Global Change Education Program Mentor Abstracts

Atmospheric Science and Biometeorology

Marc L. Fischer
Research and teaching:

I conduct research and teach in the areas of atmospheric science, biogeochemistry, ecology, and human resource use, with the unifying goal of providing scientific information to help guide sustainable co-existence on Earth. Research activities include instrument development, field measurement campaigns, data analysis, and numerical modeling. I currently lead a project to plan an atmospheric measurement strategy to monitor regional exchange of CO2 and other greenhouse gases in California. I also collaborate on a project to conduct carbon cycle measurements at the US DOE Atmospheric Radiation Measurement Site in the Southern Great Plains. Possible student projects in these areas include measurements, analysis, or modeling 1) to quantify anthropogenic emissions and terrestrial exchange of CO2 and other trace gases, and 2) to determine how the exchanges are affected by and feedback to land use and management, and climate on plot to regional scales.

Sue Grimmond
Our reseach involves measurement and modelling of earth-atmosphere interactions. We are interested in boundary layer and micro-scale processes. We have an AmeriFlux site (http://www.indiana.edu/~co2/) just north of Bloomington where we conduct continuous measurements of CO2/H20/Heat etc.

Joyce L. Tichler
BNL and the State University of New York at Stony Brook (SUNY) are jointly purchasing a satellite receiving station that will be used to acquire both AVHRR and SeaWiFs data covering the northeastern portion of the US. These data will support a number of research studies and operational projects that are currently underway and/or planned for the future. The eastern region of the National Weather Service headquarters office is also interested in collaborating with BNL and SUNY in future research efforts using these new data sources.. Finally, the BNL Office of Education Programs hopes to use the availability of such data to develop an outreach environmental study program for local high schools and for community outreach. The student or fellow would participate in this new program.

Carbon Cycle Modeling

Inez Fung
Our research focuses on biosphere-atmosphere interactions, with the goal of gaining predictive capability of how atmsopheric composition and climate may evolve in the future. The principal tool we employ is NCAR's Climate System Model (CSM) into which we are implementing interactive terrestrial and oceanic carbon modules. Analysis of interannual and longer-term variations in the carbon cycle reveals the climate sensitivity of the terrestrial and oceanic systems. We have also studied the cycles of methane, mineral aerosols and other trace consitutents in the atmosphere, and have sought explanation for their abundance in past climates. The work is done in collaboration with S. Doney of NCAR and others of the NCAR community. Model integration will be carried out on DOE NERSC's cluster of supercomputers.

Tom Guilderson
Our research follows two parallel and related themes the role (amplification, feedback, and primary forcing) of CO2 in climate change. To this end we are engaged in modern process studies in the terrestrial and oceanic realms documenting and understanding the spatial and temporally varying sinks and sources of CO2 to the atmosphere. In tandem, we are studying climate change (local, regional, and global) in the context of developing paleoclimate records with sufficient resolution and time-control to understand the processes governing seasonal to millenial to glacial-interglacial climate change. Examples of this research include but are not limited to: development of high-resolution coral-14C time-series to document seasonal to decadal changes in ocean circulation, the role of mineral phases in the uptake and storage of soil carbon, decadal-centennial

duration droughts in the US, paleo-oceanographic proxy studies in the California borderlands to study the link between the terrestrial and oceanic climate records, soil carbon turnover rates, and the long-term potential carbon uptake in specific ecosystems under naturally elevated CO2 concentrations. We work closely with various modelling groups both in-house to LLNL (ASD & PCMDI) and the broader external scientific community, but our primary focus is the acquisition and interpretation of real-world data.

Atmospheric Boundary Layer Modeling

Kenneth J. Davis
Prof. Davis's research examines earth-atmosphere interactions via observation and modeling of the atmospheric boundary layer. A major focus is determining ecosystem-atmosphere exchange of CO2 at various temporal and spatial scales. Much of this work is centered on an AmeriFlux site in northern Wisconsin (http://cheas.umn.edu). He is also actively involved in lidar observations of the atmospheric boundary layer.

Starly L. Thompson
Global climate simulation with atmospheric general circulation models and coupled atmosphere/ocean models. Biospheric and cryospheric feedbacks to the global climate system. Paleoclimatic modeling. Climate downscaling techniques. Modeling ocean thermohaline circulation response using simple box models. Global carbon cycle simulation using coupled climate and biogeochemical models.

Global Climate Modeling

Philip B. Duffy
My research involves trying to understand the effects of human activities on climate, and the societal impacts of those climate changes. To understand human influences on climate, I am performing simulations with global and regional climate models at spatial resolutions fine enough to give credible predictions on a regional spatial scale. To understand the societal impacts of climate change, I am collaborating with researchers who have expertise in diverse relevant areas; a particular subject of interest is the effects of climate change on the hydrological cycle and water availability. Finally, I am developing and testing new techniques for estimating uncertainties in predictions of future climate.

Steven J. Ghan
I am currently supported by the DOE Climate Change Prediction Program to apply a parameterization of subgrid orographic effects to a the NCAR Community Climate Model. The parameterization treats the influence of unresolved variations in surface elevation on temperature, humidity, clouds, precipitation, radiative transfer, and land surface processes. The parameterization has already been applied to a regional climate model, demonstrating much improved simulation of precipitation and particularly snow pack. I am looking for someone interested in helping me with the evaluation of the parameterization in the CCM. This will required working with both station data and model data.

Robert Jacob
My research starts with an interest in the Earth's climate: how it functions and how it changes. In particular I try to understand what role the ocean has in controlling variability in the Earth's climate. This question has led me to work on the development and application of ocean and coupled climate models and the computational, mathematical and theoretical issues involved in their construction. Lately, I have been working on a new parallel coupler for the Community Climate System Model.

Surabi Menon
As part of the climate group at LBL, and in collaboration with the NASA Goddard Institute for Space Studies. we are engaged in research related to aerosol effects on climate. Aerosols affect climate through changes in the radiation and cloud fields that in turn affect temperature, precipitation, energy budgets etc. A challenging issue is determining the extent of the influence of aerosols on climate through the aerosol-cloud interaction process. Aerosol impacts on cloud microphysical and radiative properties are estimated to be sufficiently large as to partially offset the greenhouse gas effect. However,

considerable uncertainty exists in this aerosol-cloud interaction process and thus, various opportunities still exist in this area of research. We encourage applications from students who are interested in investigating climate change through models and observations. Research topics include (1) comparing climate diagnostics from model simulations of climate change with satellite based retrievals, (2) investigating aerosol and cloud properties from field measurements from various locations and relating it to model produced diagnostics, (3) evaluating the role of dynamics in aerosol-cloud interactions through models, observations and reanalyses data. The job requires knowledge in programming as the student will be expected to work on large data sets (model and satellite based data).

Warren M. Washington
Parallel Climate Model (PCM) With Emphasis On A Parallel River Transport Model

Because of changes in supercomputer technology, climate models are increasingly adapting to parallel processor architectures. The DOE Climate Change Prediction Program is addressing the need for next generation climate models, especially, the atmosphere, land/vegetation, ocean, and sea ice components. One of the novel features of this climate model is that the components have been developed at different research centers and universities to make use of massively parallel processor (MPP) distributed memory (SD) supercomputers. Highly parallel computers are likely be the trend in the future as federal plans for advanced scientific computing are being developed in this direction. One of the purposes of the Scientific Simulation Initiative (SSI) is to accelerate the use of high capacity computers toward the goals of global systems modeling.

