine, results in $100 million damage annually to southern forests.



Robert Anderson

economically important forests of the southern United States could face difficult times. Hotter, drier summers would mean more regeneration failures, less growth, higher incidence of insect outbreaks, increased incidence and severity of fire, higher protection costs, and restricted access for recreation and resource management. Increased winter rains would push up logging costs. Greater year-to-year variability in weather would make planning of forestry operations much harder. Certain ecosystems, such as the Southern Appalachian spruce-fir forests and forested wetlands could be especially at risk. The most dire predictions suggest migration or even extinction of entire forested ecosystems. Predictions of this nature are subject to great scientific uncertainty, but there are reasons for concern.

The fact that the current climate of the South adversely affects forest health and productivity is one reason. Another concern is related to the longevity of trees. Today we are planting the forests that will be alive in the next century. Many of the hypothesized climate changes are projected to occur by mid-century. Will the growing stock that is being planted today be well suited for the future physical and chemical climate? Will the landscape-scale mosaic of species, communities, and ecosystems that are present today be well suited for environmental conditions of the future? The stakes are high and the problem is that there is still a great deal we do not know. Global change is a potential threat to southern forests, but the magnitude and likelihood of the threat are uncertain.

There are 21 million acres of planted pine in the southern United States, such as this stand in North Carolina.

The Southern Global Change Program

To reduce some of the uncertainty, the Southeastern and Southern Forest Experiment Stations of the United States Department of Agriculture (USDA) Forest Service chartered a joint research initiative in 1990 called the Southern Global Change Program (SGCP). The SGCP was developed to improve our understanding of the interactions among southern forests, air pollution, and climate change. The interactions of interest include both the effects of atmospheric changes on forests and the effects of forests on the atmosphere. Growing forests remove carbon dioxide from the atmosphere and store some of the carbon as wood, thus playing an important role in the global carbon cycle. This effect of forests on the atmosphere is receiving increasing attention, as policymakers consider options to mitigate climate change by altering the carbon flux from forests. The South may be one area with a high potential for increasing productivity on existing forest lands and planting new forests as part of a strategy for removing carbon from the atmosphere.

The SGCP will address questions about the ecological and socioeconomic impacts of global change on the South, as well as questions about how management practices and policies should be modified in order to adapt to or mitigate these effects. The SGCP will provide information necessary to meet the challenge of maintaining forest health, productivity, and diversity in the face of global environmental change. This document describes the activities of the SGCP and identifies its relationship to the U.S. Global Change Research Program.

Part of a National Effort

Concern about global change among elected officials in the U.S. Government led a President's Committee on Earth and Environmental Sciences to recommend, in 1989, the establishment of a long-term national program of research on global change. The goal of the U.S. Global Change Research Program is to provide the scientific basis for informed decision making. The three major activities of the U.S. Global Change Research Program are (1) to document global change, (2) to improve our understanding of key processes, and (3) to develop predictive models.

The USDA along with other federal agencies, has established a research program to address this high priority issue. The USDA Global Change Research Program is designed to assess the effects on agricultural, pastoral, and forest ecosystems. It will also assess the effects of agriculture and forestry on global change. Each agency within the USDA, such as the Agricultural Research Service, Cooperative State Research Service, and the Forest Service, participates in this program.

The U.S. Global Change Research Program

The U.S. Program organizes ongoing research around four integrating themes.

1. *Climate Modeling and Prediction:* To improve predictive capability for the Earth as a whole and to enhance regional resolution, with initial priority given to the climate system

2. *Global Water and Energy Cycles:* To improve understanding of water cycling (precipitation; evapotranspiration; soil moisture; and ice quantity, type, and movement) and energy cycling (warming/cooling, radiative balance, solar variability, and latent heat)

3. *Global Carbon Cycle:* To improve understanding of the carbon cycle by quantifying natural and anthropogenic terrestrial and oceanic sources and sinks of key carbon compounds

4. *Ecological Systems and Population Dynamics:* To improve assessment of the effects of global change on natural and managed ecosystems at regional scales. Research focuses on species composition, distribution, and productivity of ecosystems

These four integrating themes provide a means of focusing research on the most critical issues.

Mitigation and adaptation research strategies are also important components of the national global change program. They are designed for two types of evaluation: (1) how potential changes to the atmosphere can be reduced and (2) how humans and ecosystems can adapt to likely changes in the atmosphere.

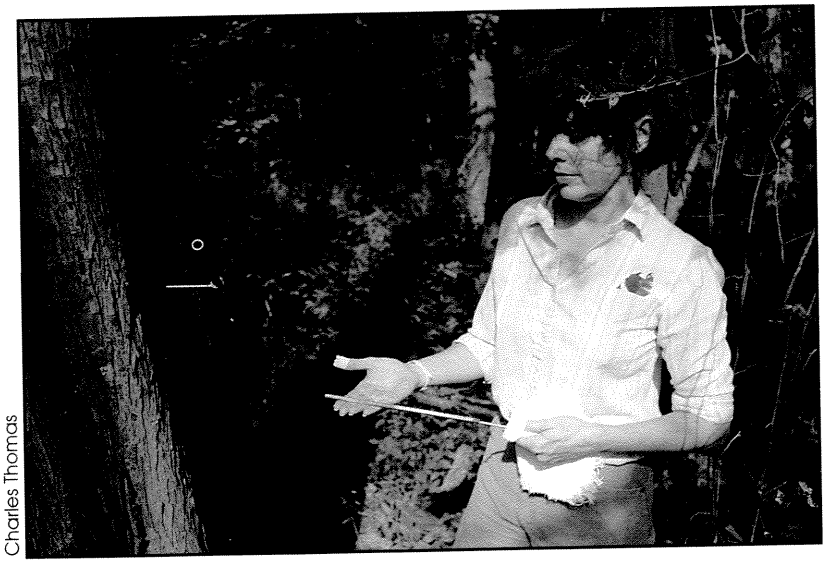
The Forest Service Global Change Research Program focuses on predicting the impacts of global change on sustainable forest ecosystems and providing forest resource managers with viable response strategies. It will develop policy options for sustaining forest productivity, health, and diversity. To understand ecosystem responses, it is necessary to improve our understanding of how biological processes, species, and community complexes respond to change. The SGCP is one component of the Forest Service research effort on global change.

The Forest Service Global Change Research Program

The Forest Service established four regional research programs to study the impacts of global change on forests, and a fifth program to study global change and the forest products industry. The regional programs in the South, North, Interior West, and Pacific West address the high-priority research needs of their region. Each program is distinct because of the inherent differences in the resources at risk in each region.

The **Southern Global Change Program** is described in detail in this publication. The **Northern Program** encompasses the grassland, deciduous forest, and coniferous forest biomes of that region. Its research is accounting for strong moisture gradients from west to east and strong temperature gradients from north to south. The **Interior West Program** emphasizes the threats of global change to water availability and to the biodiversity harbored in existing wilderness areas. The **Pacific Program** addresses impacts to heterogeneous ecosystems with large numbers of ecotones from the polar regions of Alaska to the tropical systems of Hawaii. The **Forest Products Laboratory** is finding ways to reduce emissions of volatile organic compounds from wood treatments as well as developing less energy- intensive methods for making wood products.

