Oak Ridge National Laboratory (ORNL)
Climate Change Program Plan Overview

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Scientific Focus Areas (SFAs) Addressed in this Plan include:

Climate Change Forcing
Climate Change Response
Climate Change Mitigation

Introduction

Due to human activities of fossil fuel burning and land use change, the Earth's environment is changing on all scales, from local to global. Global change predictions made by the present generation of coupled climate-carbon cycle models are hampered by uncertainty surrounding fundamental climate-ecosystem feedbacks and by climate change impacts on ecosystem structure and function. Current understanding of these feedbacks and impacts is not adequately represented in today's state-of-the-science analyses of Earth system dynamics[1]. The ORNL Climate Change Program's (CCP) approach to Earth system analysis combines the development and improvement of terrestrial land surface models with the deployment of new measurements and experiments. This is done in coordination with complementary ORNL efforts in global climate and coupled climate-carbon model development and simulation. Improved understanding of terrestrial land surface responses and feedbacks to climate and atmospheric change will be integrated in global-scale Earth system models for future climate change research and applications. The CCP paradigm is to identify and target critical uncertainties in coupled climate and terrestrial ecosystem processes and feedbacks, prioritized by their influence over global change predictions on decadal and century timescales. New measurements and experiments are then employed to obtain new knowledge required to reduce these uncertainties, identifying and filling gaps in the representation and parameterization of fundamental processes within existing Earth system models. Major uncertainties and critical knowledge gaps under current consideration are outlined in the science plans attached to this document.

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[1] The "Earth system" is the unified set of physical, chemical, biological, and social components, processes and interactions determining the state and dynamics of planet Earth.

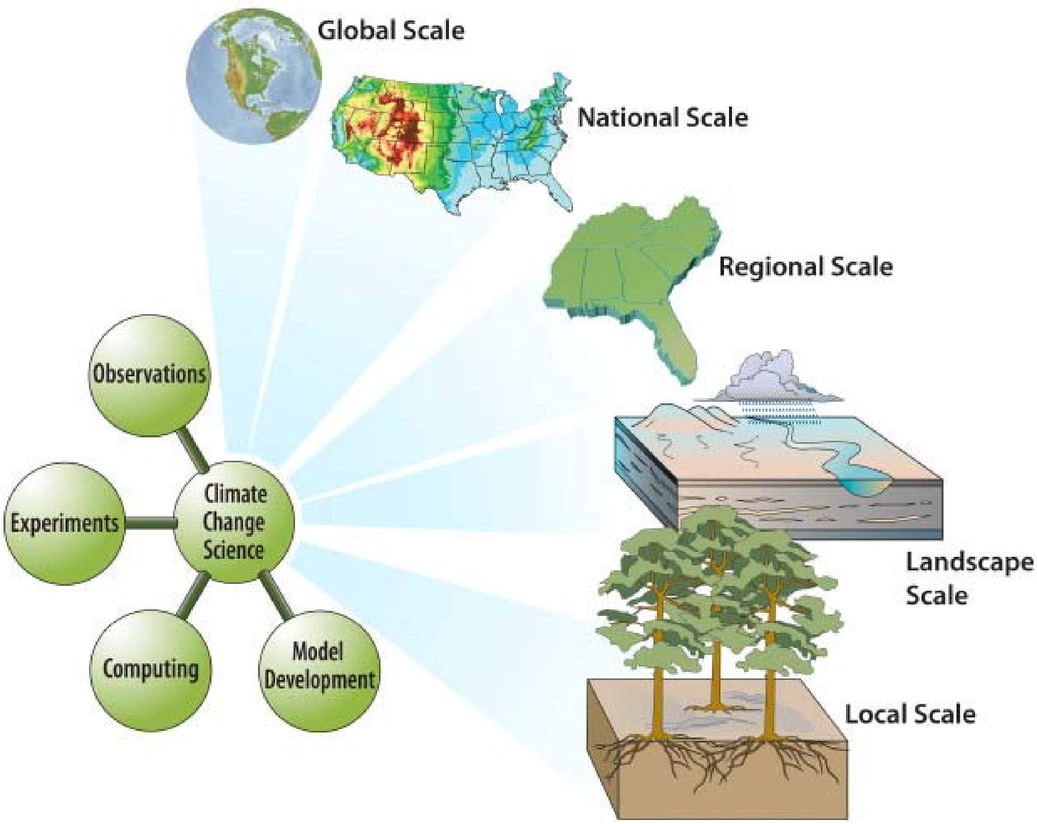

Figure 1. Conceptual philosophy of the ORNL Climate Change Program combining observations, experiments, modeling and computational capabilities to address climate change issue across scales.