The atmospheric component is the NCAR Community Climate Model version 3 (CCM3), the ocean component is the Parallel Ocean Program developed at the DOE Los Alamos National Laboratory, and the sea ice component has been developed at the Naval Postgraduate School in Monterey California. The University of Texas at Austin has developed a parallel river transport model component, and we are incorporating this component in the PCM. Including river transport completes the hydrological cycle. In the present configuration of the PCM the surface and subsurface runoff of water does not go into the ocean locally at the mouths of river basins. This problem effects the ocean circulation systems. This project involves refining the river transport methods, testing the model in overall climate system, and examination of the role river hydrological processes on ocean circulation systems.

ARM

Steven J. Ghan
I am currently supported by the DOE Atmospheric Radiation Measurement (ARM) program to develop and evaluate a stratiform cloud parameterization for global climate models. The parameterization predicts cloud droplet mass and number concentration, cloud ice mass and number concentration, and mass concentrations of rain and snow. We are currently working on the treatment of subgrid variability in the cloud properties and cloud processes, initialy focussing on subgrid variability due to boundary layer turbulence. We use single column models, regional circulation models, and global circulation models as testbeds for the parameterization, and evaluate the performance using in situ, surface, and satellite measurements.

Steven K. Krueger
My research uses numerical models of cloud systems to better understand the physical processes that govern the formation, maintenance, and dissipation of clouds. We use measurements made at ARM Cloud and Radiation Testbeds (CARTs) to provide the boundary conditions needed to run these models and also to evaluate the models. The ARM CARTs are providing unprecedented observations of the vertical structure of cloud systems and the associated atmospheric radiative fluxes at three sites in very different climatic regions: an Arctic site, a mid-latitude continental site, and an oceanic Tropical site.

Dr. David Parsons
My current research for DOE is associated with the Atmospheric Radiation Measurement (ARM) program. This program is aimed at testing and improving the treatment of cloud and radiative transfers in climate models. Our effort relatively broad effort addresses the ARM objectives using both observations and numerical models for both tropical and middle latitude atmospheres. Current work includes 1) examination of how the equatorial atmosphere recovers through cloud and radiative processes following the arrival of extremely dry air from middle latitudes, 2) the dynamics of the tropical atmosphere near the initiation of the strong 1997 El Nino, and 3) statistical evaluation of cloud and radiative parameterizations used in climate and mesoscale models against ARM observations in the southern Great Plains of the United States.

Joyce E. Penner
Under funding from ARM, we are modeling the global distribution of aerosols (dust, sea salt, organic carbon, black carbon from fossil fuels and biomass burning, as well as sulfate aerosols) and their interactions with clouds. We are also analyzing ARM data to understand the effects of aerosols on cloud reflectivity.

William M. Porch
Our work next summer involves both theoretical and experimental aspects. The theoretical work involves improvement of radiation tranfer and data quality algorithms to improve quality assessment of ARM data. The experimental work includes testing of remote and in-situ climate instrumentation in Albuquerque, NM. We will also be preparing for experiments using tethered balloons and kites to make atmospheric profile measurements of water vapor in Oklahoma. Calibration and calibration checks are a very important part of the Department of Energy's Atmospheric Radiation Measurement (ARM) program. Almost all climate variables necessary for understanding climate change must be measured at (or even beyond) current instrument measurement accuracy specifications. Our short-term goal is to improve our understanding of how accurate each measurement made by ARM is, and our long-term goal is to improve on these levels of instrument accuracies. We are looking for students who are interested in experimental atmospheric physics, instrumentation, and analysis.

Stephen E. Schwartz
Much of our recent research focuses on the radiative influence of anthropogenic aerosols on climate in connection with the larger issue of possible human-induced climate change, the so-called global warming issue. Aerosols affect the earth's radiation budget directly, by scattering incoming shortwave (solar) radiation and thereby enhancing the earth's albedo, and indirectly, by modifying the microphysical properties and reflectivity of clouds. We and others have presented a body of work over the past decade that indicates that anthropogenic aerosols are exerting an influence on climate change that is comparable (but of opposite sign) to the anthropogenic greenhouse effect. However the magnitude of these aerosol influences is quite uncertain in comparison to that of longwave (thermal infrared) radiative forcing by incremental concentrations of greenhouse gases (mainly carbon dioxide and to lesser extent methane, nitrous oxide, and others) resulting from industrial activity. Specific research projects include studies of the influence of atmospheric aerosols on atmospheric radiation transfer and shortwave forcing of climate change. For more details see:
Research Topics

Dr. Tim P. Tooman
I am working on the retrieval of cloud fraction and morphology from high resolution image data and the comparison of results with those from other methods. A potential research topic is the calculation of pristine sky short wave radiative fluxes for near and below horizon solar positions.

Atmospheric Science Program - ASP

Carl Berkowitz
Present Work for DOE/global change: Our broad interests involve evaluating component processes associated with high pollution events. This has been a slow and sometimes painful three-step process that 1) starts in the laboratory, where members of our team are evaluating uptake coefficients and rate constants for reactions postulated to be of importance in the atmosphere. These numbers are being employed in 2) air chemistry models that allow us to synthesize both chemistry and meteorology. The final step has been working with other ACP scientists in 3) the collection of field data to evaluate model performance under a variety of conditions. Having evaluated how the model performs, we can then return to a number of basic questions related to the goal stated at the start of this paragraph: evaluating how component processes of the chemical/meteorological cycles relate to high pollution events. With this approach, we have been able to identify limitations in gas-phase mechanisms, elucidate the role of boundary-layer mixing on peak surface ozone values, and clarify the role of nocturnal jets on ambient ozone levels. Our short-term activities, for the immediate future, involve making field measurements to evaluate the interactive role of aerosols and oxidants.

Gregory R. Carmichael
The importance of heterogeneous reactions in tropospheric ozone and aerosol formation, and their impact on O3-precursor relationships are being studied through a multidisciplinary approach which combines modeling and laboratory components. The primary objectives of this study are to:

- Evaluate the extent to which heterogeneous chemistry affects the photochemical oxidant cycle, particularly, tropospheric ozone formation;
- Conduct laboratory studies on heterogeneous reactions involving VOCs on aerosol surfaces; and
- Explore the sensitivity of ozone and aerosol composition to changes in precursor emissions on regional scales.

The importance of heterogeneous reactions in tropospheric ozone formation and its impact on O3- aerosol precursor relationships is being studied using both box and three-dimensional models. Heterogeneous chemistry effects are being evaluated initially with a time-dependent multi-phase chemistry box model. A combined aerosol/gas-phase chemistry model has been developed for this purpose, in which the detailed multicomponent aerosol dynamics and heterogeneous chemistry on the aerosol surface are explicitly included. Regional simulations using the heterogeneous chemistry based on laboratory and box model studies will also be performed in order to evaluate these processes under different aerosol, emissions and ambient conditions. Simulations with and without aerosol reactions, and for various levels of NOx and VOC emissions are being conducted to evaluate how the heterogeneous reactions perturb the ozone and secondary aerosol precursor relationships. The modeling activity provides both a means to rapidly evaluate the significance of the new laboratory findings and will help guide the laboratory studies. Laboratory studies will be directed to those areas which have high sensitivity and high uncertainty. The experimental methods to be used in the laboratory studies include Fourier-transform infrared spectroscopy, UV-vis spectroscopy and Knudsen cell measurements. A molecular level understanding of the mechanism of adsorption and reaction of atmospheric gases on aerosol surfaces will be obtained from the infrared data and more quantitative reaction probability data will be obtained from the Knudsen cell measurements.

Paul Davidovits
A series of experiments is in progress to study heterogeneous processes related to the chemistry of tropospheric oxidants and aerosols. Studies focus on the heterogeneous chemistry of NOx, O3, HO2, HONO and volatile organic compounds (VOC's). Experiments are specially focused on understanding the nature of interactions at the gas-liquid interface. Ongoing studies fall into three categories:

- Uptake studies with O3, HO2, NOx, HONO, and a series of VOC's by liquids as a function of acid and various ionic concentrations.
- Co-deposition studies of O3, HO2, NOx, HONO, and VOC's to determine the effect of surface reactions and surface complexes on the uptake of gas phase species.
- Studies of processes that interconvert NOy and NOx.