Although each of the five programs that contribute to the Forest Service Global Change Program is distinct, coordination is provided by a National Program Coordinator located at the Forest Service's headquarters in Washington, DC.



Charles Thomas

Tree cores are removed by Dr. Margaret Devall in a project developing a chronology of bald cypress from living trees, sunken logs, and lumber from plantation houses. Cat Island Swamp, Louisiana.

Overview of the Southern Global Change Program

The mission of the SGCP is to conduct research and monitoring in the southern region of the United States; to determine the interactive responses among forest ecosystems, atmospheric pollution, and climate change; and to use this knowledge to manage and protect the forest environment and resources. The SGCP will also provide information that can be used to define the role of southern forests in the global energy, carbon, and water cycles.

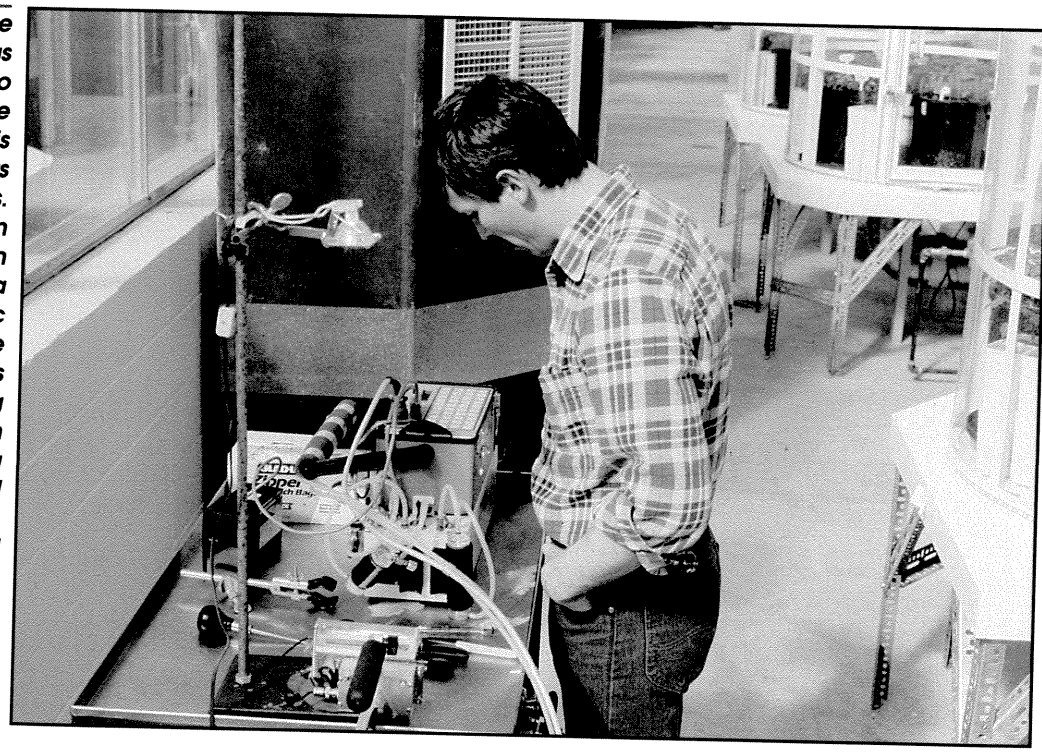
This mission reflects the breadth of concerns associated with a changing atmospheric environment and the need for an ecosystem perspective. The SGCP will conduct research to address the following objectives.

1. **Determine what processes in southern forest ecosystems are sensitive to physical and chemical changes in the atmosphere.**

2. **Evaluate how atmospheric changes will influence the structure, function, and productivity of southern forests, and related ecosystems.**

3. **Evaluate how forest management activities should be altered to sustain southern forest productivity, health, and diversity.**

The keystone of the SGCP research effort is the research conducted at the Southeastern and Southern Forest



Shepard Zedaker

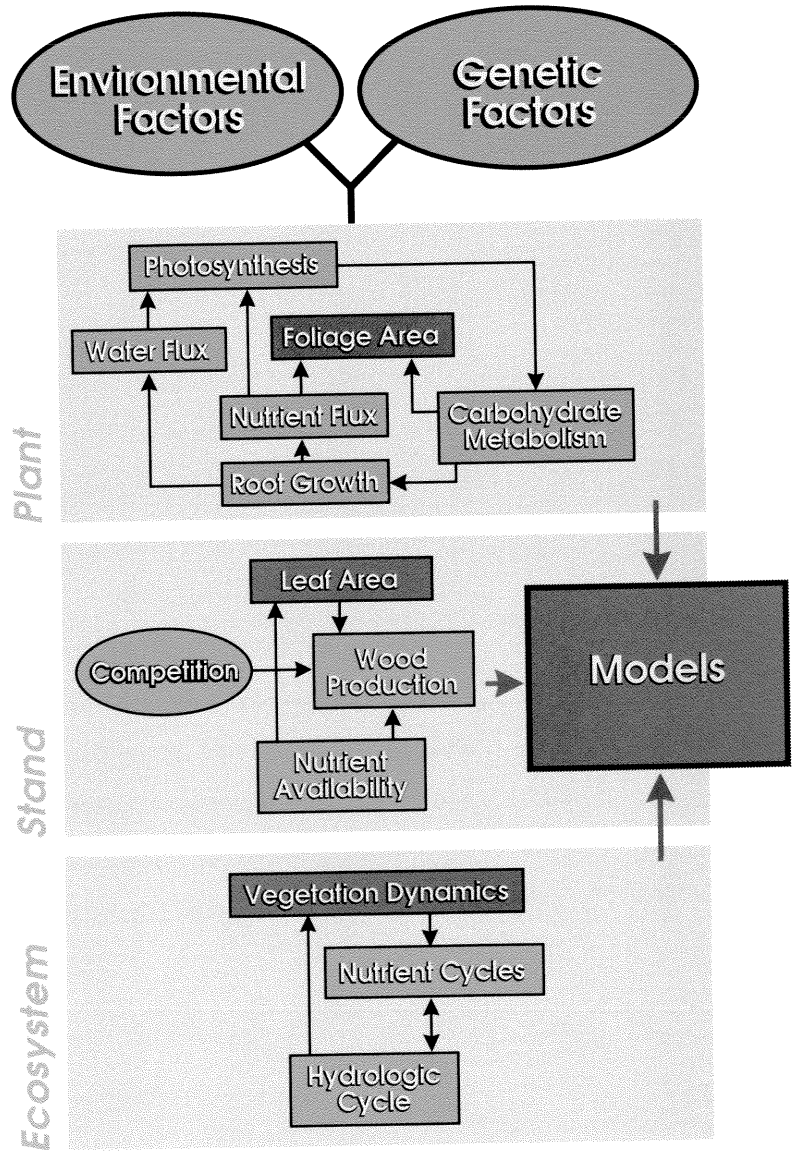
Scientists use infrared gas analyzers to measure the rate of photosynthesis on plants exposed to stress. Here Dr. John Seiler from Virginia Polytechnic Institute and State University is determining photosynthesis on sweetgum in a study of elevated carbon dioxide, water stress, and nitrogen fertilization effects.