The CCP will develop a capability for quantitative projection of future atmospheric greenhouse gas concentrations that incorporates complex feedbacks and responses among terrestrial ecosystems, human activities, and Earth's climate system. Spatial and temporal analyses of terrestrial ecosystem responses will provide robust and fundamental scientific results, syntheses and analyses to advance fundamental understanding. The breadth and complexity of this undertaking requires the scientific and technical expertise of more than 50 scientists across the DOE complex, and is focused on delivering timely answers to questions of national importance. Quantitative, transparent and accessible science products produced by the CCP can be used by decision-makers and stakeholders to evaluate and address climate change consequences, mitigation actions, and the needs for future societal adaptation.

The CCP team's unique strengths in measurement, experimentation, and modeling will be synergistically combined to answer some of the most pressing global change science questions, while ORNL's powerful computation and informatics capabilities are available in support of this vision of Earth system analysis. The broad scope of knowledge and expertise required to address the Earth system analysis problem dictates that the CCP science team tackle the research problems most suited to the team's current strengths and potential for development, while establishing complementary collaborations with other agencies and universities that together address the full Earth system scope. The CCP will focus on interactions among the climate system, terrestrial ecosystem dynamics, biogeochemical dynamics, land use change, and terrestrial biological greenhouse gas mitigation strategies.

The following overarching science questions, proposed scientific focus areas, and the subsequent description of key goals and milestones target significant uncertainties in climate change prediction and the resulting hypotheses for terrestrial ecosystems.

Overarching Questions and Relevant Science for the CCP

How will interactions among the physical climate, biogeochemical cycles, ecological processes, fossil fuel emissions and land use evolve and influence one another over decades and centuries to come?

1. What terrestrial ecosystem processes, interactions and feedbacks control the level and rate of change of atmospheric CO_2 and other greenhouse gases? (Forcing SFA)
2. How will the magnitude and rate of atmospheric and climatic change alter the structure and function of terrestrial ecosystems and their capacity to provide goods and services to society? (Response SFA)
3. To what extent does using land for greenhouse gas mitigation affect soil C storage, the surface energy balance, and the net flux of greenhouse gases and what impact would such land-use changes have on climate? (Mitigation SFA)

To answer these critical and interrelated questions, the CCP will use the active integration of measurement and experimentation, joined by simulation and advanced informatics, to synthesize new knowledge, guide new investigations, and improve prediction of Earth system dynamics. Top-level integration and synthesis activities are carried out by the CCP team as a whole while individual SFA teams integrate activities within their respective disciplines.

The following will be managed by the integrated CCP team:

- Identification and prioritization of critical uncertainties affecting the prediction of terrestrial land surface responses and feedbacks
- Design of new experiment and measurement projects to address uncertainties
- Model development and critical evaluation of the structure and function of terrestrial land surface and C cycle models
- Implementation of informatics and data systems to support the science
- Coordination with research partner institutions and engagement with stakeholders.

Goals and Milestones

The long-term CCP Science Plan will address the following five research goals and associated milestones for near-, mid-, and long-term deliverables where near-term implies activities to be addressed in the next three years, and mid- and long-term objectives imply actions to be accomplished in 5 to 10 year time frames:

1. ***Resolve uncertainty in the sign and magnitude of global climate-terrestrial C cycle feedbacks under future climatic warming and rising CO_2.*** Current terrestrial C cycle models used in coupled C cycle-climate simulations show a range of responses so large that we

cannot determine the sign of the terrestrial C cycle feedback with climate with any real confidence.

- Near-term: Deliver a functional C cycle model including element feedback constraints and CO_2 response conclusions from completed experiments capable of quantifying global patterns of terrestrial C sources and sinks. Develop plans for new measurement and experimental needs, highlighted by forcing uncertainties.
- Mid-term: Integrate landscape scale measurements of C, water and energy fluxes, and forcing-experiment results with coupled C-cycle model development to provide the new knowledge needed to quantify rates and controlling mechanisms of climate-carbon cycle feedbacks.
- Long-term: Provide an operational system to analyze C sources and sinks that integrates global C measurements, data assimilation and experimental results to quantify the sign (net uptake or loss of C from terrestrial ecosystems) and more tightly constrain the magnitude of the global climate-terrestrial C cycle feedbacks.

2. ***Understand and quantify organismal and ecosystem vulnerability to warming through the use of new experimental manipulations employing multi-level warming with appropriate CO_2 exposures and measures of water and nutrient limitations.*** Projected magnitudes and rates of future climatic and atmospheric change exceed conditions associated with current interannual variations or extreme events. It follows that a suite of processes will be impacted to a degree and in ways that we have insufficient information to predict from observations alone: experimental manipulations are required.

