Fiscal Year 2010 Annual Progress Report
for the
Response Science Focus Area (Response SFA)
of the
Oak Ridge National Laboratory
Climate Change Program

Submitted by Paul J. Hanson
and staff members of the Response SFA

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Dr. Paul J. Hanson, Response SFA Lead — Date

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1. Program Overview

Experimental work under the Climate Change Response SFA focuses on the identification of critical response functions for terrestrial organisms, communities, and ecosystems. Both direct and indirect effects of these experimental perturbations will be analyzed to develop and refine models needed for full Earth system analyses. Response SFA research is organized around a climate change manipulation focusing on the combined response of multiple levels of warming at ambient or elevated CO_2 (eCO_2) levels. The experiment provides a platform for testing mechanisms controlling vulnerability of organisms and ecosystems to important climate change variables (e.g., thresholds for organism decline or mortality, limitations to regeneration, biogeochemical limitations to productivity). The experiment also evaluates the response of existing biological communities to a range of warming levels from ambient to +9°C. The ambient, +3°C and +9°C warming treatments will also be conducted at eCO_2 (in the range of 800 to 900 ppm). The Spruce and Peatland Responses Under Climate and Environmental change (SPRUCE) experiment will be conducted in a *Picea mariana* [black spruce] – *Sphagnum* spp. forest in northern Minnesota. This ecosystem located at the southern extent of the spatially expansive boreal peatland forests is considered to be especially vulnerable to climate change and to have important feedbacks on the atmosphere and climate. This science plan for the Response SFA also includes support for core long-term tracking of the hydrologic, biogeochemical and biological response of the Walker Branch Watershed to inter-annual climatic variations.

2. Outline of Scientific Objectives

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 carbon cycle, vegetation and Earth system models.

ORNL's vision for the Climate Change Response SFA is to provide key components of the science necessary to understand the consequences of climate and atmospheric change for terrestrial ecosystems. Measurements through time and across space have shown that the responses of terrestrial ecosystems to both chronic and acute perturbations of climatic and atmospheric drivers can lead to changes in ecosystem structure (e.g., species composition, leaf area, root distribution) and ecosystem function (e.g., plant physiology, soil microbial activity, and biogeochemical cycling). The projected magnitudes and rates of future climatic and atmospheric changes, however, exceed conditions associated with current interannual variations or extreme events, and represent conditions that need to be applied to experimental manipulations. Therefore, it seems logical that a suite of ecosystems structures and processes will be impacted in ways that we have insufficient information to predict

To acquire a fundamental understanding of projected changes, ORNL is focusing on future experimental work under the Response SFA for the identification of critical response functions for terrestrial organisms, communities, and ecosystems. This approach includes the development and utilization of experiments that expose critical ecosystems and their components to a broad range of temperature increases (both above- and belowground) combined with atmospheric CO_2 enrichment. Both direct and indirect effects of these experimental perturbations will be analyzed to develop and refine regional and global carbon (C) cycle models that are needed for full Earth system analyses. Response SFA research is organized around a climate change manipulation focusing on the combined response of multiple levels of warming at ambient or eCO_2 levels. This experiment provides a platform for testing mechanisms controlling vulnerability of organisms and ecosystems to important climate change variables (e.g., thresholds for organism decline or mortality, limitations to regeneration, biogeochemical limitations to productivity).

The experiment focuses on critical, yet poorly understood processes that we believe will determine rates of mortality and regenerative success of future ecosystems in a changing climate. The work will be characterized by the identification of critical organismal responses (growth, mortality, reproduction and community change) and ecosystem-level functional changes operating through key interactions between organisms and the biogeochemical and hydrologic cycles (CO_2 and CH_4 net efflux).

This science plan for the Response SFA also describes support for core long-term tracking of the hydrologic, biogeochemical and biological response of the Walker Branch Watershed to inter-annual climatic variations. Such support will continue over the next several years until the activity transitions into the National Science Foundation's National Ecological Observation Network.

Science Questions

Providing answers to the following overarching science questions with the SPRUCE experiment will inform higher-order models of vegetation change for projected future climates.

1. How vulnerable are terrestrial ecosystems and their component organisms to atmospheric and climatic change? Can we quantify the potential for shifts in local species dominance and regeneration success to assist projections of future biome changes over decades to centuries?
2. Will novel species assemblages or loss of species that result from species-specific responses to climatic and atmospheric change have unanticipated impacts on ecosystem processes? Do changes in ecosystem services precipitate a change in state (e.g., loss of a dominant plant functional type)?
3. What are the critical air and soil temperature response functions for ecosystem processes and their constituent organisms? Do those response functions for ecosystem processes depend on shifts in species interactions and composition?
4. Will full belowground warming release unexpected amounts of CO_2 and CH_4 from high-C-content northern forests.
5. To what degree will changes in plant physiology under elevated CO_2 (eCO_2) impact a species' sensitivity to climate or competitive capacity within the community?
6. Will ecosystem services (e.g., biogeochemical, hydrological or societal) be compromised or enhanced by atmospheric and climatic change?

Answering these questions for keystone ecosystems will inform higher-order models of vegetation responses under projected levels of climate variability and atmospheric change.

3. Description of Program Structure

As conceived in the ORNL Climate Change Science Program (CCP) plan the Response SFA was one component of an integrated program of climate change science including three science focus areas and additional defined projects on global climate modeling (Fig. 1). The Response SFA coordinated by Paul J. Hanson is dominated by manipulative experiments designed to provide mechanistic understanding of the response of terrestrial vegetation, microorganisms, and associated fauna to changing atmospheric (i.e., elevated CO_2) and climatic conditions (predominantly warming). The Response SFA also includes long term monitoring efforts on Walker Branch Watershed that are managed and coordinated by Pat Mulholland for ultimate transition to the National Science Foundation's National Ecological Observation Network (NEON) in approximately 2013.

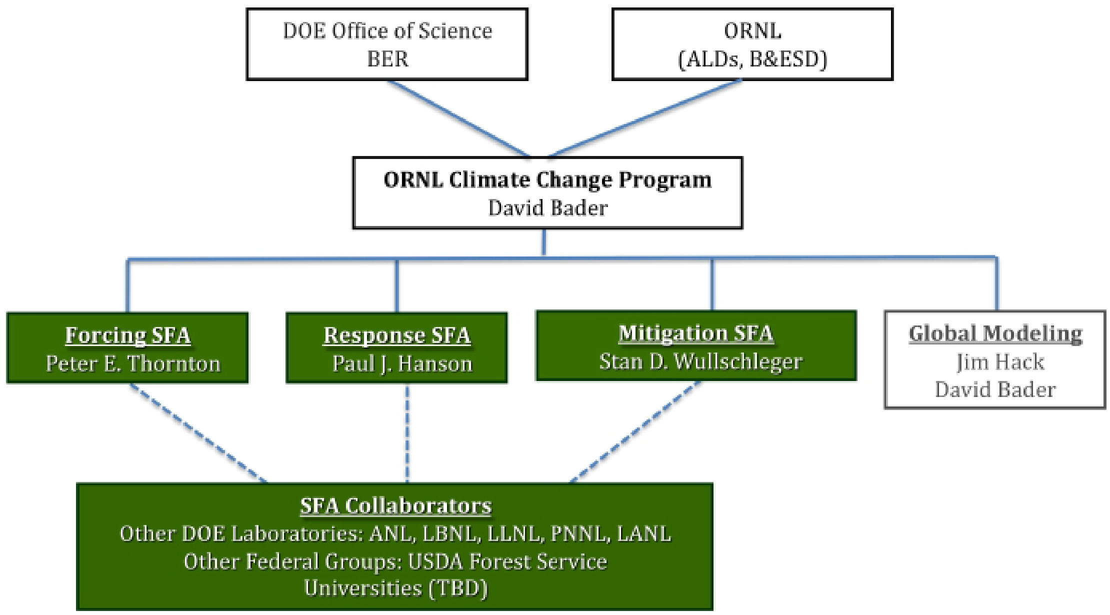


Figure 1. Overall organization of the ORNL Climate Change Program.