Ecological Research

Experiment Stations. Decades of research on the biology, ecology, physiology, and morphology of southern forests provides a foundation for addressing current concerns about forest health. The contributions of participating Forest Service Research Work Units are supplemented by extramural research conducted by university, industry, and other public agency cooperators. These cooperators include 13 universities, the National Council of the Paper Industry for Air and Stream Improvement, Oak Ridge National Laboratory, the Tennessee Valley Authority, the Environmental Protection Agency's Atmospheric Research and Exposure Assessment Laboratory, and the USDA Agricultural Research Service. At this time, approximately 80 scientists are cooperating in the 26 research and modeling projects supported by the program.

There are three major components in the SGCP efforts: (1) ecological research, (2) socioeconomic research, and (3) assessment activities. The SGCP can accomplish its mission only to the degree that there are contributions from each of these components.

One of the important attributes of the ecological research in the SGCP is the emphasis placed on studying the interactions of stresses associated with global change. In nature, individual trees and entire forests are exposed to any number of co-occurring stresses. Research on multiple stresses will allow us to make greater progress in understanding forest response to pollution and climate change.



Judson Edeburn

Foresters use controlled burning to reduce competition from secondary vegetation and to prepare a site for planting after harvesting, as seen here in North Carolina. But burning releases carbon and other chemicals into the atmosphere which contribute to air pollution and climate change.

The specific global change stresses of concern will depend on the ecosystem being studied. In general, the SGCP is investigating the effects of elevated concentrations of carbon dioxide, temperature stress, and moisture stress. Ozone, sulfur and nitrogen deposition from the atmosphere, and flooding and salinity changes are stresses of concern in certain ecosystems. In the strictest sense, elevated carbon dioxide levels are not a stress for plants. In fact, in short-term studies, increased carbon dioxide stimulates plant growth; however, the degree of stimulation varies by species and depends on the other environmental stresses present. Current information suggests that elevated carbon dioxide levels may affect competition between species, and thus the composition of plant communities. Carbon dioxide is therefore one of the stress factors of concern to the SGCP because it is an environmental factor, associated with global change, that is expected to have effects on forest ecosystems.

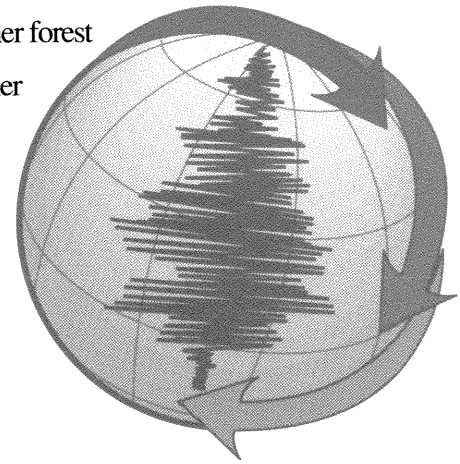
To address questions about the ecological effects of global change, the SGCP will conduct hierarchical research in several important forest types, as well as research on the effects of global change on biological diversity.

Hierarchical Studies

Our primary goals are to be able to make accurate predictions and useful recommendations at the ecosystem level. Much of the research, however, must be done at the individual-tree and stand levels. We are acutely aware of the need to move freely and precisely through this hierarchy. We have chosen an approach in which studies will be done at the most practical level and models will be

constructed to relate findings to higher and lower levels. Modeling, therefore, is an important component in the hierarchical research. Models will be used to identify knowledge gaps, to integrate and interpret data gathered, and to make predictions. Linkages between models at each level of the tree-community-ecosystem hierarchy will be used to determine the importance of variables at one level to processes at other levels.

Hierarchical research will be conducted in four southern forest ecosystems: (1) pine ecosystems, (2) hardwood ecosystems, (3) spruce-fir ecosystems, and (4) forested wetland ecosystems. Hierarchical research in pine ecosystems is the most fully developed component in the SGCP research program. Hierarchical research in the other forest types will be further developed as resources permit.



Selected Research Projects

Ecological and socioeconomic research in the SGCP will improve our understanding of the complex interactions between forests and the atmosphere. SGCP studies address some of the key questions about the interacting effects of global change on the structure, function, and productivity of southern forests. These studies will

- detect genetically controlled differences in the responses of loblolly pines to climate;
- investigate the effects of climate change on nutrient cycling;
- investigate the effects of climate on the hydrological cycle and soil processes in a forested wetland;
- investigate the relationships between climate, site factors, and forest productivity;
- determine the interacting effects of drought and ozone on shortleaf pine;
- determine the effects of elevated carbon dioxide levels, elevated temperature, and altered soil moisture on mature loblolly pine trees and stands;
- evaluate the effects of elevated carbon dioxide and moisture stress on the competition between several pine and hardwood species;
- develop models to evaluate the effects of global change on forest stands and methods to estimate the regional responses to global change;
- evaluate socioeconomic impacts of climate change effects on southern forests;
- evaluate the interaction of climate, insects, and disease in hardwood decline; and,
- determine the interactions between ozone exposure and the tent caterpillar in sweetgum seedlings.

Robert Teskey

Branch chambers, like these at the University of Georgia, are used to expose foliage to elevated levels of carbon dioxide. Oklahoma State University and the USFS in North Carolina are conducting similar research.