The effect of photochemistry on these processes is examined. Experiments are conducted using a droplet train apparatus and a horizontal bubble train appparatus. These experimental techniques have been developed over the past several years in a collaborative effort between the Chemistry Department at Boston College (BC) and the Center for Chemical and Environmental Physics at Aerodyne Research, Inc. (ARI). Supported in part by the DOE ACP, to date heterogeneous gas-liquid interactions have been studied for more than forty atmospherically important gas phase species.

Paul Doskey
My currently funded DOE Global Change Research involves experimental and theoretical approaches to study the behavior of nonmethane organic compounds (NMOCs) in the atmosphere. Participation in collaborative field experiments with government agencies and academic institutions is a significant component of the ongoing research effort. The experiments are designed to (1) reconcile sources of NMOCs in urban areas, (2) examine regional scale atmospheric chemistry from aircraft- and surface-based measurements of NMOC distributions, and (3) measure air-surface exchange rates by enclosure and micrometeorological methods. The project includes sampling and analytic technique development and also field measurements from surface and aircraft platforms. Whole-air sampling, solid sorbent preconcentration, and direct cryogenic preconcentration procedures are used to collect NMOCs in ambient air. The samples are analyzed by cryogenic preconcentration/high-resolution gas chromatography with a variety of detection systems (e.g., flame ionization, photoionization, electron capture, and ion trap mass spectrometric). The data is interpreted in collaboration with meteorologists and numerical modelers of the atmospheric physics and chemistry group at Argonne.

Jerome D. Fast
Abstract 1
We are currently performing an extensive analysis of air chemistry and meteorological data collected over the past 10 years, as well as a series of photochemical modeling studies, to evaluate the contribution of stratospheric ozone to high surface ozone mixing ratios over North America. Our hypothesis, which forms the basis of our research, is that variations in mid-tropospheric ozone resulting from stratospheric intrusions frequently contribute to high ozone concentrations at the surface that exceed the National Ambient Air Quality Standard (NAAQS) for ozone. The data analysis will consists of potential vorticity calculations, satellite measurements of total column ozone, ozone profiles, near-surface ozone measurements, and other supplemental meteorological measurements over North America to find evidence of stratospheric intrusions of ozone. A series of modeling studies are being performed using a coupled photochemical-mesoscale modeling system to elucidate the interactions of synoptic, mesoscale, and boundary-layer processes responsible for the downward transport of ozone within the troposphere and evaluate the relative contribution of naturally-occurring ozone of stratospheric origin and tropospheric sources (natural and anthropogenic) to high surface ozone concentrations over the eastern United States.

Jerome D. Fast
Abstract 2
I will be working with several investigators to 1) determine the spatial and temporal distribution of vertical motions resulting from convergence and divergence within a basin and their effect on mixing of near-surface emissions during stably stratified conditions and 2) determine how multi-scale flows interact to either enhance or suppress the mixing of pollutants within a basin. An integrated measurements, analysis, and numerical modeling approach will be used to describe the characteristics of the convergence and divergence fields and the meteorological processes by which near-surface emissions along the basin floor are transported upwards and downwards within the basin atmosphere during stable conditions. Analyses will performed using measurements obtained from radar wind profilers, sodars, airsondes, backscatter lidar, and perfluorocarbon tracers during a field campaign that will probably take place in the in the Salt Lake City basin in the fall of 2000. A series of modeling studies, with and without four-dimensional data assimilation, will be performed using a coupled mesoscale meteorological and Lagrangian particle dispersion model to elucidate the interactions of synoptic, mesoscale, microscale, and boundary layer processes responsible for the vertical advection and diffusion of pollutants. We will also be looking at ways to improve simulation of the dynamics and thermodynamics of thermally-driven circulations, such as diurnal slope flows and valley wind systems, that affect the mean and turbulent vertical motions within basins or valleys. This will be accomplished by 1) evaluating the representation of topography in mesoscale models and its effect on simulations of vertical exchange processes, and 2) evaluating existing subgrid-scale turbulence parameterizations and developing improved treatments.

Jeffrey S. Gaffney
Atmospheric chemistry of organic air pollutants is studied in our laboratory. Particular focus is on the chemistry of organic oxidants, particularly peroxyacyl nitrates and associated organic peracids and nitrates. We are using Fourier transform infrared spectroscopy to characterize these compounds and their chemical reactions along with electron capture detection gas chromatography. We are also working on the development of rapid and selective detection systems for peroxyacyl nitrates (PANs) and nitrogen dioxide by coupling fast gas chromatography to luminol chemiluminescent detection. This approach is being used in field studies on the ground and in the air using the G-1 aircraft. The project also is examining the chemistry of carbonaceous aerosols with respect to their interactions with PANs, NO2 and ozone. We are also exploring the determination of aerosol atmospheric lifetimes by collecting size fractionated aerosols and examining the 210Pb and associated 210Po and 210Bi daughters disequilibria. Field efforts in the past have included work in Mexico City, Albuquerque, NM, Pasco, WA, and Portland, OR. Future field work is being planned for Nashville, TN, Philadelphia, PA, and Houston, TX for both G-1 and ground based measurements of PANs, nitrogen dioxide, ozone, uv-b, and temperature, and aerosols. This project is funded by the DOE's Atmospheric Chemistry Program (ACP).

Dr. Henry L. Gholz
Gholz is co-PI (along with Dr. Kenneth L. Clark) of the DOE/NIGEC Florida AmeriFlux CO2 and H2O tower flux measurement site. We currently maintain two tower flux sites. One is a recent clearcut, replanted on 1/24/99, which had previously been monitored for 2 years (as reported in an Ecological Applications article by Clark, Gholz et al., currently in press 1999) when covered by a mature, rotation-aged (24/25-yrs-old) slash pine (Pinus elliottii) plantation. The second is a 10-yr-old, mid-rotation slash pine plantation. Thus, we have a chronosequence of pine plantations for which we have flux data that we are using to examine both environmental as well as management controls over net ecosystem fluxes of carbon dioxide, water vapor and energy. We have previously also made measurements in a mature, natural pond cypress (Taxodium ascendens) wetland ecosystem, and are interested in maintaining some research in the swamp as well. We are collaborating with Dr. Monique Leclerc (Univ. of Georgia) on a second DOE/NIGEC project that is examining within canopy sources and sinks, as well as canopy turbulent characteristics, and estimation of the "footprint" of the tower flux measurements. We are also collaborating with Dr. Mark Castro (Univ. of Maryland) on soil trace gas fluxes, especially of methane and CO2 (but also N2O). Currently three graduate students are involved in this research.

Allen H. Goldstein, Assistant Professor
Our research seeks to link understanding of atmospheric chemistry with ecology, plant physiology, pedology, and atmospheric transport. Much of our field work is currently done at the Blodgett Forest Research Station in the Sierra Nevada Mountains of California where we established an Ameriflux site for studying the processes controlling biosphere-atmosphere exchange of trace gases (CO2, H2O, O3, VOCs, etc.) and energy. A unifying theme is to understand the balance between the natural and anthropogenic sources of trace gases, and to elucidate the biogeochemical and anthropogenically induced processes that control the sources and sinks. Major comprehensive research questions include; What controls the atmospheric concentrations of greenhouse gases and photochemical oxidants? What controls the oxidation capacity of the troposphere?