Dr. Paul J. Hanson is the overall research manager for the Response SFA reporting to the ORNL CCP Manager (Dr. David Bader). Dr. Hanson has overall responsibility for the Response SFA and for communicating directly with each technical task leader for a variety of functional and measurement tasks associated with the SFA. Dr. Patrick J. Mulholland with technical and postdoctoral support manages and coordinates the Walker Branch long-term monitoring objectives of the Response SFA. The Response SFA will include scientific staff with the most relevant expertise as needed to support the SFA experimental and observational tasks. In fiscal year 2010 (FY2010) ORNL has also initiated the Climate Change Science Institute within which the CCP provides a core of experimental and observational activities to be integrated with global climate and earth systems modeling and analysis activities.

The SRUCE experiment is comprised of the research tasks identified in Figure 2. The key task leads and supporting personnel are also listed in the Figure 2.

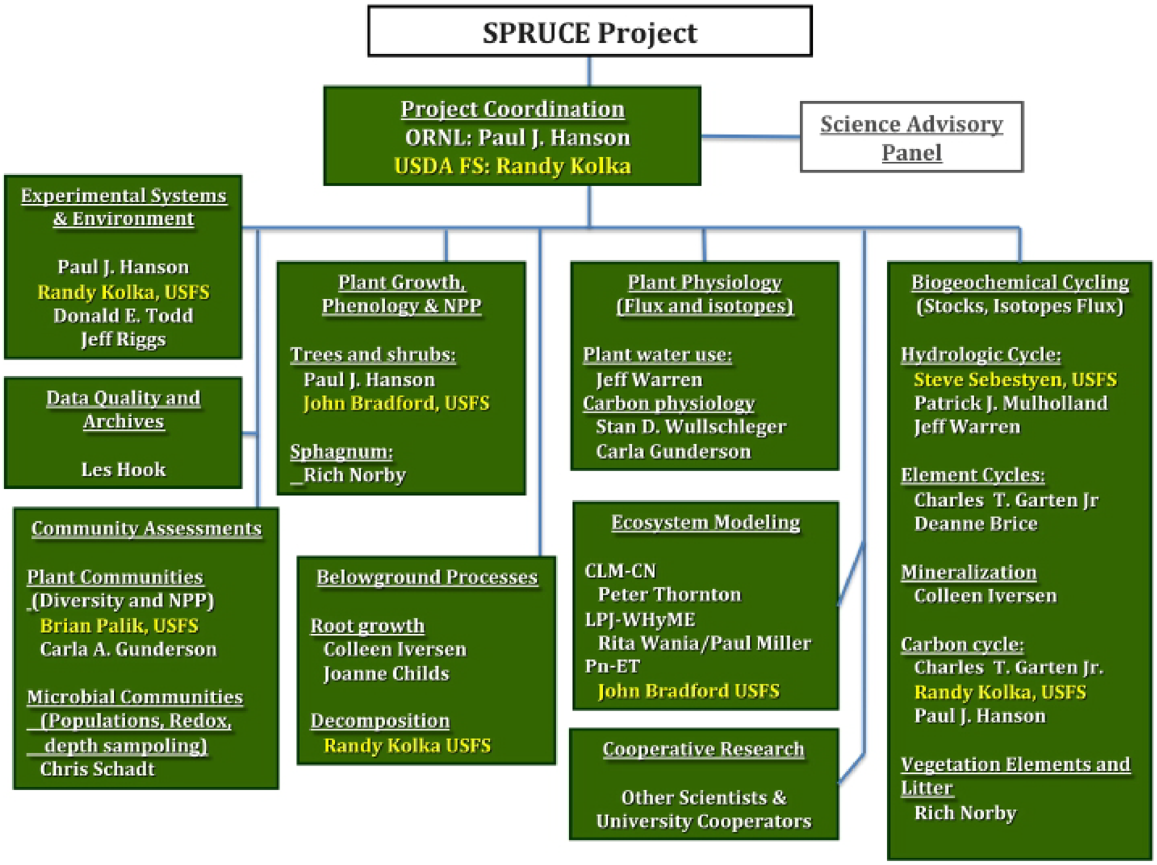


Figure 2. Organization of the SPRUCE experiment.

A coordinating panel made up of the Response SFA research manager (Paul J. Hanson), the Minnesota USDA Forest Service contact (Randall K. Kolka), the Technical Task leaders listed in Figure 2, and a panel of external science advisors will make up the experimental advisory panel. This coordinating panel will serve as the decision-making body for major operational considerations throughout the duration of the experimental activity and it will be the panel for vetting requests for new research initiatives to be added to the experiment when it becomes operational.

4. FY2010 Performance milestones and metrics

A. Major Response SFA milestones for FY2010

We are on track to fully achieve our key milestones for the Response SFA by their respective deadlines.

RS-01 Sep 2010 — Complete a priori biogeochemical modeling simulations using a global land-surface model for the SPRUCE experiment by modifying CLM-CN and completing and documenting the analysis.

Status: On target for completion in September of 2010.

A site-specific version of the CLM-CN model has been developed for specific application to the interpretation of results of the SPRUCE experiment. We are pursuing direct improvement of the CLM-CN model, because it is the dedicated land component of the comprehensive global CCSM model. By working directly with a model that is integrated within complex global simulations, we hope that the translation of experimental lessons-learned from the SPRUCE experiment will be possible without delays.

The new site-specific version of CLM-CN is being tailored for use on the S1-bog of the Marcell Experimental forest, and being structured to account for the major vegetation types present on the bog using digital representations for the dominant vegetation components: trees (*Picea* and *Larix*), ericaceous shrubs (*Ledum* and *Chamaedaphne*), and the ubiquitous surface *Sphagnum* layer (Figure 3). It may also be necessary to add a representation for the contributions of sedges and forbs as a minor component of annual net primary production. The belowground algorithms in CLM-CN are also being updated to allow for its application to the peatland ecosystems. Specific attention to the hydrologic budgets within CLM-CN to allow for appropriate projections of seasonal changes in water table depth and the associated influence that such variability has on the belowground production of CO_2 and CH_4 from the bog are a priority for model
Improvements;

The installation of environmental monitoring equipment for air and soil temperatures, gross and net radiation, precipitation, water table depths and contents, and records of phenological growth stages were completed in June of 2010 and are beginning to generate half-hourly data that will be used to exercise the model for site specific runs. To facilitate *a priori* models runs while such data are accumulating, half-hourly data from a northern Wisconsin AmeriFlux site (Willow Creek) will be obtained to facilitate early model simulations. Throughout the winter months of 2009 and 2010 the SPRUCE research group has been evaluating previously published data from the Marcell Experimental forest covering ecosystem composition, carbon balance, physiological functions, and intra- and interannual variability to provide parameterization data for the modeling efforts.