- Near-term: Select a target ecosystem or ecosystems on which to focus experimental studies of response to warming and CO_2 increases based on feasibility, projected vulnerability, societal and scientific importance. Complete the design and construction of new experimental manipulations, and initiate treatments.
- Mid-to-long term: Conduct and complete experimental manipulations and synthesize results including the development of algorithms for characterizing changes in plant growth, mortality and regeneration and associated changes in water balance and biogeochemistry under climatic change.

3. ***Develop an improved, process-based understanding of soil C pools and fluxes to improve predictions of net greenhouse gas emissions in Earth system models and to inform mitigation strategies through ecosystem management.*** Soil C is the largest terrestrial C pool, and the dynamics are difficult to quantify due to the myriad of biological, environmental, and edaphic factors present at all scales of space and time. Current understanding of mechanisms governing soil C dynamics is inadequate for projecting the potential for mitigating climate change through the manipulation of managed terrestrial ecosystems for soil C sequestration.

- Near-term: Complete and synthesize CCP experiments and measurements on the forms, fate and transport of soil C based on isotopic tracer and other studies in natural and managed ecosystems.

- Mid-term: Provide improved and quantitative algorithms of soil C processes, and expand the quantitative and process-based understanding of soil C storage to globally significant managed ecosystems.
- Long-term: Provide a flexible model of soil C storage in managed ecosystems and natural ecosystems based on land use metrics for incorporation in fully-coupled Earth system models.

4. ***Incorporate new findings on interannual and seasonal dynamics, episodic events and extreme events revealed by sustained landscape flux measurements into terrestrial components of terrestrial C and Earth system models emphasizing the importance of the decadal time scale.*** Landscape-level measures of C, water and energy flux provide essential data for the evaluation of land-atmosphere exchanges in order to validate and improve terrestrial C and Earth system models.

   - Near-term: Synthesize existing land-atmosphere C, water and energy measurements and experimental results for constraining interannual and seasonal dynamics in terrestrial land surface and C models.
   - Mid-term: Provide improved algorithms for the mechanistically valid expression of effects of episodic and extreme events on C and water fluxes in terrestrial ecosystems for prognostic simulations of responses to altered event frequency and size.
   - Long-term: Achieve predictive capacity to simulate interannual to decadal dynamics important to water balance, biogeochemical cycling and vegetation response to climatic change across ecosystems.

5. ***Search out key uncertainties within global land-atmosphere-climate models and future Earth system diagnosis models as the basis for proposing new measurements and experiments as new knowledge is gained.*** This capability will focus on terrestrial ecosystem-climate interactions and consider both natural and managed ecosystems and the interaction of land-use patterns with anthropogenic impacts on climate. The modeling component of this capability will include both diagnostic and prognostic capabilities for simulation of past, present, and likely future Earth system states. The predictive modeling capability will be developed as an extension of coupled climate-carbon cycle models, while the diagnostic capability will be developed as a cross-scale hierarchy of observations, ecosystem models, and data assimilation techniques.

   - Near-term: Deliver an initial system for both diagnosis and prediction capabilities, including biogeochemical feedback constraints, and use this system to perform a quantitative assessment and prioritization of critical uncertainties in our understanding of climate-ecosystem interactions.
   - Mid-term: Deliver a second-generation system, with diagnostic and predictive capabilities enhanced by including knowledge gained from completed and ongoing manipulation studies, landscape C and water flux data sets, synthesized data archives, and new data assimilation techniques. New model capabilities will include improved C-nutrient allocation, interactive phosphorous cycle, and interactions with ecosystem management practices.

- Long-term: Resolve major components of terrestrial feedback uncertainty for the entire Earth system. New model capabilities will include improved process-based representation of soil organic matter dynamics and new representation of ecosystem climate change response mechanisms derived from experiments.

Specific planned milestone deadlines and deliverables are further defined in the subsequent science plans, and will be further discussed and formalized by the CCP team in consultation with DOE/BER to balance priorities against available resources.

ORNL's CCP Approach

Research to accomplish these broad goals and objectives will be organized into three integrated components that focus on specific aspects of climate change and terrestrial ecosystems. The three scientific focus areas include: terrestrial Forcing, Response, and Mitigation. These research SFAs will also interact with global modeling activities at ORNL to improve the representation of terrestrial C cycle processes and climate-vegetation-C cycle feedbacks required to reduce uncertainty in predictions by global climate and Earth system models of future climate and terrestrial responses. The research SFAs will also incorporate data systems and informatics activities at ORNL to enhance integration efforts within and between SFAs and broaden the applicability of SFA results.