Research within our group addresses several current environmental issues: air quality, impacts of air pollution on ecosystems, greenhouse gases, and stratospheric ozone depletion. 1) Production of tropospheric ozone is sensitive to anthropogenic emissions of hydrocarbons and oxides of nitrogen, as well as to biogenic hydrocarbon emissions. Uncertainties in these emissions make it difficult to assess strategies for control of air pollution. Our work reduces these uncertainties by quantifying biogenic hydrocarbon emissions and studying their impact on regional photochemistry. 2) Tropospheric ozone is a pollutant that is responsible for forest damage worldwide. It is a potent oxidant that invades foliage through stomatal pores and impairs normal physiological function. Our work seeks to understand the processes regulating ozone deposition to sensitive ecosystems and to examine the relationship between ozone deposition and ecosystem stress. 3) Greenhouse gases such as carbon dioxide have a complex array of sources and sinks. Our work elucidates the factors controlling biogeochemical cycling of greenhouse gases through natural and managed ecosystems. 4) Stratospheric ozone loss is exacerbated by methylbromide, a fumigant that is currently the focus of national and international environmental legislation. Our work seeks to quantify the fraction of atmospheric methylbromide originating from industrial sources. Our research often seeks answers to scientific questions that will guide policy initiatives directed at mitigation of anthropogenic impacts on our environment.

Thomas W. Kirchstetter

The impact of air pollution on climate remains uncertain in large part because the role of aerosol particles is unclear. Aerosols may directly impact climate by scattering and absorbing solar radiation. Carbonaceous aerosols, including organic carbon (OC) and black carbon (BC), comprise a significant fraction of aerosol mass. BC is the principal light-absorbing aerosol species, while BC and OC scatter light. Our research focus is to improve measurements of mass concentrations and knowledge of optical properties of carbonaceous aerosols to reduce the uncertainty in aerosol direct radiative forcing estimates. Research efforts involve hands-on experimentation and development of analysis methods. Examples include a) sampling experiments and understanding OC measurement artifacts, b) using optical transmission to measure the wavelength dependence of the light absorbing properties of aerosols, c) development of a thermal-optical analysis method to characterize aerosol sample composition and light absorbing properties, and d) laboratory experiments to generate aerosol mixtures containing BC for analysis using advanced aerosol instrumentation.

Steve Lindberg

THE ROLE OF MERCURY AIR/SURFACE EXCHANGE PROCESSES IN THE GLOBAL BIOGEOCHEMICAL CYCLE

S. E. Lindberg, P. J. Hanson, W. Stratton, T. Meyers, K. Kim, A. Carpi, H. Zhang, J. Owens, A. Vette, M. Gustin, R.Turner, J. Munthe, F. Schaedlich, J Price, M. Barnett, R Ebinghaus, S Schmolke, W.Schroeder, and D. Wallschl□ge

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Atmospheric sources are significant in the cycling of Hg in the biosphere, but there have been few reliable data on air/surface exchange of Hg in terrestrial or aquatic systems until recently. Since the first Global Hg Conference in Gavle, Sweden, there have been significant developments in the areas of automated field analysis, flux chamber enclosure, and tower-based micrometeorological gradient methods for measuring gas-phase Hg fluxes over waters, soils, and vegetation. Numerous groups have now applied these methods in flux campaigns around the world, and the data base on Hg fluxes has increased significantly. An important milestone was reached in 1997 when scientists from several countries collaborated in an EPRI-sponsored field intercomparison of Hg flux measurements using seven field flux chamber designs and four micrometeorological approaches at the Steamboat Springs Geothermal Area, Reno, Nevada. This study led to important improvements in flux measurement methods. Another major recent advance was the development of methodologies for determining the speciation of atmospheric Hg. The discovery of measurable levels of water-soluble Hg compounds (reactive gaseous mercury, RGM) in both flue gas, and, more recently, ambient air has significant implications for modeling the fate of airborne Hg. All these advances and their recent application have provided important clues to the behavior of Hg in the global bigeochemical cycle.

There is no longer any doubt that Hg, once deposited, has the capability to be re-emitted from environmental surfaces, and that re-emission is significantly enhanced by green plants via a transpiration-like process. There is also no doubt that Hg associated with geological sources demonstrates a similar capacity. What is in doubt is the relative role of these so-called natural emissions in the global cycle, and to what extent Anatural@ emissions include re-emitted Hg. On the other end of the Hg Abehavior scaleA, recently measured levels of RGM compounds support the hypothesis that the dry and wet deposition of Hg may be strongly influenced by the behavior of RGM and that elevated regional exposure may be possible near major point sources of RGM compounds. This appears to be true even though RGM may represent only a few percent of total mercury in air. Source measurements have indicated that RGM is formed in combustion processes, and the recent discovery of so-called Hg-depletion events in the Arctic suggests that there may be atmospheric reaction pathways for the production of RGM from Hg_. These are exciting times for Hg!

This talk will attempt to summarize the state of our understanding of these processes and how they influence the global Hg cycle, based on studies largely completed since the 1990 Mercury Conference. Research sponsored by EPRI, Florida DEP, US EPA, SFWMD, NOAA, Lake Superior Trust, and the U.S. Department of Energy under contract with ORNL. ORNL is managed by Lockheed-Martin Energy Research, Inc., for the U.S. Department of Energy.

Yin-Nan Lee, Ph. D.
We focus our research on identifying the role of multi-phase atmospheric chemistry in the transformation, transport, and removal of key atmospheric trace species. Multi-phase atmospheric chemistry embodies chemical interactions between the gas phase and a condensed phase such as aerosols and hydrometeors in the atmosphere. The objectives are: (1) to determine the aqueous chemical and physical properties of important atmospheric constituents; (2) to develop measurement techniques for soluble reaction intermediates and products; (3) to characterize the atmospheric distributions of these species in the gas phase and in aerosol particles; and (4) to examine the agreement between model predictions and field measured data. This research is expected to allow an improved understanding to be gained for the following processes: transformation of sulfur and nitrogen compounds, production of radicals and radical precursors, degradation of hydrocarbons, life cycles and composition of aerosol particles, and the scavenging and removal of these species.

Judith Weinstein-Lloyd
Abstract: Our research involves determining the abundance of reactive species in the atmosphere, with the goal of understanding photochemical air pollution and devising remediation strategies. Much of our work involves hydrogen peroxide and organic peroxides, formed from the self-reaction of peroxyl radicals (HO2 and RO2). These unstable intermediates are produced from a series of reactions involving sunlight, ozone (O3), water vapor, and volatile hydrocarbons (VOCs). Once formed, peroxyl radicals may react with nitric oxide (NO) from combustion sources to produce nitrogen dioxide (NO2). If there is insufficient NO, two peroxyl radicals combine to form peroxides. There is evidence that peroxides in fog and rain act as phytotoxins when absorbed by leaf cells. Peroxides in cloud water oxidize sulfur dioxide to sulfuric acid, the principal component of acid rain in the Northeast U.S. In addition, NO2 formed via the peroxyl radical reaction above may be photolyzed and the resulting O atom may combine with O2 to produce tropospheric ozone, an important ingredient in urban smog. In the course of this research, we conduct laboratory studies to design and validate new analytical methods for peroxides and related species, participate in the ground and aircraft based field studies where we deploy our instrumentation, and work with colleagues to fit our measurements into a picture that describes the chemistry and dynamics of air masses.

Sasha Madronich
Project: UV RADIATION IN THE POLLUTION SHIELD. Ultraviolet (UV) radiation is a primary driving force of atmospheric photochemistry. Together with hydrocarbons and nitrogen oxides, it controls air quality on a variety of geographical scales, ranging from urban photochemical smog, rural oxidant pollution episodes, and global lifetimes of gases (e.g., methane) that may alter the Earth's climate. In turn, pollutants can change the optical properties of the atmosphere, and therefore affect the amount of UV radiation available to drive the photochemistry. Such pollutants include aerosol particles (scattering and absorbing, e.g., sulfate or soot), and some gases and some gases (ozone, sulfur dioxide, nitrogen dioxide). This project focuses on better quantification of the coupling of the UV radiation field with the chemistry of air pollution, through the use of both modeling and measurements.