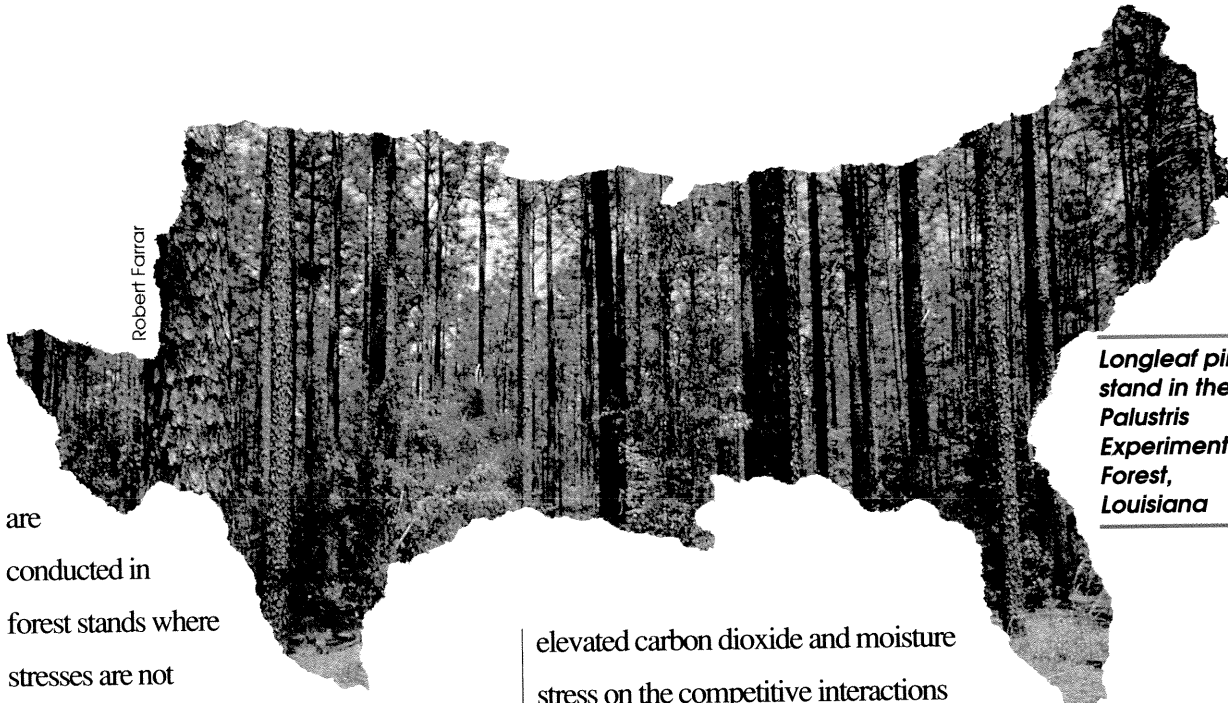
Pine Ecosystems

Hierarchical research in pine ecosystems has been the primary area of emphasis in the first phase of the SGCP. Research focuses on the dominant species of pines, but some study of the role of hardwoods in pine stands is being undertaken. Pine ecosystems are given prominence because of their importance to local, regional, and national economies; because of the prevalence of this type of forest in the southern United States; and because of the importance of these forests for recreational use and for wildlife habitat.

The impacts of five stresses are being studied: (1) carbon dioxide, (2) ozone, (3) temperature, (4) moisture, and (5) nutrients. Our greatest interest, however, is in interactions of these stresses. These interactions are complex, as are the various methods to determine and evaluate biological responses. Approaches being used in the SGCP include correlational, experimental, and modeling research. Correlational studies

Brad Toups

View of open-top chambers used by scientists from Texas A&M Agricultural Experiment Station to study the effects of ozone and drought stress on shortleaf pine. Nacogdoches, Texas.



Longleaf pine stand in the Palustris Experimental Forest, Louisiana

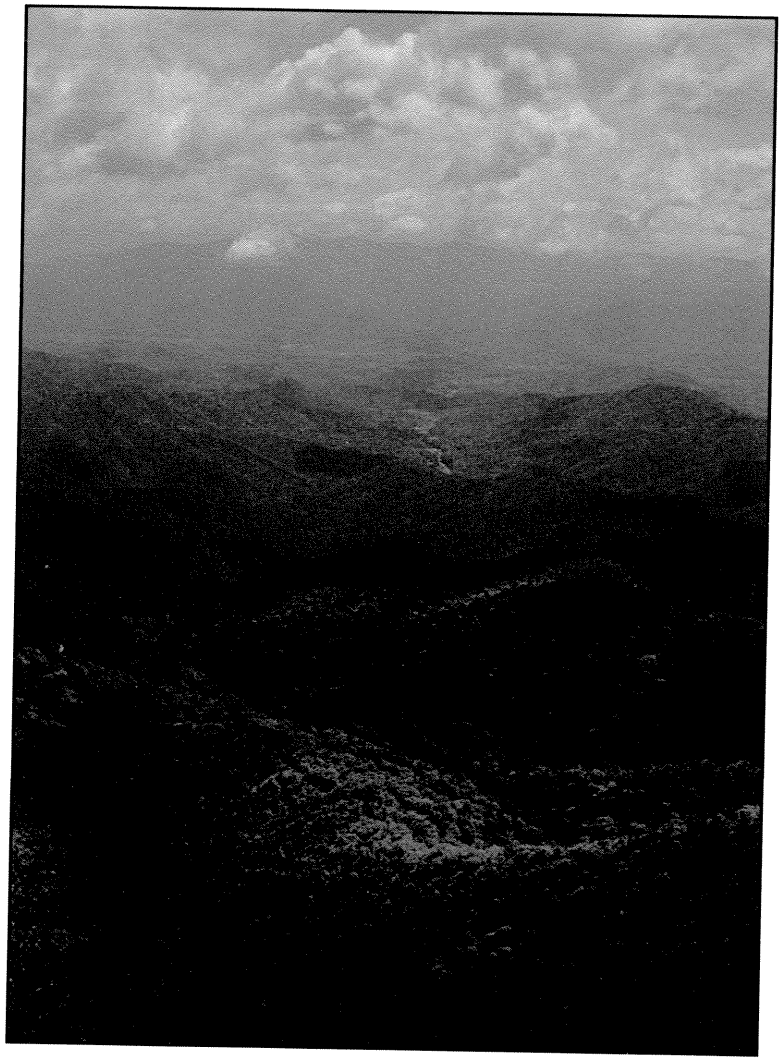
are conducted in forest stands where stresses are not manipulated, but where varying levels of stress exist in the ambient environment. Experimental studies are conducted under controlled conditions in greenhouses or in field chambers. Both types of research will address above- and below-ground processes. These two types of research allow us to study different aspects of forest responses to global change stresses. Modeling efforts at different hierarchical levels will allow us to synthesize our results.

Research in pine ecosystems is investigating the effects of global change factors on seedlings, saplings, and mature trees. For example, the SGCP is studying the effects of ozone and moisture stress on the physiology and growth of shortleaf pine seedlings, the physiological effects of elevated carbon dioxide and temperature on mature loblolly pine trees, and the effects of elevated carbon dioxide and moisture stress on the competitive interactions between selected pine and hardwood seedlings. Other SGCP research projects are examining the relationships between climate factors and nutrient dynamics in forests, and the relationships among climate, site factors, and forest productivity. Results will provide a basis for predicting how forest management practices may need to be altered to sustain forest productivity in a changing physical and chemical climate. Other SGCP research will provide estimates of the carbon budgets of mature trees and the effects of pine forests on the carbon balance of the atmosphere.

Pine modeling studies emphasize the interactions of multiple stresses on forest responses. Models of physiological processes, nutrient cycling, tree growth, and stand dynamics are being developed. These models will be integrated to predict the expected responses of trees and forests to future environmental conditions.

Hardwood Ecosystems

About half of the timberland of the South is occupied by hardwood forest ecosystems, and the proportion of hardwoods is expected to increase as nonindustrial, private landowners allow natural regeneration after harvests of pine forests. Hardwood ecosystems provide valuable products, wildlife habitat, and recreation opportunities. Their species composition, genetic diversity, and biology are highly complex. Hardwood ecosystems, therefore, are likely to vary more in response to environmental conditions than pine ecosystems. Evaluating the effects of global change factors on hardwood ecosystems will be a great challenge.



Robert Szaro

View of oak-hickory forests in the Coweeta Watershed, Nantahala National Forest, North Carolina.

Research on southern hardwood ecosystems will address effects of changes in atmospheric chemistry (i.e., carbon dioxide and ozone), moisture stress, and temperature. Available information will be synthesized, and gaps in knowledge will be identified and filled through research.