I. The *Forcing SFA* supports research to understand and predict how global change will impact C, water and nutrient cycles of terrestrial ecosystems, their feedbacks to climate, and how changes in ecosystem structure and land use alter those biogeochemical feedbacks. The Forcing SFA advances the integration among measurement systems, ecosystem-scale experimental data, and process model development by using model-data assimilation methods. The optimal use of measurement and experimental data at regional and global scales will result in a C cycle reanalysis capability to improve understanding of the current C, water and nutrient dynamics of terrestrial ecosystems. This process understanding leads to improved model representations that can be used for application within Earth system models. This research recognizes that land-use decisions and trends yield interactions among biogeochemical and economic/technical systems and that dealing with and reducing uncertainty in fossil-fuel emissions will produce benefits in understanding Earth's terrestrial ecosystems.

II. The *Response SFA* provides a targeted experiment to predict vulnerability of important terrestrial ecological systems to projected changes in climate and atmospheric composition and how those responses might alter both the delivery of ecosystem goods and services and the feedbacks from ecosystems to the atmosphere and climate. Fundamental processes controlling vegetation change discovered by these studies will be used to formulate mechanisms for application within terrestrial C cycle and Earth system models.

III. The *Mitigation SFA* provides an improved and quantitative understanding of the processes controlling soil C storage that will enable the incorporation of greenhouse gas mitigation strategies in Earth system modeling and lead to the successful development of technologies and strategies for enhancing C sequestration in managed ecosystems.

As described in the following paragraphs, ORNL will plan interactions with global modeling projects and incorporate data systems and informatics into climate change science.

Global Modeling Activities at ORNL contribute to the development, testing and application of fully coupled climate and Earth system models needed to project the likely response of the climate system to natural and human-induced climate forcing. They deliver global and regional scale evaluations of critical uncertainties affecting the climate prediction problem at decadal and century time scales focusing on interactions between terrestrial ecosystems and climate. Global modeling helps guide the design and implementation of new measurements and experimentation, and synthesizes and integrates data and insights from experimental research and C cycle measurements.

Data systems and informatics are not a separate focus area, but an integral part of the overall CCP concept. ORNL will develop and deploy data information and integration capabilities needed for the collection, storage, processing, discovery, access, delivery, and assimilation of available measurements, synthetic analysis results, model forcing and boundary condition datasets, and model outputs. Such an information system facilitates model-data integration and provides accessibility to model output and benchmark data for analysis, visualization, and synthesis activities. Data systems and informatics will enable the CCP vision of transforming the science of climate and atmospheric change and significantly improving global change prediction. A strong capability in this area will also facilitate delivery of CCP products and results to interested stakeholders. Through the CCP SFAs and over mid- to long-term time frames ORNL's CCP will develop and implement leading edge, open-source informatics tools needed to enable rapid model-data intercomparison studies, automated data analysis and integration, and semantic interoperability of data and information across both the CCP and related programs.

Unique Capabilities and Facilities Contributing to the CCP

ORNL is uniquely positioned to deliver the science required to support this vision. The CCP team assembled and supported by this commitment includes more than 50 dedicated scientific and technical staff at ORNL with a long history of research, publication and leadership in climate change research. We have established a relationship with research partners at other National Laboratories and faculty and students at universities across the country and around the world. Our emphasis on delivering an integrated Earth system analysis capability mandates that we bring together exceptional multidisciplinary expertise, and that we retain staffing flexibility to respond as new research priorities are identified, yet retain the continuity that National Laboratory leadership provides. ORNL provides the necessary state-of-the-science measurement and ultra-scale computing capabilities in coordination with advanced scientific informatics, and ORNL provides a stimulating scientific environment where we can accomplish exceptional science.

ORNL has been demonstrating its commitment to climate change research through substantial investments over many years in climate change modeling, the development of innovative large-scale experimental infrastructures through the Laboratory Directed Research and Development program (LDRD), and in the construction of other critical infrastructures, including a new field support building, greenhouses, the Joint Institute for Biological Sciences, and renovations in support of molecular ecology. New experimental systems developed for the CCP will be implemented as open facilities to foster the broadest possible collaboration. A new Climate Institute building, which would house the scientific staff of the CCP, is under discussion. Further evidence of an institutional commitment to climate change research is apparent in the ORNL strategic plan for FY 2009 where it is stated that ORNL will take a leadership role in addressing how environmental influences, including climate variability and change, will broadly impact our energy, food, and water systems.