Nancy A. Marley
Chemiluminescent detection methods are underdevelopment for rapid measurement of peroxyacyl nitrates and nitrogen dioxide using fast gas chromatography with luminol detection. We are also in the process of developing a real-time instrument for measurement of non-methane hydrocarbons using temperature dependent ozone chemiluminescent reactions. This instrumentation is being adapted for both ground field measurements and aircraft measurements onboard the Atmospheric Chemistry Program's G-1 aircraft. Past studies have included Phoenix, AZ and Mexico City. Future studies are being planned for Nashville, TN and Philadelphia, PA in the summer of 1999, and Houston, TX in 2000. Also of interest in our laboratory is the optical characterization of aerosols. Samples are size fractionated using cascade impactors onto optical plates for characterization in the uv-visible, near infrared, and far infrared using integration spheres which can allow both scattering and absorption of the aerosols to be addressed. As well, we are making use of natural radioactivity to assess the atmospheric lifetimes using 210Pb daughters and 7Be, using ultra low level detection methods. Cylindrical internal reflectance spectroscopy and diffuse reflectance spectroscopic methods (FTIR) are used to characterize dissolved organic and inorganic aerosol species as well as aerosol surfaces in studies of aerosol heterogeneous chemistries. This effort is supported by DOE/OBER as part of the Atmospheric Chemistry Program (ACP).

Joyce E. Penner
Project: Modeling of Global Tropospheric Gas and Aerosol Chemistry, including the Effects of Trace Gases and Aerosols on Climate. Our DOE ACP project emphasizes the global distribution of volatile organic compounds and their possible effects on OH. We are initially studying the distribution of CO and CH4 and their interactions with OH. To do so, we are improving the sources of CO and aerosols from biomass burning acitivities.

Barbara J. Finlayson-Pitts
Sea salt particles are common not only over in remote areas over the oceans, but also in coastal areas. There is increasing evidence that the reactions of various gases with sea salt particles produce photochemically active halogen gases. Upon

photolysis, they form halogen atoms, which are highly reactive and drive the chemistry of the troposphere in much the same way that the OH radical does. They also react directly with ozone, an energy-related air pollutant and greenhouse gas. Studies in this laboratory are directed to elucidating the nature of these reactions with sea salt particles, and their kinetics and mechanisms. Techniques used include FTIR, MS, Knudsen cells, atmospheric pressure ionization mass spectrometry and differential optical absorption spectrometry, as well as a new aerosol chamber designed for these studies. Through collaborative efforts, the results these studies are used as inputs for atmospheric models and for designing field experiments.

Stephen E. Schwartz
For the past 20 years my colleagues and I been examining the chemistry of Atmospheric Energy-Related pollutants (AER pollutants). The principal substances of our attention have been sulfur and nitrogen oxides emitted into the troposphere as byproducts of fossil fuel combustion, and their oxidation products, i.e., sulfuric acid and nitric acid and the salts of these species. These substances are of concern from the perspective of human health, acid deposition, visibility reduction, and radiative forcing of climate. Because these materials are introduced into the atmosphere in association with energy-related activities, the environmental consequences of these emissions are of concern to the Department of Energy, and much of the support for my research comes from the Environmental Sciences Division within the Office of Biological and Environmental Research of the Department of Energy. Specific research projects include development of model based representation of aerosol evolution, especially by moment methods, and incorporation of these methods into chemical transport and transformation models. For more details see:
Research Topics

Jian Wang
Atmospheric aerosol affects the climate by scattering and absorbing sunlight (direct effect) and by changing the microphysical structure, lifetime, and amount of clouds (indirect effect). Our research is focused on study of the microphysical, optical, and chemical properties of atmospheric aerosol and understanding its effects on global climate through aircraft/ground based measurements. Our work includes (1) characterizing aerosol microphysical, optical, and chemical properties and studying aerosol ambient processes using research aircraft, (2) development of new instruments for accurate characterization of aerosol microphysical and optical properties, (3) study of aerosol hygroscopic properties and cloud nucleation properties through both field measurements and laboratory experiments.

Dr. C. David Whiteman
Project no. 1-Vertical Transport Mechanisms in Evolving Urban Basin Cold Pools

A four-year research project will identify and model the processes leading to formation, maintenance and destruction of cold air pools in urban basins. These pools, which occur frequently in the western US, have a strong influence on vertical transport and mixing of pollutants in basins. When the pool is present pollutants are trapped within the basin; when the pool is destroyed pollutants are released vertically from the basin.

The research investigates the three primary cold pool buildup and destruction mechanisms identified in our earlier research: (1) differential temperature advection associated with traveling weather systems, (2) turbulent erosion at the top of the cold pool, and (3) cold pool mass buildup and removal by slope flows on the basin periphery. A bulk thermodynamics approach guides the work, provides a mathematical basis for incorporating the mechanisms, and allows generalizations to other topographical situations. This model, with further development, will predict the timing of cold pool destruction and the rate of mass removal from the pool.

Two field studies will be conducted, one for diurnal cold pools and one for persistent multi-day wintertime cold pools. Both studies are designed with integrated meteorological and tracer study components. Analysis methods are stated and coupled mesoscale dynamics and Lagrangian particle dispersion models are used to interpret the observations, verify hypotheses, and provide further insight into physical mechanisms.

The research will lead to useful advances in knowledge of air pollution transport and diffusion in urban basins and valleys and in the ability to forecast cold pool buildup and breakup cycles.

Project no. 2 - Large-Scale Meteorological Influences on Urban Cold Pools in the Intermountain Basin

The VTMX experiments will be conducted under statically stable conditions in an urban basin in the Intermountain Basin (IB) between the Rocky and Sierra-Cascade Mountains, with the Salt Lake and Phoenix Basins being the two likely candidates. The IB is affected by flow and stability phenomena on scales larger than an individual urban basin. In the Salt Lake Basin (SLB), for example, these include flows from the Great Salt Lake north of the SLB, from the Utah Lake Basin to the south, from persistent temperature inversions that develop over the entire IB, and from blocked flow situations upwind of the Rocky Mountains.

We hypothesize that mechanisms responsible for vertical transport and mixing in the urban basins are frequently affected by circulations and temperature structures on scales that extend beyond the urban basin, and that the understanding of regional-scale effects is critical to the interpretation and understanding of mechanisms in the urban basin.

Climatological investigations and short-term case studies will be conducted for the VTMX field study periods to place the urban basin studies within their proper meteorological and climatological contexts to aid in the design and interpretation of the field studies. The investigations will proceed through analyses of local- and regional-scale phenomena from data networks in the IB (rawinsonde, Mesonet, radar profiler/RASS), from satellite data and from model-assimilated NCEP/NCAR 40-year Reanalysis data.

Terrestrial Carbon Studies and Ecosystem Research

Jeffrey S. Amthor
Current research is mechanistic modeling of tree and soil processes (physiology and physics) within the context of a forest ecosystem model of carbon, water, and energy exchange as well as tree growth. Some experimental field work on tree leaf physiology (photosynthesis and respiration) supplements the modeling. Modeling is carried out in conjuction with DOE/OBER field experiments at ORNL (i.e. the Throughfall Displacement Experiment, and the Free-Air CO2 Enrichment Experiment). Beginning work with new DOE/OBER Center for Enhancing Carbon Sequestration in Terrestrial Ecosystems.