Preliminary research has indicated that carbon dioxide stimulates the growth of hardwoods more than softwoods. There is little information, however, on responses to interacting factors, such as increasing carbon dioxide concentration in combination with increasing moisture stress or temperature stress. Because hardwood stands are seldom managed, growth, development, and survival in them are controlled largely by interactive

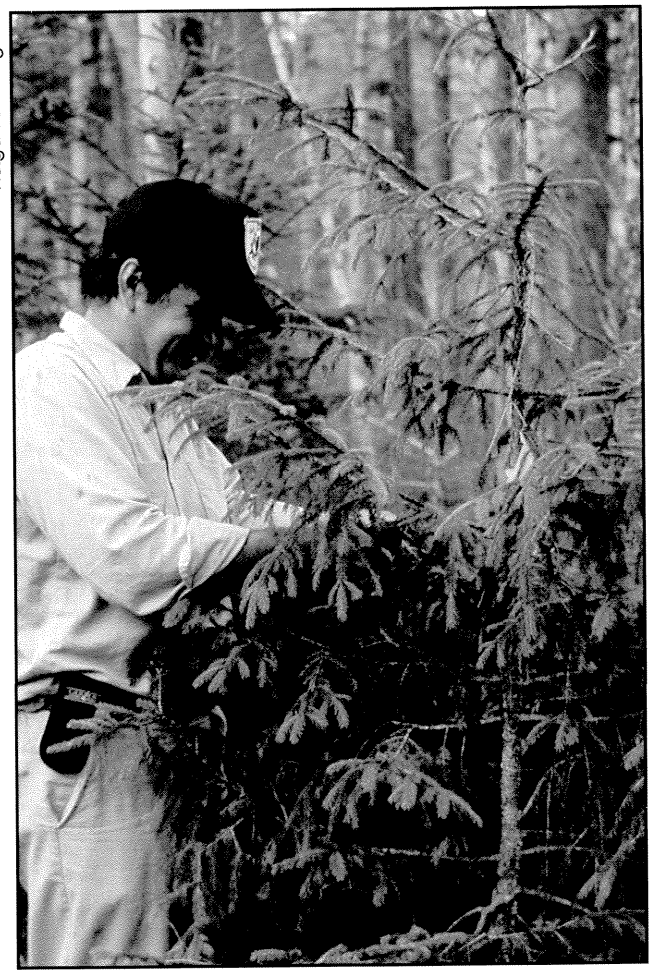
competition. Program research will ascertain how the outcome of this competition will be influenced by the stress factors associated with global change. It also will address the effects of ozone, in combination with other stress factors, on southern hardwoods. A number of hardwood species are sensitive to ozone, and the response to ozone in the presence of other stresses needs to be examined. The relationships between climate and the occurrences of hardwood ecosystems also warrant further study.

Spruce-Fir Ecosystems

The spruce-fir forests in the Southern Appalachians are small but significant. Dominated by red spruce and Fraser fir, they are important because they add biological diversity and provide recreation opportunities. In the South, these forests occur only at high elevations. Typically they grow on thin, rocky soils and are exposed to extremely cold winter conditions. These forests are also exposed to high sulfur and nitrogen deposition from clouds and to moderate ozone concentrations.

The SGCP will build on past research in the spruce-fir forests of Virginia, North Carolina, and Tennessee. Research will expand our understanding of the relationships between atmospheric deposition and forest health and will elucidate the potential effects of climate change. The stresses to be investigated include atmospheric sulfur and nitrogen deposition, nutrient stresses, and climate stresses.

Helga van Miegroet



A scientist from Oak Ridge National Laboratory samples red spruce foliage to test for aluminum toxicity.

Significant mortality has been observed in some spruce-fir forests in the South, and the roles of natural and human factors need to be clarified. The immediate cause for mortality in Fraser fir is an insect pest, the balsam woolly adelgid. Whether atmospheric chemicals are predisposing fir to insect attacks or reducing radial growth of red spruce warrants further investigation. Research is also needed in forests that appear healthy to determine if air pollutants are causing cumulative, chronic injury. Because spruce-fir forests are near the southern edge of their range, they are vulnerable to climate warming. Thus, research on the relationships between southern spruce-fir forests and climate could be highly revealing.

Forested Wetlands

About one-third of the Nation's wetlands are in the forests of the South. Pocosins, bottomland hardwood stands, Carolina bays, and cypress-tupelo swamps are examples of southern forested wetlands. These areas provide enormous environmental and monetary benefits, including habitats for plant and animal species, recreation sites, and maintenance of water quality.

The effects of predicted climate changes on wetland ecosystems are unknown, but some ecosystems could be seriously threatened. Climate changes

If climate changes, it could alter the frequency and severity of storms. Hurricane Hugo resulted in millions of dollars of damage to forests in the South. Francis Marion National Forest, South Carolina.

Lonnette Edwards

Virginia Burkett, U.S. Fish and Wildlife Service.

"Ghost" cypress forest killed by rising water levels and salinity, Louisiana.

could alter the extent and composition of forested wetlands. A warmer and drier climate, for example, could be expected to yield a net loss of wetlands. Sea-level rise, which some models predict, will cause changes in salinity that may adversely affect some species. As in other forest types, elevated carbon dioxide concentrations may change competitive relationships between species.

The SGCP will sponsor research to explore relationships between forested wetland ecosystems and potential environmental changes. The stresses of concern include water stress (flooding, drought, and changes in hydroperiod), temperature stress, salinity changes, and carbon dioxide. Research results will be used to evaluate, modify, and develop management strategies for forested wetlands and their associated upland habitats.

Lonnette Edwards

Pitcher plants in the Chattahoochee and Oconee National Forest, Georgia.

Biological Diversity

Natural areas in the southern United States are well known for the diversity of life they support. Forest ecosystems in the South provide unique environmental conditions for endangered and threatened species as well as more common plants and wildlife. For example, some of these systems require a wetland hydrological cycle, some require periodic fire, and some require both. The red-cockaded woodpecker, the Alabama leatherflower, and the gopher tortoise are just a few of the endangered or threatened species that are found in these areas. The Southern Appalachians also provide unique environmental conditions. High elevation, high precipitation, moderate to low temperatures, and uncommon soil types enable this region to support northern plant species.

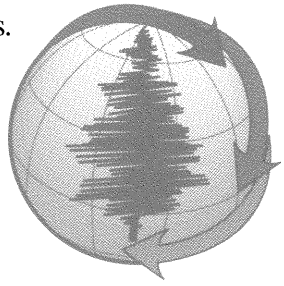
The USDA Forest Service has a heavy responsibility for species preservation on the land it manages. That responsibility translates into a mandate to maintain diversity in the National Forest System. Genetic, species, population, community, and landscape diversity, and the processes that promote it, have gained much national and international attention over the past decade. Throughout the world, habitats have been altered rapidly, and losses of species have accelerated. More than a third of the 600 U.S. species listed as threatened and endangered are found in National Forests. To prevent loss of species, the USDA Forest Service has incorporated stewardship of biological diversity as a research and land management objective.

Donal Hook

Little Blue Heron, South Carolina.

Forest ecosystems and the biological life that they support may be at great risk from global-scale changes in environmental conditions. The future climate of the South could be very different from today. Storms and fires could be more frequent and intense. Global change, in conjunction with increased population growth, increased forest fragmentation, and other causes of habitat alteration or loss, could affect southern forest diversity. For example, the Southern Appalachians might no longer function as a refuge for the northern relict plant species.