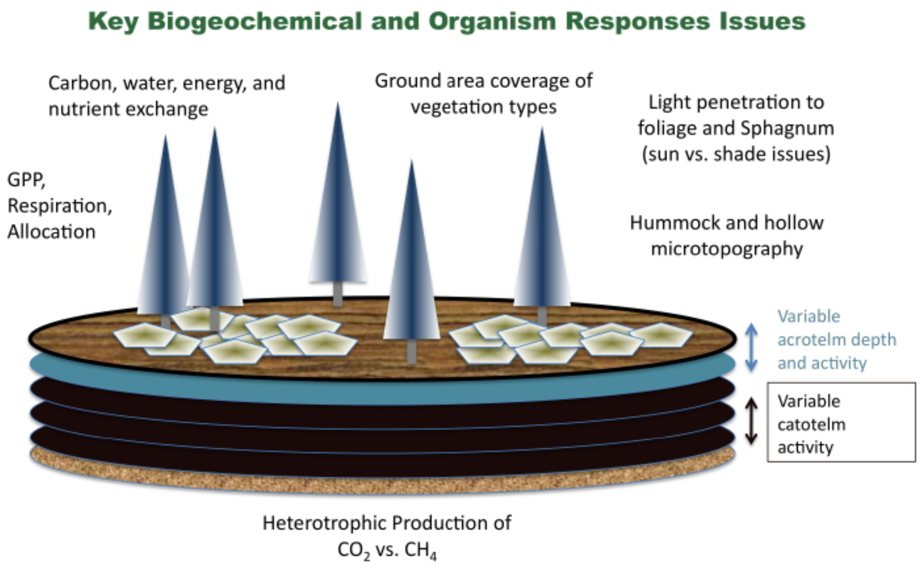


Figure 3. Important components for a site-specific version of CLM-CN for its application to SPRUCE.

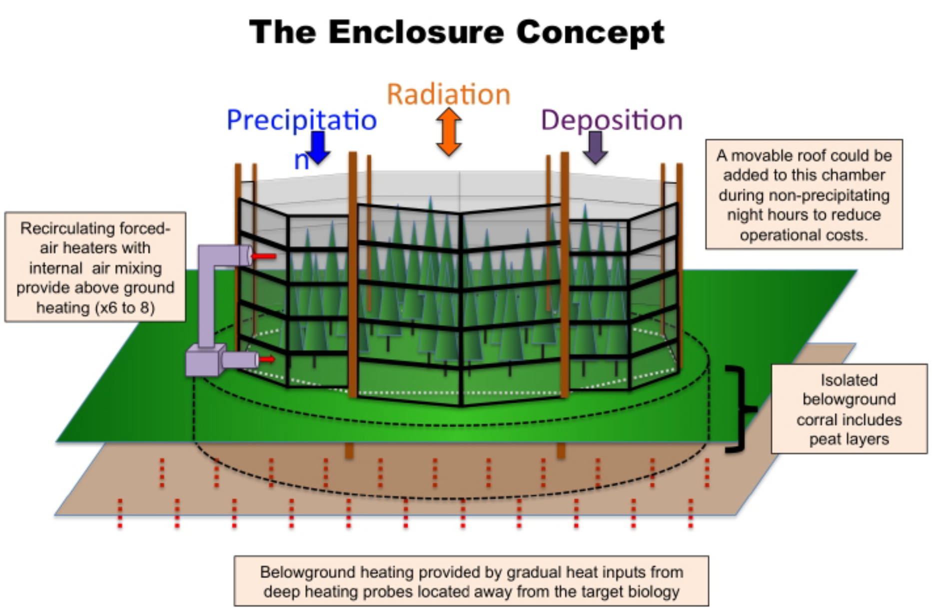
To supplement our efforts with CLM-CN, we are establishing a subcontract with the Paul Miller at the University of Lund to work closely with Rita Wania of the University of Victoria to conduct a priori model runs with their LPJ-WHyMe model. That model is already structured to accommodate the vegetation types of the S1 bog, and it includes initial formulations for belowground CO_2 and CH_4 flux that are appropriate to the experiment.

RS-02: Oct 2010 — Complete 12-m prototype enclosure development including energy and CO_2 use evaluations and the construction drawings, parts lists, and subcontracting documents necessary for boardwalks, electrical services, belowground corrals and aboveground plot enclosures for the SPRUCE experiment.

Status: Prototype design and construction is complete. Testing is on schedule for completion in October of 2010.

We succeeded in bringing our vision of a next-generation warming and CO_2 exposure enclosure for use in the SPRUCE experiment to reality. In October of 2009 we had a conceptual idea for an enclosure that would provide both above- and belowground warming treatments to a complex ecosystem including trees, shrubs and a complex high-carbon soil. ORNL scientists and engineers produced full construction plans for the concept by February of 2010, established subcontracts for its construction in March, and on 18 June 2010 took ownership of a full-scale prototype of the enclosure for testing evaluation and continued improvement (Figure 4).

While planning and constructing the enclosure, we also engaged ORNL expertise in complex fluid dynamics modeling in various exercises to estimate the turbulence dynamics and energy use needs of the enclosure being constructed. Figure 5 illustrates the results of some of this work. Simulations covered various assumptions about external wind velocities, chamber design modifications, and the presence of internal vegetation. The simulations provided energy use estimates for an enclosure under conditions likely to