James K. Bishop
Ocean Carbon Cycle Processes

Our research focus is on the role of biological processes in the vertical transport of carbon and related elements in the ocean and how they might change in response to human and climate induced changes to the ocean. The bottom line goal is to determine what these changes mean for levels of atmospheric CO2. Experimental approaches include satellite remote sensing and at-sea studies of carbon dynamics using a combination of ship-deployed in-situ sample collection systems and in-situ remote sensing using long lived robotic carbon observers. We develop new ways to observe ocean carbon and biological processes. Our analysis approach is fully interdisciplinary ranging from computers to micro beam anaysis methods. More detail is found at http://www-esd.lbl.gov/OBP

Barbara J. Bond
We are testing the hypothesis that hydraulic resistance increases as trees grow and age, and that this increased resistance results in lower rates of photosynthesis and transpiration (per unit leaf area) in older trees and reduced productivity in older stands. To test this hypothesis, we are conducting a "suite" of measurements using Douglas-fir at sites of three age classes at Wind River, a 20-year-old stand, a 40-year-old stand, and the old growth trees in the canopy crane circle. Measurements include whole-tree sap flow, leaf-level gas exchange, and foliar nitrogen and carbon isotope content. Subsequently, we will use a process model to estimate stand-level performance.

Dr. Peter S. Curtis
My research centers on plant responses to global change and the effect these responses will have at the individual, population, and ecosystem level. Global change phenomena of interest include rising atmospheric carbon dioxide, altered climatic drivers such as temperature and precipitation, increased tropospheric ozone, and changes in land use. At the University of Michigan Biological Station in northern lower Michigan (www.umich.edu/~umbs) we are measuring landscape level carbon, water, and energy exchange over a northern hardwood forest using micro-meteorological methods in order to relate changes in net ecosystem fluxes to patterns of climate variability and to ecological processes operating at the plant and soil level. This work combines biosphere-atmosphere interactions analyzed above the canopy with forest eco-physiological processes, such as photosynthesis, respiration, and water use, measured from the tree crown to the rooting zone. Collaborating institutions include the University of Michigan and Indiana University.

Eric A. Davidson
Link to more information about our NIGEC-funded research: http://www.whrc.org/science/neforest/neforest.htm

We are studying the interannual variation in CO_2 emissions from soils in New England forests. We have study sites at the Harvard Forest in central Massachusetts and the Howland Forest in central Maine. We routinely monitor soil respiration, soil temperature, soil water content, and profiles of CO_2 concentrations within the soil. We study how variation in precipitation from year to year affects the processes of root respiration and microbial decomposition of soil organic matter.

Kenneth J. Davis
My work focuses on the relevance of the atmospheric boundary layer to climate, atmospheric chemistry, biogeochemical cycles and the hydrologic cycle. The development of novel methods of flux measurements was an early emphasis of my work. I am active in aircraft, balloon, tall-tower, LIDAR (light detection and ranging) and radar observations of trace gas transport and atmospheric structure. I also work closely with colleagues whose expertise is large-eddy simulation. My current research emphases are remote sensing of atmospheric mixing, mesoscale variability, and the water-vapor budget, long-term monitoring of forest-atmosphere carbon dioxide exchange and analyses of plant-soil-atmosphere interactions, boundary-layer entrainment processes, and the impact of boundary-layer processes on biogenic hydrocarbon mixing and chemistry.

Evan H. DeLucia
Effects of Elevated Atmospheric CO_2 on the Carbon Budget of a Forest Ecosystem.

Terrestrial ecosystems, particularly forest ecosystems, are important in regulating atmospheric CO_2 through the balanced effects of photosynthesis and respiration. Many experiments indicate that increased CO_2 will stimulate plant growth and suggest that this increase in growth will sequester CO_2 thereby slowing its rate of increase. While some studies show an enduring growth stimulation by elevated CO_2, others indicate that the growth enhancement decreases with time, and under nutrient-limited conditions typical of most forests there may be no growth stimulation. A central question in "climate change" research remains whether the initial photosynthetic and growth enhancement observed for tree seedlings and saplings with a doubling of CO_2 will be sustained for large trees, and hence forested ecosystems, experiencing the full suite of forest ecosystem processes. The objective of our proposed research is to determine if a time-dependent decline in the CO_2-stimulation of growth occurs in an intact forest ecosystem.

We have identified three broad mechanisms operating at the tree level that are homeostatic in that they may serve to maintain a proper balance of tissue carbohydrate and nutrient status but at a potentially lower growth rate. The mechanisms are: 1) down-regulation of photosynthesis resulting from source/sink constraints; 2) increased allocation to support structure and roots with concomitant increases in maintenance respiration; and 3) plant nutrient imbalance as growth exceeds the delivery of limiting nutrients. We are studying these processes by estimating a) changes in leaf-level photosynthetic capacity and photosynthetic enzymes, b) changes in the allocation of biomass to above- and below-ground structures c) alterations in respiration rates, d) changes in foliage dynamics and nutrient levels, and e) carbon budgets of individuals and loblolly pine stands. These mechanisms are interdependent and represent homeostatic adjustment of trees to altered resource states that directly influence carbon cycling and storage in a forest ecosystem.

We recently completed the first full growing season of the FACE study under the treatment conditions. During the first year we observed a significant growth stimulation for pine trees and little evidence of down-regulation of photosynthesis. A single year of CO_2 treatment may not be a sufficient time period to draw firm conclusions about the homeostatic mechanisms outlined in this proposal. We are requesting three additional years of funding to document long-term changes in the growth stimulation as well as the timing and magnitude of "down regulation" of loblolly pine under CO_2 enrichment. We expect that the responses of this forest to elevated CO_2 will become transient as reallocation of biomass and nitrogen in trees is initiated, as the full complement of foliage is developed under the CO_2 treatment, and as ecosystem feedbacks associated with altered litter chemistry begin to express their influence on nutrient cycling in this system. The mechanistic examination of these processes over the course of this study will enhance our understanding of potential ecosystem interactions and feedbacks and strengthen our ability to predict long-term responses of forests to global change.

Nelson T. Edwards
I measure stem and branch respiration in the major hardwood species in the Throughfall Displacement Experiment (TDE) located on Walker Branch Watershed. This experiment is designed to divert natural rainfall in a way that creates plots with ambient, 33% above ambient, and 33% below ambient rainfall. The respiration responses to moisture levels are documented and related to both treatment responses and year to year variations in natural rainfall. I also measure sweetgum stem and branch respiration responses to elevated atmospheric CO_2 at the new FACE site at ORNL's Global Change Research Facility. In both these experiments respiration responses are used as indicators of growth and maintenance of the woody tissue. Also, in both experiments the data feed into stand level carbon models. An experiment will be initiated this summer to examine the effects of elevated CO_2 at the FACE site on sweetgum root decomposition rates as indicated by respiration rates of dead roots.

Jim Ehleringer
Sensitivity to Change in Arid Land Ecosystems (SCALE)
Arid land ecosystems are among the most sensitive to change, whether this change is associated with anthropogenic land-use activities or shifting climatic conditions. These ecosystems experience high interannual variability in precipitation, with El Ni–o and La Ni–a events representing two extremes of a moisture-input scale. Most ecosystem processes in arid lands are constrained to brief moisture pulses. Because of the constraints water has on arid land ecosystem processes, changes in water availability are likely to play a much more prominent role in the functioning of arid land ecosystems in the near future than are other global change factors. Our SCALE project is directed at understanding how both short-term precipitation pulses and longer-term interseasonal and interannual precipitation variability affect ecosystem structure and function. We will examine changes in ecosystem function with respect to carbon, water, nitrogen, and trace gas fluxes. The core idea of our research is that climate change acts on arid land ecosystems through changes in the magnitudes and distributions of moisture pulses. We have established that there are functional- group differences in soil moisture use, implying possible long-term instability in current species composition with a shift in precipitation input patterns. Through a series of field experiments, field manipulations, and modeling we are examining the impacts of climate change on arid land ecosystems on the Colorado Plateau.