In keeping with Forest Service stewardship goals, the SGCP will support research on the effects of potential changes in environmental and climatic conditions on the biological diversity of southern forests. Full use will be made of existing information and ongoing research throughout the region. Research in this area will span several forest types and will focus on possible species responses and habitat alterations due to changes in the physical and chemical climate. Issues of particular concern include loss of specialized habitats and refuges, shifts in species ranges, and potential losses of species or populations.

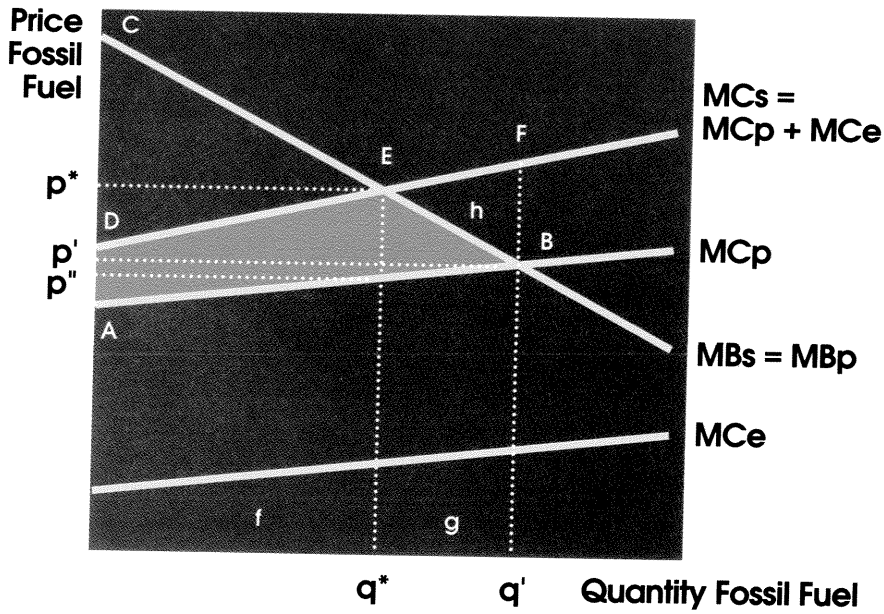


Socioeconomic Research

Much of the impetus behind global change research has been the concern for the possible impacts on people. If large-scale environmental changes occur, the effects on forests and, in turn, people could be enormous. Because global change has the potential to alter societal welfare, the SGCP is conducting socio-economic research, as well as ecological research. Information on the socioeconomic impacts of global change is of importance to legislators who must decide if tighter controls on sources of emissions are cost-beneficial.

The SGCP has begun a program of socioeconomic research to examine impacts of global change on human populations. These studies will explore both the monetary and nonmonetary consequences of changes in the global environment. The program will (1) evaluate the usefulness of current forest biological information for analyzing the socioeconomic impacts of global change on southern forests, (2) develop partial or general equilibrium models to evaluate the regional economic impacts of global climate change on southern forests, (3) determine the costs and benefits of adapting southern forest management practices to mitigate the impacts of global change, (4) develop methods to incorporate risk and uncertainty into economic decision models of global change, and (5) explore how forest policies and legislation might change under altered global conditions.

The SGCP socioeconomic research will contribute to an evaluation of the regional economic impacts of global change on southern forests. One project currently underway is linking climate scenarios, predictions of pine productivity changes, and economic forecasts.



Global change impacts on social welfare must include a thorough economic evaluation of the costs of air pollution and climate change impacts as well as a determination of the benefits of a cleaner environment.

Assessment

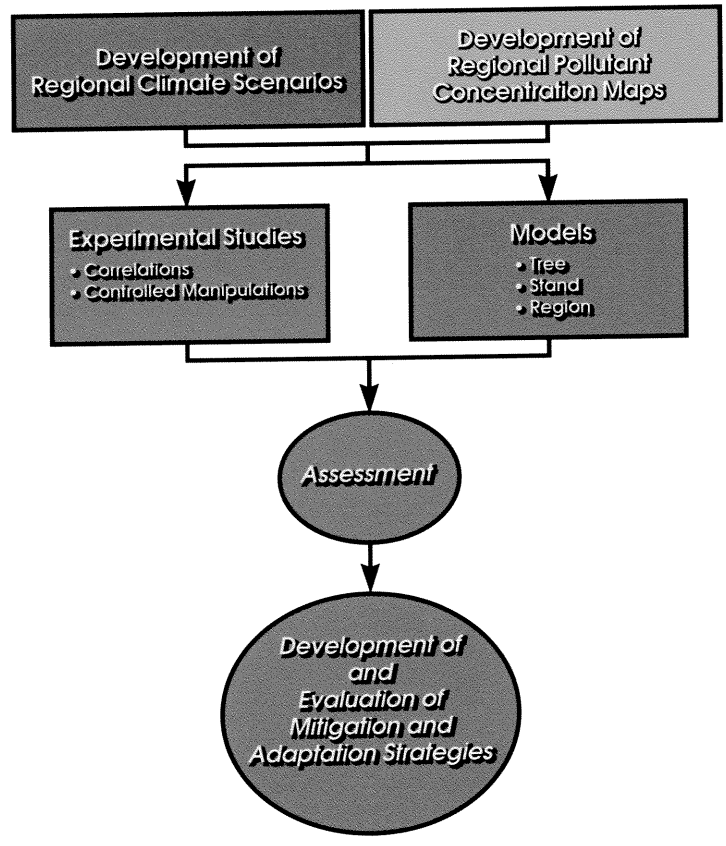
To meet diverse needs for information, the SGCP will synthesize its ecological and socioeconomic research to develop assessments from both the science and policy perspectives. These assessments will support major decisions about public policies relating to climate change. An early target date of 1995 has been set for the completion of the initial assessments. These assessments will synthesize what has been learned and will identify information gaps. These documents will provide guidance for a redirection of future research, if necessary.

Assessments will be made of the state of knowledge of global change effects on the major forest ecosystems of concern. The amount of information available will be greatest for pine ecosystems. The pine ecosystem research will have three assessment components targeting different aspects of the potential effects of global change on natural resources. The SGCP will prepare an ecological assessment, a resource/risk assessment, and a socioeconomic assessment. These different assessments will be published or presented in peer-reviewed articles, books, and symposium presentations and proceedings.

Ecological Assessment

This assessment will comprise two parts. The first will be a report on the state of knowledge about how the five stresses (ozone, carbon dioxide, temperature, moisture, and nutrients) interact to affect southern pine ecosystems. The second part of the ecological assessment will be a report synthesizing predictions on the effects of the five stresses under future climate and atmospheric conditions. The predictions will focus on effects on carbon, water, nutrient, and growth dynamics.

Structure of Research in the Southern Global Change Program Used for the Assessment



■ Cooperative Program not funded by SGCP.