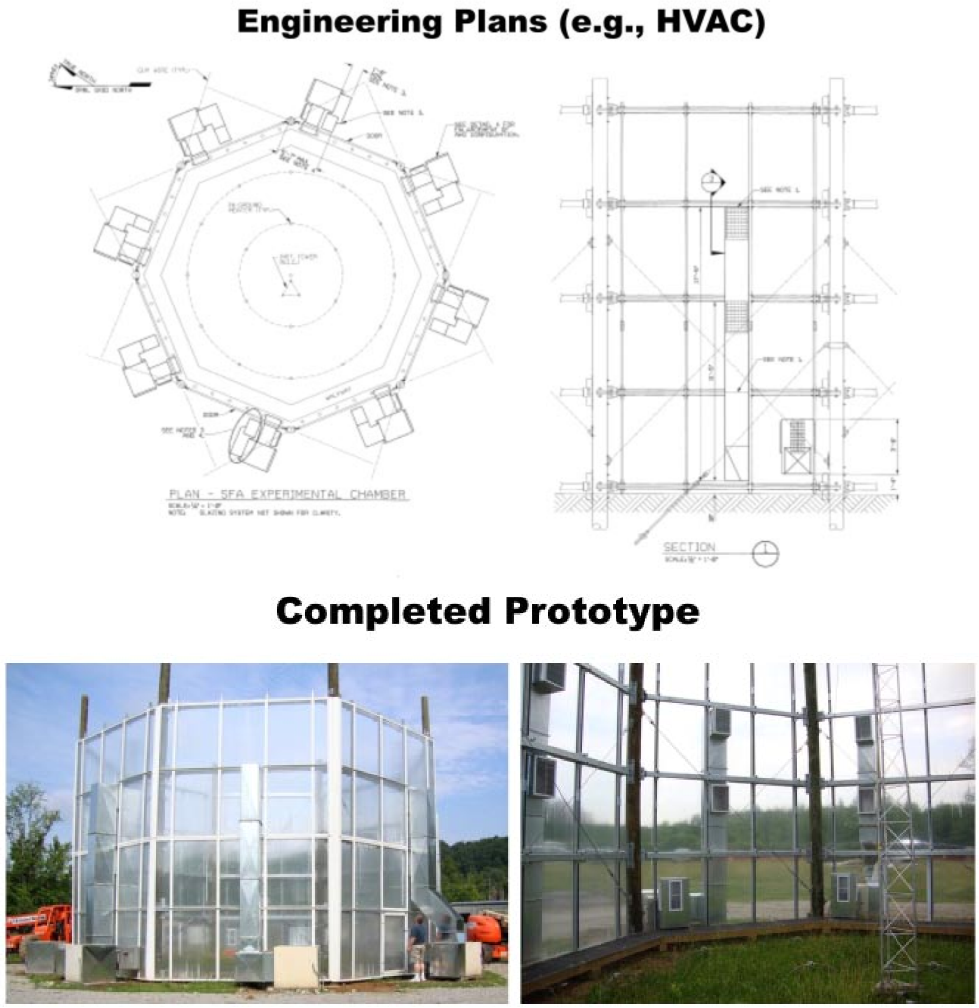


Figure 4. Progression of the prototype development over the past 9 months.

be experienced at the Minnesota SPRUCE experimental location. Over the next weeks we will populate the enclosure with a variety of temperature sensors (air and soil), relative humidity sensors, CO_2 sampling tubes, and an array of radiation sensors to evaluate its true performance.

ORNL engineers and safety personnel traveled to the Minnesota experimental site in June to gain first hand experience with the environmental conditions of the S1 bog, evaluate a boardwalk design for use as our access and utility corridor to the experimental treatment blocks, and to engage in scoping discussions with the local electric company and propane suppliers. Planning and execution of the detailed construction diagrams and plans that will form the basis for subtracts to build out the experiment on the S1 bog will be completed over the next several months for action in FY 2011.

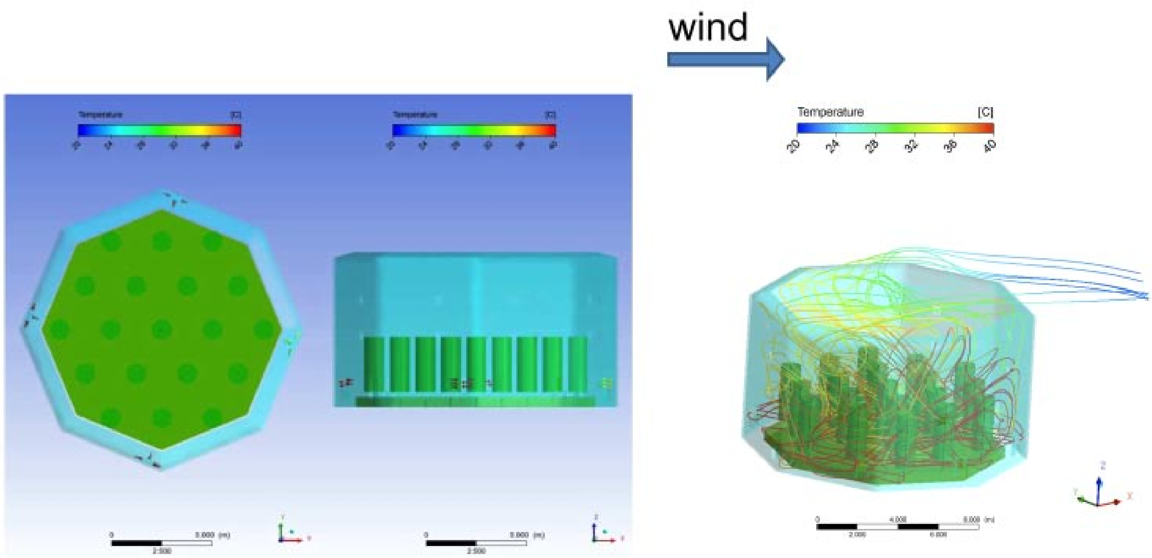


Figure 5. Conceptual diagram of the SPRUCE warming enclosure showing idealized spruce trees and an ericaceous shrub layer (left figure). Results from complex fluid dynamics simulations of the prototype warming enclosure showing streamlines for "packets' of heated air as they tumble around within the enclosure and periodically become ejected. Simulations suggest substantial residence time of the air volume within the enclosure and reasonably uniform temperatures throughout the 'stirred' air volume.

B. Additional SPRUCE experiment progress

National Environmental Policy Act Approvals

DOE procedures for approving experimental activities both on and off of the Oak Ridge Reservation led to the decision that an Environmental Assessment of the SPRUCE activity was needed. The preparation of that document is underway including a detailed analysis of a full range of physical, biological and sociological impacts the installation and operation of SPRUCE might have on the surrounding natural ecosystem and adjacent human populations.

SPRUCE Project web page

A SPRUCE project web page has been established to facilitate both public and password protected project information. It is available at http://mnspruce.ornl.gov. The web page contains relevant project planning documents, use agreements, data management arrangements, and will be the site for containing project data during the active operation of SPRUCE. At future dates consistent with the data management described below, project data will be transferred to publically accessible archives for long-term retrieval.

Memorandum of Understanding

A memorandum of understanding (MOU) between UT-Battelle and the USDA Forest Service was developed to define the roles and responsibilities of each institution in the long-term operation of the SPRUCE experiment. The full memorandum of understanding is available in the project web page.

Surveys of the S1-bog experimental site

An initial Bog Survey of above and belowground characteristics of the S1 bog needed to clarify logical blocking arrangement of the final experimental design was conducted in late September of 2009. We also subcontracted with a research group at Rutgers University to conduct ground penetrating radar estimates of peat depth distribution across the S1 bog to further clarify the best locations for future experimental blocks. Figures 6 and 7 show tree distribution and peat depth data collected from these efforts, respectively.