Vincent P. Gutschick
We study how plants exert physiological control over fluxes (water vapor, CO2, heat) that are important in the climate system, via stomatal control and acclimation of photosynthetic capacity. Our study sites cover a variety of ecosystems - temperate forest in Wisconsin, riverine forest in New Mexico, deserts in New Mexico and Nevada, crops in New Mexico. We start from mathematical / computer models of plant performance to develop hypotheses and then test them in the field. This involves measuring leaf gas exchange, light interception by leaves, sapflow in branches (reached with 10-to-25-meter boomlifts in the forests) and whole tree trunks, etc. The sites include the WLEF tall tower (474 meters) in Wisconsin and the Nevada Desert FACE site with CO2 enrichment. We build a lot of our own electronics, so we have need of people in a wide variety of disciplines, from computing (data analysis, programming, image analysis) through electronics to plant physiology and ecology.

Julian L. Hadley
I am a research associate at Harvard University, working at the Harvard Forest. My research into the carbon balance of an old-growth hemlock forest is sponsored by NIGEC's Northeast Regional Office. I am measuring all major carbon fluxes in the forest and continuously monitoring solar radiation, wind, humidity, air temperature and soil temperature in order to develop an ecosystem-level carbon exchange model. The model is driven by climatic variables and it will estimate hemlock forest carbon exchange in present and potential future climates. The model output will also estimate the possible influence of hemlock stands on carbon exchange estimates from NIGEC-sponsored research at the Harvard Forest by Wofsy et al. These estimates have been published in Science and received wide attention. Output from the hemlock forest model will also be able to estimate the effect on regional carbon balance of expected large-scale hemlock mortality due to the hemlock woolly adelgid. In my research, students will get experience in measuring all types of carbon fluxes in a forest ecosystem, and also gain experience in developing a carbon exchange model. I look forward to participation by either undergraduate or graduate students.

Tom Hinckely
Summary: Many previous attempts to "scale up" physiological measurements, such as transpiration or photosynthesis, to an entire forest stand have been based upon measurements at the individual leaf level which have been extrapolated to an entire canopy. Sampling and extrapolation errors burden this technique, as well as the fact that certain microclimatological conditions that are key to leaf physiological function are negligible at the canopy level. Remote sensing technology could provide an opportunity to circumvent these scaling problems by yielding direct estimates of canopy-level gas exchange, as well as yield indicators of foliar productivity and stand structure. This study will evaluate the relationship between ground-based stand-level measurements of transpiration, net photosynthesis, canopy structure and foliar chemistry with remotely sensed data. This will be done by examining two forest types in Washington state: a Populus hybrid plantation on the east side of the Cascade Mountains, and an old-growth Pseudotsuga menziesii forest (the "Canopy Crane Site") growing on the west side of the Cascades.

George R. Hendrey
As manager of the FACE project at BNL and National Coordinator for DOE's FACE Program, I am interested in students to work in a range of fields from plant physiology to computer networking and wireless communications.
BNL developed Free-Air CO2 Enrichment (FACE) technology and coordinates the national FACE program for the Department of Energy. FACE experiments not only deal with CO2 enrichment, but also with the interaction of CO2 and plant nutrients, water, and stresss agents like ozone. There are now nine BNL-designed FACE field facilities in a range of ecosystems including two agricultural sites in Europe, a tropical forest in Panama, the Mojave Desert, pine forest, deciduous forests, prarie, and agricultural systems in the USA. BNL operates the Forest-Atmosphere Carbon Transfer and Storage

experiment at Duke university. BNL scientists are P.I.s or co-P.I.s in most of these studies. We would like to have students interested in a range of topics from the molecular controls on photosynthesis and other topics in plant physiology, to engineering topics such as wireless computer networking. Additional information on FACE can be obtained at our web site http://www.face.bnl.gov/face1.htm .

Robert B. Jackson
The goals of our field research are to test the role of grassland ecosystems as future carbon sinks, and whether they may in fact already be acting as carbon sinks. The field experiment in a C3-C4 grassland near Temple, Texas provides atmospheric CO2 in a continuous gradient from 200 to 550 ppm (concentrations found before the industrial revolution to those likely reached next century). The research also examines the interaction between CO2 and other resources, particularly water, that limit production in many terrestrial systems. Field measurements include plant productivity, gas exchange, microbial assays, soil carbon and nutrients, and soil water availability. Experimental results are combined with modeling to examine the interaction of CO2 and water availability and with efforts to improve global estimates of carbon biomass and productivity in terrestrial ecosystems. Much of this work is in collaboration with Wayne Polley and Hyrum Johnson of the ARS and other researchers.

Julie Jastrow
Our research seeks to better understand and quantify the processes involved in soil carbon storage and turnover, which is essential for determining the carbon sequestration potential of terrestrial ecosystems. Soil carbon may be stabilized because of its biochemical recalcitrance, but soil structure plays a dominant role in controlling microbial turnover processes. Relatively labile material may become physically protected from decomposition by incorporation into soil aggregates. Thus, an understanding of the processes involved in the formation, stabilization, and degradation of aggregates may provide the theoretical basis for isolating measurable carbon pools with functionally meaningful relationships to soil carbon dynamics. We are using physical and biological fractionation techniques to (1) identify and quantify measurable carbon pools that may better parameterize the conceptually defined pools used by models to simulate soil organic matter dynamics and (2) determine whether the size, lability, and dynamics of these measurable carbon pools are modified under elevated atmospheric concentrations of CO2. Many of the soils being investigated are obtained from experimental atmospheric CO2 enrichment facilities at Kansas State University, Oak Ridge National Laboratory, the Desert Research Institute of the University of Nevada at Reno, and other sites.

Jeffrey M. Klopatek
This research will explore and document the differences in belowground C storage and release over a chronosequence of paired sites of Douglas-fir stands with and without the presence of red alder. Paired site comparisons will be made of a 20, a 40 and a 70 year old and compared with the old growth Douglas-fir and western hemlock (Tsuga heterophylla) stand at the Wind River Canopy Crane Research Facility (WRCCRF) site. Emphasis will be placed on the intrasystem storage and release of C: litterfall, decomposition, root production and soil CO2 efflux. Above- and belowground pool sizes of both C and N will be determined for all the stands. Annual and seasonal changes in soil CO2 efflux will be determined with measurements throughout the year with emphasis on the growing season. The attainment of these objectives will provide answers to how the ecosystem processes vary between different stand compositions with different age classes and size structures over different seasons. Data will be made available to determine belowground C allocation and will be used in the eddy flux models being developed for the sites.

Nate McDowell
Forest fire has been largely excluded from Western North America'9s forests over the last century, resulting in forests that are greatly overstocked and therefore under-productive and prone to catastrophic fire and insect attacks. Cases of catastrophic fire, insect attacks (particularly by spruce beetle and bark beetle), and low primary productivity are now commonplace. Furthermore, the devastating effects of drought on forest growth and survival are exacerbated by the overstocked nature of current forests. However, efforts are now being made to mitigate the effects of fire exclusion through stand density reductions and introduction of prescribed fire. The focus of my research is on the physiological and ecosystem scale results of fire exclusion and mitigation treatments, including manual stand density reductions and the reintroduction of fire. I am applying standard gas exchange and forest inventory techniques in conjunction with measurements of stable isotopes of carbon and oxygen in tree-rings, foliage, soil organic matter and atmospheric CO2 to improve our understanding of how fire (and lack thereof), thinning, and bark beetle attack affects photosynthesis, water use, productivity and carbon sequestration. Field sites include ponderosa and lodgepole pine forests in Oregon, ponderosa pine, mixed conifer, and pinyon-juniper forests in New Mexico, and other locations to be determined. The results of this research are of use both to the theoretical understanding of physiological behavior of forests in relation to disturbances, as well as to managers who need to know what to expect from forests in response to different management options.