Regional Resource/ Risk Assessment

The risk of air pollution and climate change to southern forest health and productivity will be defined in relation to biotic and abiotic stresses such as insects, diseases, temperature, limited nutrient availability, moisture, and wildfire. This level of assessment will focus on the effects of pollution and potential climate change on productivity, annual carbon balance, and annual water balance.

Quality Assurance

To be useful for decisionmakers, assessments must be based on good science, with uncertainties clearly identified. To ensure that SGCP projects provide the sound scientific basis needed for our assessments, the SGCP has implemented a Quality Assurance Program. The Quality Assurance Program consists of certain activities that are required to ensure that data are of known and documented quality. The quality of the research data and model outputs must be documented quantitatively to provide valid means for estimating uncertainty.

Individuals participating in the SGCP must follow established procedures for documenting the quality of output. Data quality activities include the following.

1. *Project Study Plans.* All projects are required to submit a combined work and quality assurance plan prior to the initiation of research. The plan must include descriptions of objectives, hypotheses, task and production schedules, statistical methods and analyses, experimental design, variables, power curves, methodology, data quality estimates, and reporting.

2. *Project Performance Reviews.* Project reviews verify that measurement systems are operating properly, determine that data quality information is being adequately collected and analyzed, and assess the contribution of each project to overall program objectives.

3. *Data Quality Reporting.* Data quality statistics must accompany all research data and model outputs. These statistics should indicate the accuracy, precision, and completeness of data.

Our goal is for each project to provide data and model outputs of stated quality with a stated probability of being correct. Sources of variability are identified, and, where necessary, recommendations are made to improve the accuracy and precision of measurements.

Socioeconomic Assessment

The economic impacts of pollution and potential climate change on market and nonmarket forest resources will be determined. The socioeconomic assessment will also evaluate the costs and benefits of adapting forest management practices to respond to global change. In addition, the changes in human values for forest resources with increasing population density will be evaluated.

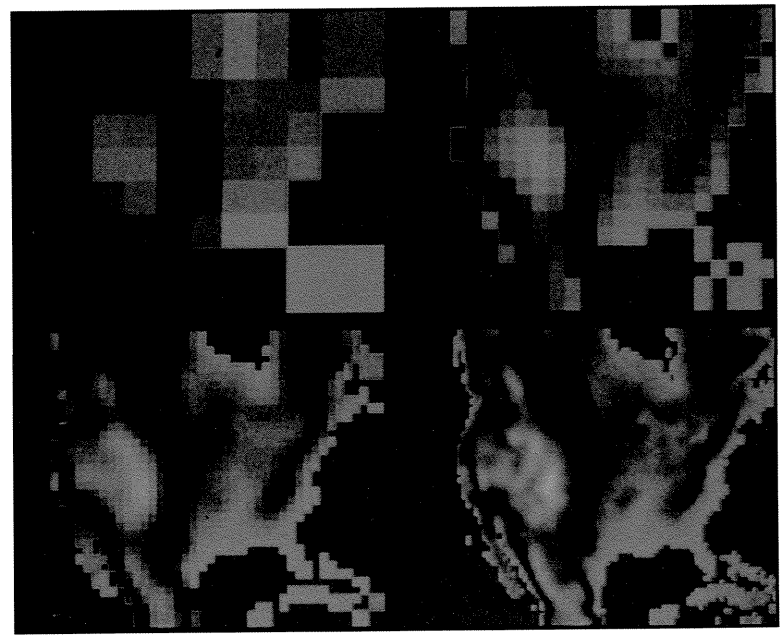
The information obtained from SGCP research on the interactions between forest ecosystems, air pollution, and climate change will provide the foundation for the ecological assessment, the results of which will be combined with resource information to prepare the resource/risk assessment. Information from these documents will be used in the development of the socioeconomic assessment and the identification of adaptation and mitigation strategies. These assessments will be used to meet the information needs of scientists, land managers, and policymakers.

Interactions with Other Programs

The research needs associated with the issue of global change and southern forests are too big for any one program, or even one agency, to tackle alone. For this reason, the SGCP is working closely with several other research programs. The National Council of the Paper Industry for Air and Stream Improvement, Electric Power Research Institute, U.S. Environmental Protection Agency, National Aeronautics and Space Administration, U.S. Department of Energy, Tennessee Valley Authority, National Science Foundation, U.S. Fish and Wildlife Service, U.S. Geologic Survey, and USDA Agricultural Research Service all have global change research ongoing in the South. The SGCP will work with these organizations to assess the regional impacts of global change. The National Council of the Paper Industry for Air and Stream Improvement is an especially important cooperator. The Council provides recommendations on the direction of research pursued in the Program and cofunds research projects on global change impacts.

The SGCP has also initiated discussions with several environmental groups, such as Audubon Society, Environmental Defense Fund, Nature Conservancy, and World Wildlife Fund, to identify areas of common interest. Biological diversity, and in particular the threat global change poses to biodiversity, has emerged as an issue of mutual concern. Input from these groups is shaping the future research directions of the SGCP.

Another example of cooperation is in the effort to develop climate scenarios. The SGCP is working with meteorologists employed by the U.S. Environmental Protection Agency in Research Triangle Park, NC, to develop future climate scenarios. Climate scenarios come from general circulation models that simulate the Earth's climate with systems of equations run on super computers. The equations are solved



National Center for Atmospheric Research, Boulder, Colorado.

The terrain of North America as modeled with increasingly higher spatial resolutions. Current climate models use the low resolution grid in the upper left. Use of higher resolution in future modeling will provide better predictions.

over finite timesteps for three-dimensional grids covering the Earth's surface and atmosphere. We are working with four of the best known general circulation models: the Geophysical Fluid Dynamics Laboratory model, the NASA Goddard Institute for Space Studies model, the Oregon State University models, and the United Kingdom British Meteorological Office model. Global climate change scenarios will be developed for the entire southern United States from Texas to Virginia. These will be available to assist researchers and research administrators. Examples of some selected output variables include mean surface temperatures, diurnal range of surface temperatures, soil temperature, atmospheric moisture, cloud cover amount, and precipitation for all four seasons. These scenarios will be instrumental in the SGCP's efforts to project the impacts of future climate change on southern forests.

Concluding Remarks

The Southeastern and Southern Forest Experiment Stations have joined together in establishing the SGCP to evaluate the complex relationships between air pollutants, climate change, and southern forests. Results from the SGCP will improve understanding of forest ecosystems and how they function, and will allow prediction of the effects of global change on southern forest resources. In addition, our efforts will provide information needed for the development of forest management and policy responses to global change. The SGCP will summarize and distribute its results on a regular basis to ensure that policymakers have the information they need in a timely fashion.

There is reason for skepticism about any particular climate change prediction. But the known changes in the chemical composition of the atmosphere are cause for concern. Research in the SGCP will provide information needed to address global change concerns and even if climate change does not occur, the improved understanding of southern forest ecosystems gained by SGCP research will be essential in efforts to wisely manage and protect forest resources.