The CCP will be supported by world-class capabilities at ORNL. The National Leadership Computing Facility provides an open, unclassified resource that we will use to enable breakthrough discoveries in climate prediction. It houses the largest unclassified computing capability available to climate change researchers in the world. The Earth System Grid (ESG), which involves six DOE Laboratories and the National Center for Atmospheric Research (NCAR), integrates supercomputers with large-scale data and analysis servers located at numerous National Laboratories and research centers to create a powerful environment for next generation climate research. The Carbon Dioxide Information Analysis Center (CDIAC) is pioneering utilization of infrastructure support for data and model integration that we will use and build upon in the CCP. The Atmospheric Radiation Measurement Program data system (ARM Archive), the NASA Distributed Active Archive Center for Biogeochemical Dynamics (NASA-DAAC), and the USGS-funded National Biological Information Infrastructure (NBII) Metadata Clearinghouse provide additional expertise in this emerging research discipline.

ORNL is also home to the High Flux Isotope Reactor and the Spallation Neutron Source, which we can use to understand physical, chemical, and biological complexity in plant and soil processes. Further, ORNL has access to the Oak Ridge Reservation and National Environmental Research Park, a unique resource comprising multiple ecosystem types that are protected, available for observation and manipulation, and supported with infrastructure. Walker Branch Watershed on the Oak Ridge Reservation is a candidate core site for the National Ecological Observatory Network (NEON), a National Science Foundation continental-scale observation system whose aim is to determine long-term changes in ecosystem structure and function in response to climate and other environmental factors.

Other facilities that we plan to use are located at collaborating DOE National Laboratories. The Lawrence Livermore National Laboratory - Center for Accelerator Mass Spectrometry (LLNL-CAMS) provides large volume, high precision ^{14}C measurements for ecosystem tracer studies. Pacific Northwest National Laboratory's Environmental Molecular Science Laboratory combines advanced instrumentation such as high-throughput mass spectrometry, advanced microscopy instruments, and NMR instruments with high performance computing. The Advanced Photon Source (APS) at ANL provides the brightest x-ray beams in the Western Hemisphere to enable analysis of chemical and physical structure of components of ecosystem biogeochemical cycles.

Organizational Structure and Key Personnel

We have assembled a highly qualified science and management team to guide and direct activities of the CCP. Responsibility for the CCP resides within the Biological and Environmental Sciences Directorate at ORNL, but we expect a high degree of interaction with the Computational Sciences and Mathematics Division (CSMD). The following organizational chart indicated inter-relationships among the scientific focus areas and other laboratory activities of the CCP.

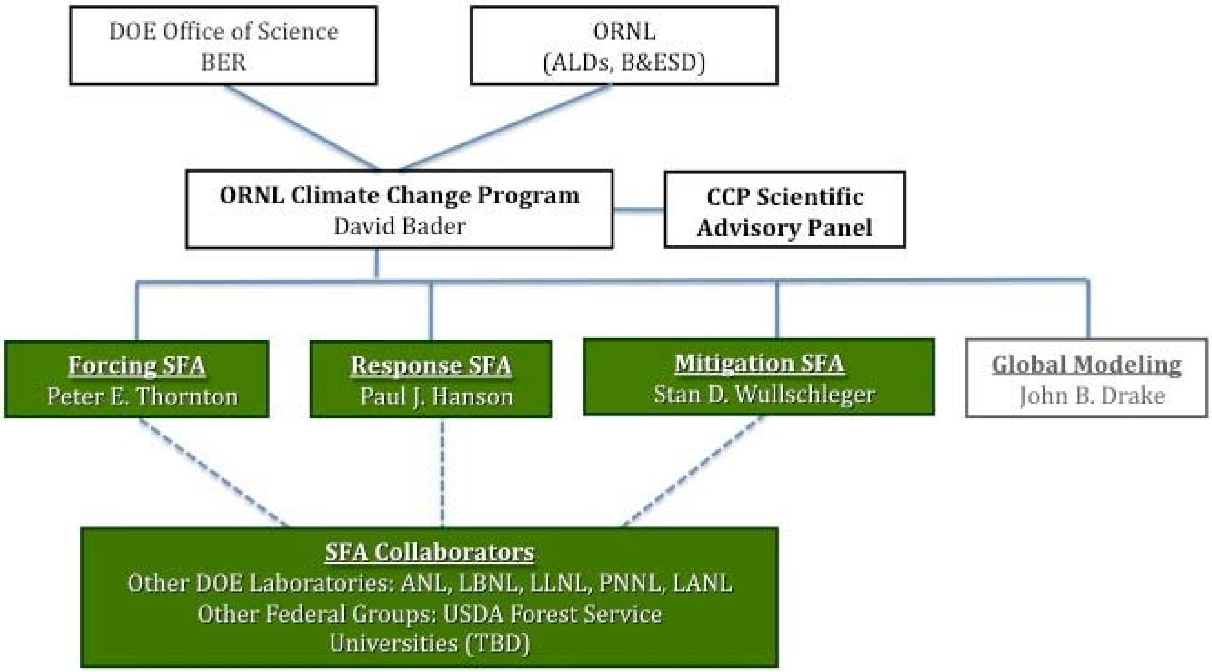

Figure 2. Organizational Chart for the ORNL Climate Change Program.