R. Michael Miller
The ability of plants to adapt or respond to a changing environment is dependent on homeostatic capacities that minimize the

cost of growth and biomass allocation. Plants' responses to environmental stresses, such as nutrient limitation, suggest that they have a centralized system of stress response involving changes in nutrient and water use, carbon allocation, hormonal balances, and reliance on mycorrhizae. Our research addresses mechanisms controlling plants with obligate and facultative dependency on the mycorrhizal symbiosis and the relative importance of these mechanisms in C3 and C4 grasses. Our overall objective is to determine whether a major mechanism of control is the balance between photosynthate supply to the roots and the host's need for nutrients. To address this objective, two general questions will be investigated: (1) What are the mechanisms controlling photosynthate allocation to the fungus and nutrient inflow to the plant? (2) Will the host's dependence on supplied nutrients influence its ability to adjust to a changing environment? This project is part of the DOE-OHER Program for Ecosystem Research, which is conducted within the DOE Global Change Program.

Patrick J. Mulholland
Research includes studies of carbon and nitrogen biogeochemistry and land/water interactions in forested catchments, nutrient cycling and metabolism in streams, watershed hydrology, and climate change effects on aquatic ecosystems and biogeochemical cycles. He conducts long-term studies at Walker Branch Watershed on the Oak Ridge National Environmental Research Park (http://walkerbranch.ornl.gov) investigating how climate variation and change effects forest growth, catchment hydrology and biogeochemical cycles, and stream ecology. He also conducts research at Fort Benning, Georgia on disturbance impacts on catchment biogeochemistry and stream metabolism and the effects of riparian and stream restoration approaches. He is coordinator for the Lotic Intersite Nitrogen eXperiment (LINX), an investigation of nitrogen uptake and retention in streams using 15N addition experiments in 72 streams in different land use types across the U.S.

Richard Norby
The responses of a closed-canopy deciduous forest stand to elevated concentrations of atmospheric carbon dioxide are being studied in a sweetgum plantation on the Oak Ridge National Environmental Research Park. A free-air CO2 enrichment (FACE) facility was constructed in the plantation and its operation began in April, 1998. Air enriched with carbon dioxide is released into two 25-meter diameter plots, and the concentration is controlled to maintain 560 ppm in the forest canopy. Tree growth and canopy production, foliar gas exchange rates, tree respiration and water use, root production, soil respiration, and nitrogen dynamics are being measured to address specific hypotheses relevant to the responses of a closed-canopy forest stand that has fully occupied the site. The facility provides a unique platform for scientists from other laboratories and universities to explore the effects of elevated CO2 in a deciduous forest.

Walter C. Oechel
Research on the impacts of global change on arctic and Mediterranean-type ecosystems. Research is being conducted at Barrow, Atqasuk, and Seward Peninsula Alaska and the SDSU Sky Oaks Biological Field Station in San Diego County. Impacts of elevated atmospheric CO2 using FACE (Free Air CO2 Enrichment) and null balance greenhouses (CO2LT) on productivity, water use, fire frequency and intensity, competition, and composition are being investigated using a range of techniques from biochemical to landscape and airborne. Impacts of intra- and inter-annual variability in climate on ecosystem carbon stocks and carbon fluxes are being measured, and the use of native ecosystems to sequester carbon, and offset CO2 emissions from anthropogenic sources evaluated. Studies of landscape processes including ecosystem structure and function using chamber, eddy correlation tower, and aircraft based measurements and modeling. Many state of the art techniques are employed. More information can be found at http://www.sci.sdsu.edu/GCRG/

Wilfred "Mac" Post
His recent work involves modeling and synthesis of experimental results related to terrestrial ecosystem response to global change and the role of terrestrial ecosystems in the global carbon cycle. Improved quantification of terrestrial exchange of CO2 with the atmosphere will result from (1) improved understanding of the carbon dynamics of terrestrial ecosystems as a function of primary environmental factors including atmospheric CO2, temperature, available water, nutrients, solar radiation, and plant/biological potential, and (2) an ability to represent these dynamics in computer simulation models at sufficient spatial and temporal resolution to capture the main features of uptake, storage, and release of CO2 at regional and global scale.

G. Philip Robertson
Research in my lab is centered around understanding fluxes of greenhouse gases from cropped and unmanaged ecosystems in agricultural landscapes typical of the upper Midwest. We are particularly interested in the gases nitrous oxide and methane, and investigate both patterns and ecological controls on these gases at scales ranging from the microbial to the watershed. Research is conducted at the Kellogg Biological Station (http://kbs.msu.edu), which hosts 15-20 undergraduate research interns per summer and also offers ecology field courses. The Station is also home of the KBS LTER site (http://lter.kbs.msu.edu).

Leonel da S. L. Sternberg
Research in my lab focuses on scaling plant ecophysiological processes to a regional scale. Stable isotope analysis of

ecosystem components is a principal tool used by my laboratory. Particular areas of interest are: (1) Carbon recycling of vegetation stands and its impact in determining gross photosynthesis and respiration with isotopic mass balance equations. Recycling here is defined as the proportion of respired CO_2 that is re-fixed by the vegetation. If substantial, as in tropical forests, this can have an impact on the net carbon isotope flux of the ecosystem. (2) The impact of forest and savanna trees water relations on the water, carbon and nutrient cycles. As an example; we have studied the contribution of transpiration to the ambient tropical forest vapor and found it to be large (70 to 90% of the total evapo-transpired vapor). In the Amazon basin this can have a significant impact on precipitation. (3) Sea level rise impact in coastal ecosystems. We use the fact that freshwater and ocean water have different isotopic signal to determine the level of fresh or ocean water usage by coastal species. Dynamics of mangrove and fresh water hammock trees are also being studied.

Susan Trumbore
Controls on soil carbon turnover in forests along a latitudinal transect
The objectives of the research are to study the spatial and temporal variation in soil respiration for temperate forests distributed along a latitudinal gradient. At each of three major sites in Maine, Massachusetts, and Tennessee, we are evaluating temperature and soil water functions as predictors of soil respiration. In addition, we are using measurements of radiocarbon in soil respiration, soil CO_2, fractionated soil organic matter and soil microbial biomass to determine how soil respiration is partitioned among plant metabolic and heterotrophic decomposition sources. By comparing these detailed studies of soil respiration across the larger latitudinal gradient, we intend to identify common controls of soil respiration scalable across sites. Isotope measurements of radiocarbon in soil organic matter and soil respiration are made at the Lawrence Livermore Center for Accelerator Mass Spectrometry.

Tristram O. West
My research falls within the goals of the DOE Consortium on Enhancing Carbon Sequestration in Terrestrial Ecosystems (CSITE). Research includes analyses of the impact of carbon sequestration options on net changes in greenhouse gas emissions, using methods of full carbon accounting. We are interested in obtaining a better understanding and quantification of the effects of terrestrial ecosystem management on regional and global carbon dynamics. In addition to human-induced changes, we seek to better understand relationships between existing environmental variables and terrestrial carbon stocks.

Stan D. Wullschleger
Mechanisms that control carbon allocation to plant roots have been the subject of considerable investigation and have historically been discussed in terms of sink strength, sink activity, and source/sink relationships. Although much of this work has helped characterize the overwhelming complexity of carbon allocation at the level of whole plants, there are still unresolved questions as to the processes that regulate root initiation and subsequent elongation, and how these traits influence the architectural arrangement of roots at the scale of whole plants. Our works uses a range of physiological, biochemical, and molecular tools to investigate the fundamental controls on root growth in trees (Populus spp.). Insights gained from this work will contribute to an improved mechanistic understanding of root growth, thereby increasing our potential ability to enhance root production for carbon sequestration, phytoremediation, and management of water and nutrient limitations in managed plantations.