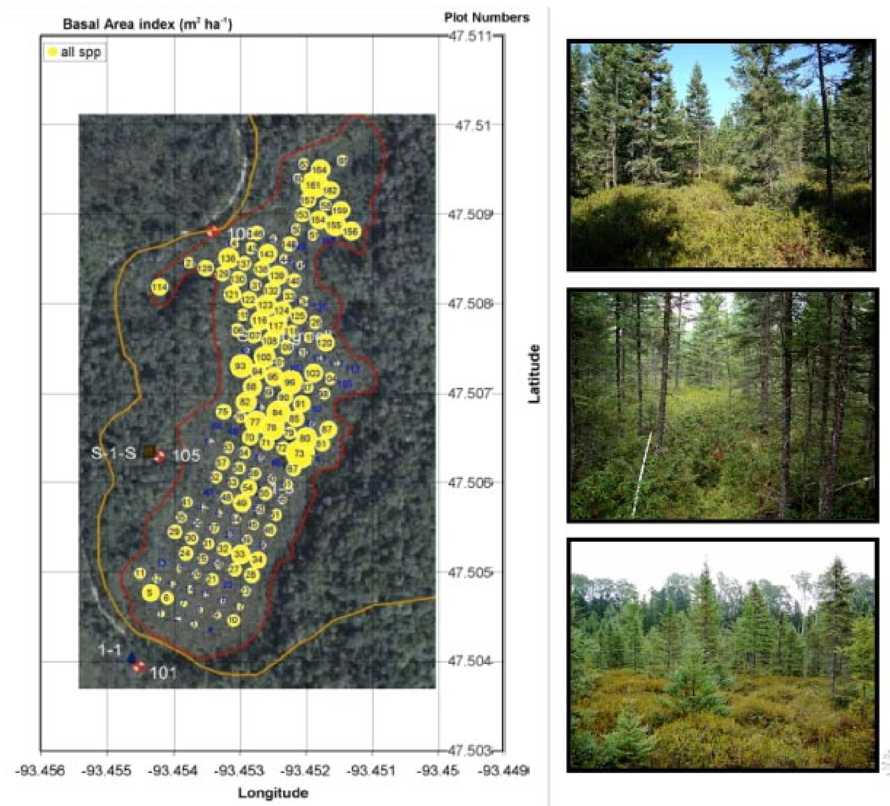


Figure 6. Results of the comprehensive bog vegetation survey collected in September of 2010 and associated photographs of the bog vegetation from south to north. These data showed mean tree heights to be variable by past forestry manipulations and indicated that the SPRUCE experimental treatments should be positioned within the "1974 cut" zones of the bog.

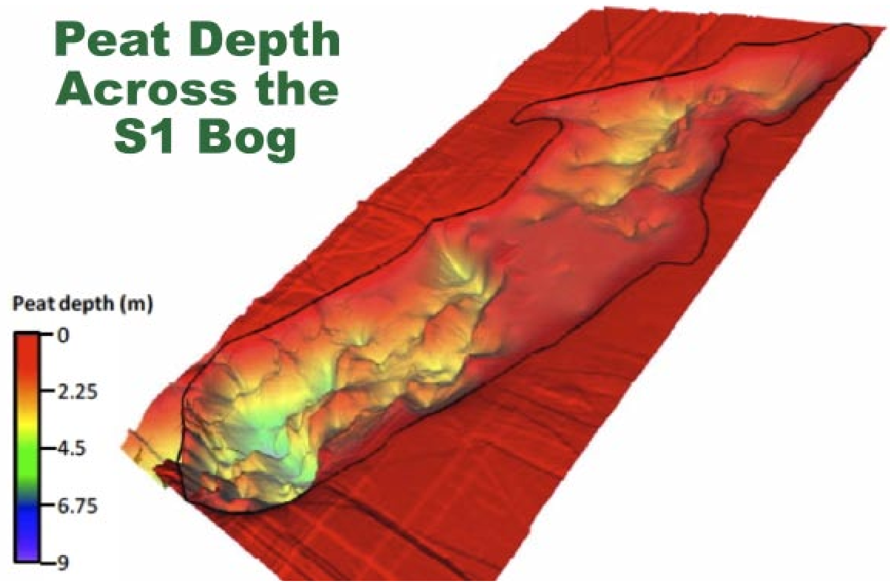


Figure 7. A 3D reconstruction of the peat thickness for the S1 Bog of the Marcell Experimental Forest based on > 8000 ground penetrating radar observations. These data suggested that experimental treatment blocks should not be placed in the central zone of the S1 bog where peat depths were shallow.

Data Management Plan

An initial data management plan for SPRUCE was completed in March 2010 and posted in final operational form on the SPRUCE web site in May 2010. This plan, developed by Les Hook, resulted from group discussions and interactions over the past 6 months and will form the basis for quality assuring and protecting our data collections in support of the SPRUCE experiment that is expected to last from pretreatment collections starting in 2011 through anticipated completion of the study in 2023 (we anticipate initiate experimental treatments in March of 2013 for full decade of manipulations.

Evaluation of time-zero measurement protocols

Task leads and individual investigators on the SPRUCE project are using the available lead-time in FY 2010 to fully evaluate and test measurement protocols to be initiated during the pretreatment years of 2011 and 2012. Field campaigns are either underway or planned throughout the rest of 2010 to evaluate and choose appropriate methods for assessing (1) physiological responses, (2) growth dynamics and net primary production, (3) important biogeochemical stocks, fluxes, and isotopic signatures for C, N and other potentially limiting elements, (4) robust methods for microbiological assessments, (5) hydrologic responses and (6) gathering data relevant to parameterize one or more models for SPRUCE.

Technical description of our new belowground warming method

A paper justifying our new belowground warming approach was submitted, reviewed and accepted for publication in *Global Change Biology* (Hanson et al. in press). This paper demonstrates the capacity of our new approach to produce logical temperature differentials both above and belowground to depths of at least 2 meters, and further indicated that the new method may produce disproportionately high carbon dioxide emissions from deep soil storage pools or enhanced root activity that have not been previously observed in warming studies. We look forward to further testing of these concepts at the 12-m diameter scale.

C. Details of Walker Branch progress

NEON preparations

Walker Branch Watershed has been selected to be one of 20 core sites in the NSF-sponsored National Ecological Observatory Network (NEON). The NEON activities in Walker Branch have gone through the ORNL NEPA review process and received approval. A Memorandum of Agreement between DOE and NSF has been signed indicating the intent of both parties to collaborate on the Walker Branch NEON site. A land-use permit has been drafted between DOE Real Estate and NEON Inc. (NSF's corporation to construct and operate NEON) for access and use of selected areas of Walker Branch for the construction and operation of NEON instrumentation.

NEON will deploy a large amount of instrumentation in Walker Branch to measure climate, biophysical, chemical, and biological characteristics of the forest and stream over a 30-year period. Included will be a new eddy covariance tower for measurement of atmosphere-forest gas exchange. Walker Branch will also be one of 10 sites at which NEON will conduct a long-term (10+ year) stream nutrient addition and consumer exclusion experiment to better understand the response of stream ecosystems to changes in key drivers and community structure.