The CCP team integrates outstanding basic and applied research capabilities.

- *Dr. David Bader* will be joining ORNL in June of 2009 to serve as the Director of the Climate Change Program at ORNL. He is currently the Director of the Program for Climate Model Diagnosis and Intercomparison at Lawrence Livermore National Laboratory. In his position as the CCP Director he will coordinate research objectives and information exchange among the SFAs and the Global Modeling Activities at ORNL and be responsible for scheduling annual and triennial performance discussions and reviews with the participation of the CCP Scientific Advisory Panel and the US DOE Office of Science Program Managers as appropriate.
- *Dr. Peter E. Thornton* will be the Technical Co-manager for the Forcing SFA. A new member to the ORNL's Environmental Sciences Division, Dr. Thornton comes to ORNL from the National Center for Atmospheric Research where he was (and remains) a key developer of the land-surface component of the Community Climate System Model (CCSM). His recent publications emphasize the importance of nitrogen limitations on the terrestrial C cycle and climate C cycle feedbacks.

- *Dr. Paul J. Hanson* will be the Technical Co-manager for the Response SFA. With 22 years of experience as a plant physiologist and environmental ecologist, he operated and managed the long-term (14-year) Throughfall Displacement Experiment on the Oak Ridge Reservation. He currently manages the 27-member Ecosystem Studies Group of the Environmental Sciences Division at ORNL, is a Subject Editor for *Global Change Biology*, coordinates the multi-lab Enriched Background Isotope Study, and is currently working with other ORNL staff to develop state-of-science capabilities for warming intact ecosystem plots.
- *Dr. Stan D. Wullschleger* will be the Technical Co-manager for the Mitigation SFA. As a physiologist with research expertise in forest management and crop and soil science, he is a participant in the DOE-sponsored Consortium for Carbon Sequestration in Terrestrial Ecosystems (CSiTE). Stan has 18 years of experience in global change biology and environmental stress physiology. He was a contributor to DOE efforts to sequence the first tree genome (i.e., *Populus*) and now uses that information to understand the mechanisms that underlie genetic and environmental controls on soil C storage in the bioenergy crops hybrid poplar and switchgrass.
- *Dr. John B. Drake* will be the Technical Co-manager for Global Modeling Activities at ORNL. John has 17 years of experience leading climate dynamics and computational sciences groups at ORNL, and he is the current leader for the Computational Earth Science Group of the Computer Science and Mathematics Division. He is also the ongoing Principal Investigator for DOE project titled "A Scalable and Extensible Earth System Model for Climate Change Science (aka: the SciDAC2 CCSM Consortium Project).

The CCP Director, the Technical Co-managers for each SFA, the analogous Technical Co-manager for ORNL global modeling activities, and a cross-SFA Data Systems Manager (e.g., Thomas Boden; CDIAC) will form the CCP Leadership Team. The CCP Leadership Team will develop yearly SFA plans and budgets, monitor progress, adjust project plans as appropriate, direct informatics development efforts, and resolve issues in a timely manner. The CCP Director will, with advice from the CCP Leadership Team, extend invitations and select a CCP Scientific Advisory Panel (SAP). The SAP will be responsible for providing advice on the scientific thrusts of the CCP, review project plans and monitor annual progress toward CCP goals. Table 1 lists initial confirmed membership of the ORNL CCP SAP.

Table 1. Members of the ORNL Climate Change Program Scientific Advisory Panel

Name	Institution	Targeted SFA/Subject Area
Pep Canadell	CSIRO, Australia	Forcing SFA
Michael Goulden	University of California-Irvine	Response & Forcing SFAs
Sara Graves	University of Alabama-Huntsville	Forcing & global modeling
Robert Jackson	Duke University	Response SFA
Jeffrey Kiehl	NCAR, Colorado	Forcing SFA & global modeling
Bill Michener	University of New Mexico	Informatics
Eldor Paul	Colorado State University	Mitigation SFA
Donald Zak	University of Michigan	Mitigation SFA

The Panel may be supplemented or modified based on peer review comments obtained on the CCP program and science plans. A key role for the SAP will be to provide perspectives on research directions, deliverables, and an external view of when ongoing science activities have been adequately addressed and matured.

Each SFA Technical Co-manager will have responsibility for communicating externally with their respective DOE/BER Program Manager at periodic intervals, and for communicating internally and regularly with the other Technical Co-managers, the Data Systems Manager, and the CCP Director.