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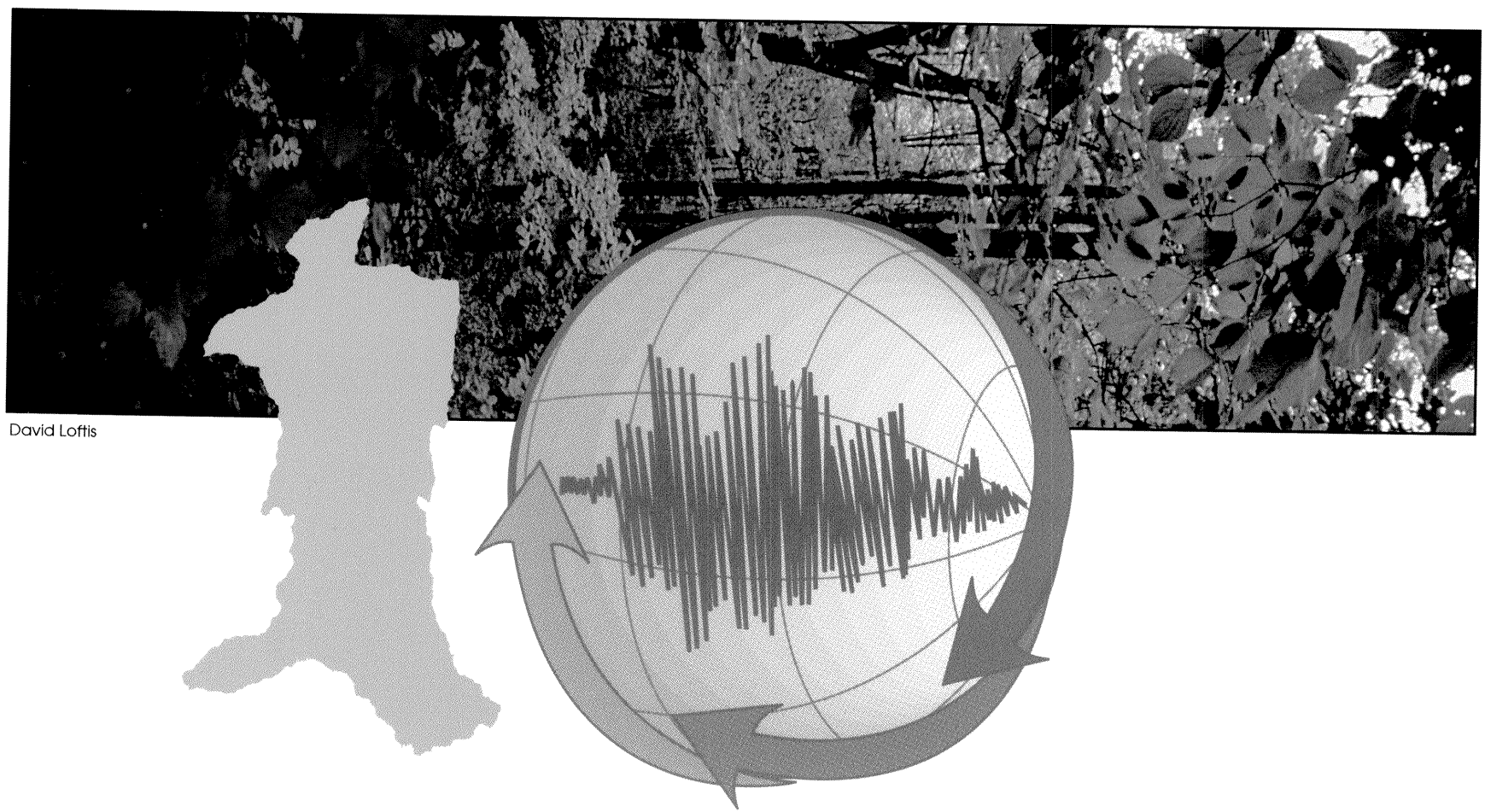
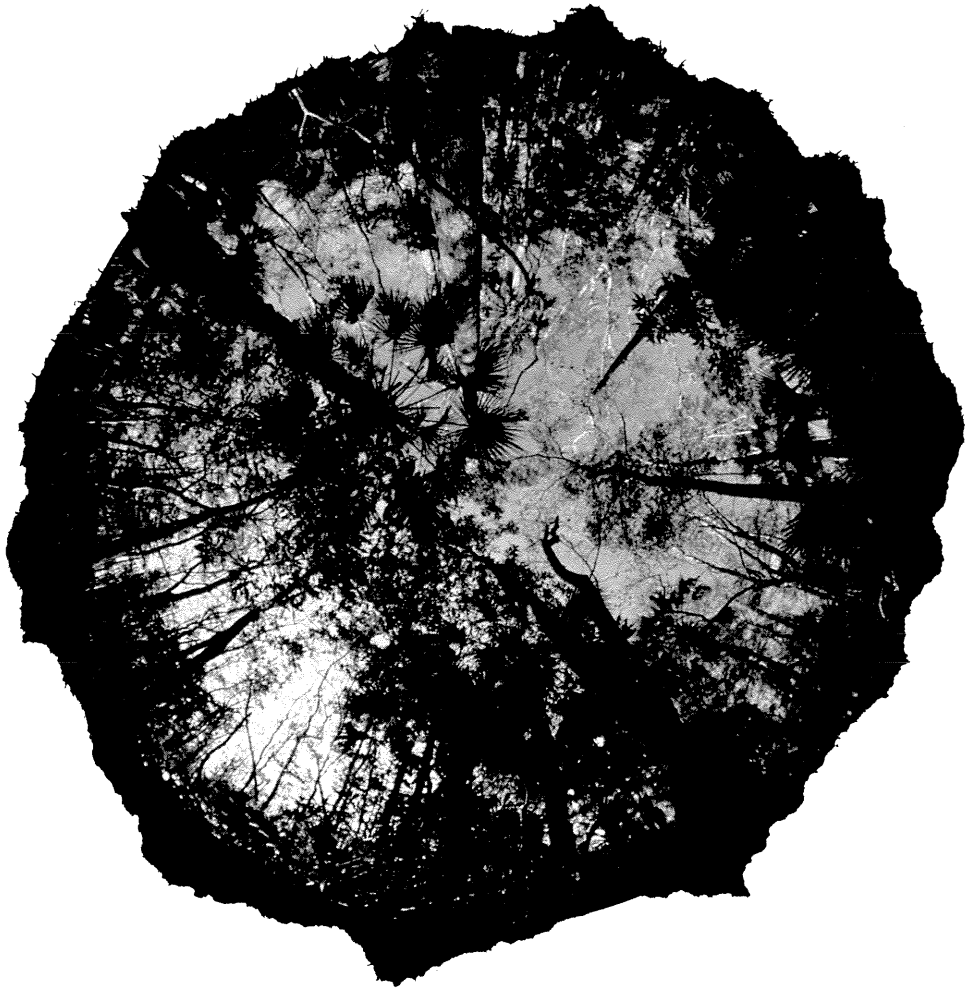
Front and Inside Cover Photo:
Mixed pine hardwood forest on the Cedar Point Tideland Trail, Croatan National Forest, North Carolina. (Photo: Robert Szaro)

Back Cover Photo:
View into the canopy of a wetland forest in the St. Marks National Wildlife Refuge, Florida. (Photo: Elijah Ramsey, U.S. Fish and Wildlife Service)



David Loftis



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