Update of long-term data records and the Walker Branch website:

The long-term data records on climate (daily), hydrology (hourly, daily, and annual precipitation; 15-min, daily, and annual stream flow), atmospheric chemical deposition (via NADP site), and stream chemistry (weekly) have been updated through 2009. Vegetation data from periodic surveys beginning in 1967 have been updated to include the 2006 survey data. These data are available via the Walker Branch Watershed website (http://walkerbranch.ornl.gov/) which has recently been extensively renovated to make it more visually appealing and navigable, more informative, and easier to download historical data. Analysis of the long-term climate and hydrology record since the weirs were installed in Walker Branch (1969) indicates several significant trends (Figure 8).

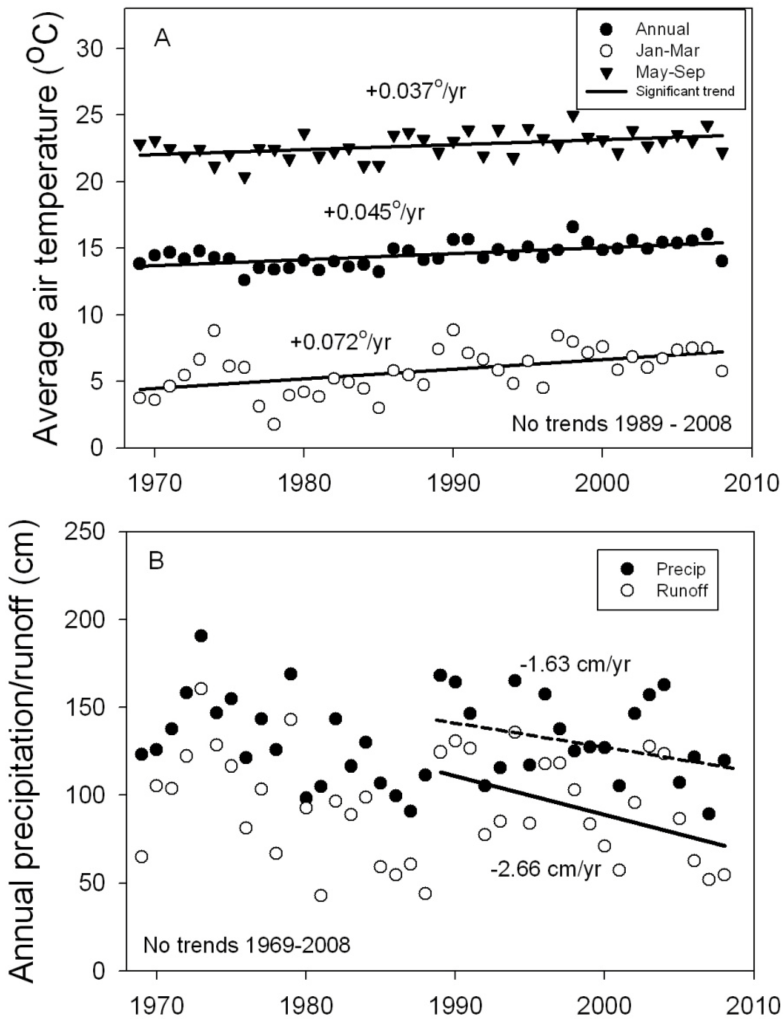


Figure 8. Long-term record of (A) average air temperature and (B) hydrology for the West Fork of Walker Branch. Significant trends are indicated by the solid lines ($P < 0.05$). Dashed line indicates marginally significant trend
(P 0.10). Precipitation and runoff trends are significant only for the period 1989-2008 (period over which stream chemistry at weekly intervals).

Long-term vegetation analysis

Analysis of the long-term vegetation record has been completed and a manuscript is now in press in *Vegetation Science* (Kardol et al. in press). Over four-decades of observation (1967-2006), forest communities underwent successional change and substantially increased their biomass. Variation in summer drought and growing season temperature contributed to temporal biomass dynamics for some tree species, but not for others. Stand-level responses to climatic variability were shown to be related to responses of component species; however, not for Pine stands. *Pinus echinata*, the dominant species in Walker Branch pine stands, decreased over time due to periodical outbreaks of the pine bark beetle (*Dendroctonus frontalis*). The outbreaks on Walker Branch could not be directly related to climatic conditions. Our results indicate that sensitivity of developing forests to climatic variability is stand-type dependent, and hence, is a function of species composition. On successional time scales, direct effects of climatic variability on forest dynamics may be small relative to autogenic successional processes or climate-related insect outbreaks. Empirical studies testing for interactions between forest succession and climatic variability might be considered in the future.

Analysis of long-term stream chemistry patterns:

Analysis of long-term stream chemistry patterns (20-year record) and preparation of a manuscript has progressed. Concentration patterns over time varied by solute. Many solutes showed distinct seasonality, most with late summer maxima when base flows are lowest, although SO4 concentrations were lowest at this time (Figure 9). Dissolved organic carbon (DOC) is generally low year-round, but slightly higher in autumn after leaf-fall. Concentrations of some solutes showed strong relationships with discharge. Ca, Mg, and to a lesser extent Si, were diluted by increasing discharge, whereas SO_4 concentration increased with discharge. Concentrations of NO_3 and soluble reactive phosphorous (SRP) were variable at low discharge, but generally low at high discharge. Concentrations of Na, Cl, NH_4, and DOC were poorly related to discharge.

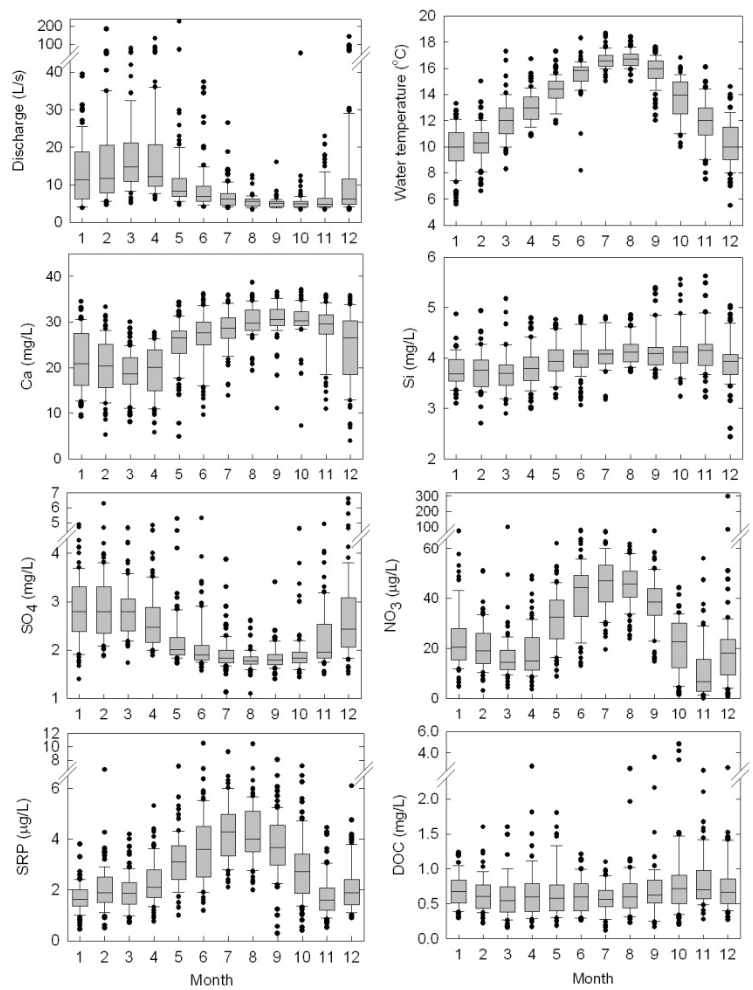


Figure 9. Box plots of monthly concentrations of solutes showing seasonality over the period 1989 – 2008. Mg is not shown because it has a very similar pattern to Ca. TSN and TSP are not

shown because their patterns are very similar to NO3 and SRP, respectively. Plots display 5th, 25th, 50th, 75th, and 95th percentiles and individual data points outside the 5th and 95th percentiles.