The CCP will be staffed by highly qualified researchers from ORNL supplemented by staff, faculty and students from other National Laboratories and universities. We will aggressively pursue a mix of early-career and senior scientific and technical staff. Attention will be given to identifying relevant expertise and facilities necessary to address the research goals and objectives of the CCP. Where appropriate, and when consistent with ORNL goals, we will recruit and hire staff to fill critical gaps in expertise and ensure the long-term viability of our research program. External collaborators at other National Laboratories and universities will participate as valued partners under subcontract or through direct transfer of funds through DOE/BER.

Management Plan for ORNL's CCP

The management plans for conducting work within all SFAs of the CCP include schedules for project plans and task execution, a data management and informatics plan, procedures for interacting with collaborators outside of ORNL, and the allocation of staff time to specific measurements, experiments and synthesis and modeling activities conducted as a part of the respective SFA. Descriptions of the core components of the CCP Management Plan are provided below.

<u>Project Planning and Execution:</u> Bi-monthly meetings will be held among SFA Technical Co-managers to review and resolve any issues with respect to integration and progress. Technical Co-managers will meet monthly with their respective teams to evaluate program integration and to ensure that research tasks are progressing and are being performed appropriately. The CCP Director and Program Managers at DOE/BER will be invited to participate in these monthly meetings. Research progress will be presented at annual retreats, which will include all SFA participants. Annual reports will be distributed to the CCP SAP and DOE/BER Program Managers by the CCP Director. Communication across the SFAs will be organized through a password-protected collaboration web site for the secure exchange of documents, papers, and information.

<u>Scientific Advisory Panel:</u> A SAP will advise the CCP Director through review of plans, progress, and participation in periodic team conference calls and meetings. A yearly meeting among all SFA participants will be held to review progress and formulate plans for the coming year. This meeting will be held prior to the annual review of the CCP by DOE/BER.

<u>Data Systems and Informatics:</u> The goals of the CCP will require a cross cutting data system capability encompassing advanced environmental-informatics and scientific data cyberinfrastructure. Due to the volume, complexity, and semantic differences inherent to data and models across the CCP focus areas, leading edge informatics tools and associated informatics research will facilitate data integration both within and across the core areas of the CCP. The vision for data systems and informatics is to support CCP research and enable cross cutting science by leveraging both leading edge informatics technologies and established standards related to scientific data stewardship, service oriented data architecture, scientific workflow, semantic interoperability and domain science ontologies, visualization, and other

collaborative technologies. By working across the scientific areas, we will deliver a more consistent and interoperable data system for less effort than would be possible with individual programs, a key element driving the integration of science across SFAs.

Staff Time and Funding Allocations: The time allotted to ORNL staff and post-docs to execute the CCP program will be detailed in the subsequent science plans. Staff time will be allocated among activities associated with simulation science, the planning, development and operation of experimental systems in important and representative ecosystems, the measurement of forcing variables for key biomes, execution of hypothesis-driven experiments to explore enhancement of C sequestration in managed ecosystems, and data management and synthesis activities to facilitate information transfer and integration across the three SFAs. In addition, significant funding over the period from 2009 through 2010 will be allocated to the design, construction and implementation of next generation experiments.

As the development of new experimental infrastructure transitions to measurements and synthesis, a small fraction of CCP funding will be set aside for task-specific discretionary or directed research. Such an allocation will be used for small exploratory research projects to move research in new directions or cross-SFA synthesis activities. These activities will be short in duration, but will address important deliverables within the program. To plan and select such directed research projects, the CCP Leadership Team and appropriate co-investigators will evaluate program needs and identify focus areas for short-term investigation. Decisions will be shared with CCP Scientific Advisory Panel and the appropriate DOE/BER Program Manager. ORNL management, the CCP Director, and the Technical Co-managers are committed to integration among SFAs and will assess and implement changes that may be needed in both process and personnel as part of our annual employee performance system. Identification and planned resolution of such issues will be included in yearly updates to the program plan and discussed with DOE/BER.

Staffing Needs, Succession Planning, and Use of Discretionary Funds: Research tasks, milestones, and deliverables are specified in the sections that follow for the Forcing, Response, and Mitigation SFAs. These will be the focus of our activities during the FY 2010–2012 performance period. Accomplishing these objectives in the short term and, more importantly an expanded set of goals over the long term, will require careful planning to ensure that relevant expertise is engaged, that a succession plan is designed and executed, and that new ideas are continually developed and pursued during the course of our investigations. A staffing plan will be developed for the CCP. Hiring needs will be identified and two avenues will be used to bring necessary expertise into the individual SFAs. We anticipate a significant expenditure for post-doctoral research associates to support our scientific objectives. Two additional post-doctoral associates will be initially hired in each SFA. Funds will be used for post-doctoral appointments to acquire expertise that is unavailable internally. We expect that hiring needs will change as the program progresses and new research directions are defined, but we are nonetheless committed to having a strong post-doctoral component at ORNL. We will also implement an Early Career Scientist program where funds are set aside every other year to hire new scientists who would bring a new and unique aspect to our science. Staff early in their career will be mentored to assume leadership positions in SFA activities, thereby ensuring the long-term continuity and viability of the research.

A portion of the SFA funds will also be budgeted for Program Directed Research. Such a fund will be used for small-scale and short duration research projects to address key needs of the program. The CCP Director together with the SFA Technical Co-managers will evaluate the program needs each year, and work with the CCP ScientificAdvisory Panel to select Program Directed Research projects for support. Decisions will be shared with DOE Program Managers.

Summary Statement

Research summarized for the CCP is ambitious in its scope, effort, and fiscal requirements. It represents a challenge that will fully utilize, test and extend the broad interdisciplinary facilities of DOE National Laboratories and further develop new facilities over the next decade. The proposed simulations, measurements, and experiments will develop our understanding of the quantitative mechanisms of Earth's climate and the terrestrial biological responses of important ecosystems to environmental and atmospheric changes and the physical and ecological interactions resulting in feedbacks between Earth and its climate. The following sections provide additional details on the three Climate Change SFAs that ORNL anticipates supporting, and include descriptions of rationale, questions, approaches, and key science personnel for each SFA. The three CCP SFAs are purposely designed to be both complementary and overlapping in their scope, such that together they will bring a broad and unified understanding of climate change impacts on Earth systems analysis. Each of the CCP SFAs will contribute to and interact with climate change modeling activities at ORNL as discussed in the appended summary section on ORNL Global Modeling Activities.

Brief Introduction to the Scientific Focus Areas and ORNL Global Modeling Work

The following brief descriptions define and constrain the philosophy and subject matter of ORNL research on climate change Forcing, Response, and Mitigation. Subsequent sections of this document will provide detailed science plans and budgets for research in these three areas.

I. ORNL Climate Change Forcing Scientific Focus Area

The Forcing SFA supports research to understand and predict the global terrestrial ecosystem forcing of the earth's climate. The research is focused on how terrestrial ecosystems affect atmospheric CO_2 and other greenhouse gases and how the ecosystem processes responsible for these effects interact with climate and with anthropogenic forcing factors. Initial Forcing SFA research is targeted at accurately quantifying the exchange of CO_2 between the atmosphere and land ecosystems through photosynthesis, autotrophic and heterotrophic respiration, disturbance, and land management practices. This research will increase confidence in making future projections by concentrating on new understandings and model representations of interactions and feedbacks: for example, interactions among CO_2 fertilization, nutrient dynamics, and disturbance or land use history, or nutrient-mediated feedbacks between climate change and land CO_2 fluxes. This research includes efforts to more accurately quantify uncertainty in anthropogenic emissions of CO_2 from fossil fuel burning, and takes advantage of ongoing efforts to quantify historical, present-day, and anticipated future greenhouse-gas consequences of land use and land cover change.

II. ORNL Climate Change Response Scientific Focus Area

The Response SFA provides targeted experiments to assess vulnerability of terrestrial ecological systems to projected changes in climate and atmospheric composition. Quantification of climate change responses allows prediction of the effects of atmospheric and climatic change on ecosystems' capacities to deliver goods and services and on feedbacks from ecosystems to the atmosphere and climate. Fundamental processes controlling vegetation change discovered by these studies will be used to formulate mechanisms for application within terrestrial C cycle and Earth system models.

III. ORNL Climate Change Mitigation Scientific Focus Area

The Mitigation SFA provides an improved and quantitative understanding of the processes controlling soil C storage that will enable the incorporation of greenhouse gas mitigation strategies into Earth system modeling and lead to the successful development of technologies and strategies for enhancing C sequestration in managed ecosystems.

Global Modeling at ORNL contributes to the development, testing and application of fully coupled climate and Earth system models needed to project the likely response of the climate system to natural and human-induced climate forcing. It delivers scalable and comprehensive Earth system models that enable global and regional scale evaluations of critical uncertainties affecting the climate prediction problem on decadal and century time scales. Atmospheric dynamical methods and parallel algorithms coupled with land and C modeling provide a focus on terrestrial ecosystem-climate interactions. Modeling helps guide the design and implementation of new measurements and experimentation, synthesizes and integrates data and insights from experimental research and C cycle measurements. The Global Modeling Activities provide a consistent framework for identifying critical uncertainties and articulating and quantifying new testable hypotheses using advanced computational techniques.