To determine the primary determinants of stream water concentrations, we modeled solute concentrations using a multiple linear regression approach that accounted for long-term linear trend, contemporaneous and antecedent stream flows, seasonality associated with phenological events (spring algal bloom prior to leaf emergence, summer period of low energy inputs in the form of organic matter and light, fall input of leaves), and temperature effects on in-stream (instantaneous water temperatures) and soil (1 week and 1 month antecedent air temperatures) processes. Models for most solutes indicated significant trends over time, and significant effects of contemporaneous stream flow and 1- and 5-year antecedent stream flow. The long-term trends were almost all positive and were strongest for NH_4, total soluble N (TSN), total soluble phosphorous (TSP), and DOC, all of which exceeded 2%/year. All solute concentrations showed significant effects of seasonality independent of flow seasonality (phenological events). Seasonality was particularly strong for NO_3 and TSN, with a large maximum in summer, a deep minimum in autumn, and smaller maximum and minimum in winter and spring, respectively. Seasonality is also quite strong for SRP and TSP, but with only one maximum in summer and minimum in autumn. DOC also shows a small autumn maximum. Seasonality was small for those solutes primarily under hydrological and geochemical control (Ca, Mg, Si, SO_4) and variation in these solutes was primarily driven by the hydrological terms in the model. Air temperature anomalies at weekly and/or monthly scales were important parameters in most of the nutrient solute models, suggesting that soil temperature may be an important determinant of stream concentrations. Weekly stream temperature anomaly was significant only for TSN and DOC, suggesting that stream temperature may not be an important regulator of stream nutrient concentrations.

All solutes, except NH4 and DOC, showed significantly declining trends in annual exports over time (Figure10). This appears to be primarily the result of a statistically significant declining trend in runoff (-2.66 cm/yr) over this same period. Exports of all solutes were strongly positively related to runoff, as expected. Annual runoff explained >85% of variation in annual export of Ca, Mg, Na, Si, Cl, SO4, and SRP, >70% of the variation in annual export of NH4 and NO3, and >50% of annual export of TSN and TSP. Annual runoff explained only 33% of the variation in annual export of DOC, however.

These results are important because they demonstrate the importance of phenological events related to the forest vegetation (shading in late spring and summer reducing light levels, autumn leaf-fall) in controlling stream nutrient concentrations. They also show the strong effect of both contemporaneous as well as antecedent stream flow conditions (droughts, wet periods) on the concentrations of most solutes. Finally, although there were small positive trends in the concentrations of some solutes, particularly NO3, exports of most solutes declined over the 20-year period due to a declining trend in annual runoff. It is not clear if these trends will continue or are part of a long-term cyclic pattern in precipitation.

Review of stream nutrient dynamics

A paper reviewing the history, current understanding, and future research needs in stream nutrient dynamics was published in early 2010 (Mulholland and Webster 2010). Improved understanding of rates and controls on nutrient cycling in streams have led to better models of nutrient transport, transformation, and export from streams and from large river basins. Among the most pressing needs is additional research to resolve: 1) the residence time and ultimate fate of nutrients (particularly N) taken up in streams, 2) the rates and controls on nutrient uptake in large rivers, and 3) effects of climate change on streams and rivers.

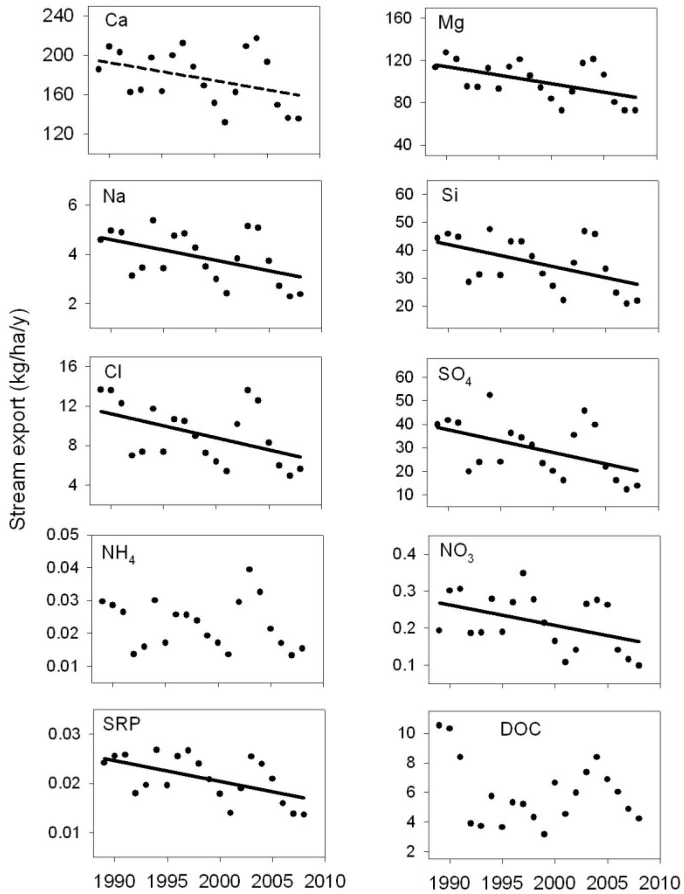


Figure 10. Trends in solute exports (kg/ha/y) over time. Lines represent statistically significant trends ($P < 0.05$).

D. Response SFA Publications in FY2010

Newly completed publications in FY2010 related to the SPRUCE experiment, publications from the ongoing observational work on Walker Branch Watershed, and publications finalized in FY2010 from prior and related climatic change experimental research are summarized below. Highlights for publications reaching final publication with page numbers have posted highlights on the Environmental Sciences Division, Ecosystem Science Group's web site (http://www.esd.ornl.gov/ecosystem_science/).

<u>SPRUCE Experiment Publications</u>

Hanson PJ, Childs KW, Wullschleger SD, Riggs JS, Thomas WK, Todd DE, Warren JM (in press) A method for experimental heating of intact soil profiles for application to climate change experiments. *Global Change Biology* DOI: 10.1111/j.1365-2486.2010.02221.x

Walker Branch Publications

Kardol P, Todd DE, Hanson PJ, Mulholland PJ (in press) Long-term successional forest dynamics: species and community responses to climatic variability. *Vegetation Science*.

Koirala SR, Gentry RW, Mulholland PJ, Perfect E, Schwartz JS (2010) Time and frequency domain analyses of high-frequency hydrologic and chloride data in an east Tennessee watershed. *Journal of Hydrology* 387:256-264.

Mulholland PJ, Webster JR (2010) Nutrient dynamics in streams. *Journal of the North American Benthological Society* 29:100-117.

Publications form Prior Climate Change Response Research

Amthor JS, Hanson PJ, Norby RJ, Wullschleger SD (2009) A comment on "Appropriate experimental ecosystem warming methods by ecosystem, objective, and practicality" by Aronson and McNulty". *Agricultural and Forest Meteorology* 150: 497-498.

Castro HF, Classen AT, Austin EE, Norby RJ, Schadt CW (2010) Precipitation regime is the major driver of changes in soil microbial community structure over CO_2 and temperature in a multifactorial climate change experiment. *Applied and Environmental Microbiology* 76:999-1007.

Gunderson CA, O'Hara KH, Campion CM, Walker AV, Edwards NT (in press) Thermal plasticity of photosynthesis: the role of acclimation in forest responses to a warming climate. *Global Change Biology* DOI: 10.1111/j.1365 2486.2009.02090.x

Hanson PJ, Gunderson CA (2009) Root carbon flux: measurements versus mechanisms. *New Phytologist* 184:4-6.

Kardol P, Cregger MA, Campany CE, Classen AT (2010) Soil ecosystem functioning under climate change: plant species and community effects. *Ecology* 91:767-781.

Kardol P, Campany CE, Souza L, Norby RJ, Weltzin JF, Classen AT. (in press) Climate change effects on plant biomass alter dominance patterns and community evenness in an experimental old-field ecosystem. *Global Change Biology* DOI: 10.1111/j.1365-2486.2010.02162.x

Luo Y, Melillo JM, Niu S, Beier C, Clark J, Davidson E, Dukes J, Evans RD, Field CB, Czimczik C, Keller M, Kimball BA, Kueppers L, Norby RJ, Pelini S, Pendall E, Rastetter E, Six J, Smith M, Tjoelker MG, Torn MS (in press) Coordinated approaches to quantify long-term ecosystem dynamics in response to global change. *Global Change Biology* DOI: 10.1111/j.1365-2486.2010.02265.x

Wullschleger SD, Strahl M (2010) Climate Change: A Controlled Experiment. *Scientific American* March 2010, pp. 78-83.

5. Staffing and Budget Summary

A. FY2010 Funding Summary

New funding in the amount of $4,500K was provided in FY2010 to support Response SFA research that was combined with approximately $1,207K of carry over funds from FY2009 for a total operating budget for the Response SFA of $5,707K in FY 2010. This financial commitment included the direct support of 69 science, technical, and various support staff (including 20 key biologists or engineers), costs for actions required to meet our obligations under the National Environmental Policy Act, development and testing of the SPRUCE experimental prototype and infrastructure, and long-term observational research on Walker Branch Watershed as delineated in Table 1.

Table 1. Funding allocation by programmatic task in FY 2010.

Cost Item	Allocation ($K)	Approximate Percent of Annual Expense
SPRUCE Scientific and technical staff	2,000	35
SPRUCE NEPA approval process	200	3.5
SPRUCE prototype development	300	5.2
SPRUCE construction, materials, and travel	1,596	28
Walker Branch	311	5.5
Postdoctoral Research Associate Subcontracts	300	5.2
Anticipated Carry Over Funds for Constructions	1,000	17.5

We anticipate carrying over approximately $1,000K of FY2010 funding into FY 2011 to cover costs of constructing the SPRUCE experimental infrastructure over the next two years.

Effort by individual scientific, engineering, technical and support staff from October 2009 through 18 June 2010 is summarized in Table 2 for the following categories of effort: (1) experimental design, (2) engineering and simulations in support of experimental design, (3) biological and biogeochemical measurements, (4) NEPA approval process, and (5) data management, archiving and web site development.

Table 2. Person hours of effort through 18 June 2010 of FY 2010 by staff person and Response SFA task area.

Person	Org.	Experimental Design	Engineering & Simulations	Biology	NEPA	Data & WWW	Totals
Brice, D	ESD			257.6			257.6
Childs, J	ESD			623			623
Devarakonda, R	ESD					48	48
Garten, C	ESD			287			287
Gunderson, CA	ESD			895			895
Gu, L	ESD			232			232
Hanson, PJ	ESD	500		125.5	200		825.5
Hook, LA	ESD					176	176
Iversen, C	ESD			246.5			246.5
McCracken, MK	ESD			186			186
Mulholland, PJ	ESD			356			356
Norby, RJ	ESD			327.5			327.5
Pan, Y	ESD					25	25
Phillips, JR	ESD			26.5			26.5
Salk, MS	ESD				59		59
Saulsbury, JW	ESD				2		2
Schadt, C	ESD			32			32
Smith, ED	ESD				54		54
Spaulding, B	ESD			120			120
Todd, DE	ESD	400		286	100		786
Thornton, P	ESD			--			--
Warren, J	ESD			113			113

Weston, DJ	BSD			56			56
Wilson, BE	ESD					6	6
Wullschleger, SD	ESD			288			288
Zimmerman, GP	ESD				16		16
Barbier, CN	Comp&Eng		451				451
Childs, K	Comp&Eng		236				236
Belcher, D	Facilities		112				112
Ellis, J	Facilities		23.5				23.5
Jekabsons, EW	Facilities		127				127
Newkirk, GR	Facilities		116.5				116.5
Tavino, C	Facilities		70.5				70.5
Thomas, WK	Facilities		31				31
Other Eng.	Facilities		97				97
Miscellaneous Technical and Craft Staff	Facilities & Instruments	2536					2536
Bradford, J	USDA FS			IKS			IKS
Kolka, R	USDA FS	IKS*		IKS	IKS		IKS
Palik, B	USDA FS			IKS			IKS
Sebestyen, S	USDA FS	IKS		IKS			IKS
Effort by Major Task		3435.6	1264.5	4457.6	431	255	9843.7

*USDA Forest Service in kind support (IKS)

B. Response SFA subcontracts in FY2010

ORISE (postdocs and students - actual and planned)	$309K
Prototype Construction (through 18 June 2010)	$269K
Walker Branch analytical contracts	$ 20K
Rutgers – ground penetrating radar	$ 59K
Lund University – LPJ-WHyMe modeling	$ 27K
SAIC for NEPA (through 18 June 2010)	$ 64K

C. Personnel actions

In FY2010 the Response SFA provide the majority of support to hire two new entry level staff scientists: Dr. Colleen Iversen and Dr. Jeff Warren to supplement our staff in the science of belowground vegetation response, and plant water use responses to climate change, respectively. We are actively seeking multiple post-doctoral research associate positions in the areas of methane production processes, biogeochemical cycling with expertise in isotopic techniques, and belowground productivity.

D. ORNL investments in the Response SFA and related programs

Investments through the ORNL Laboratory Directed Research and Development program (LDRD) of approximately $700K in FY 2008 and 2009, enabled the development of our successful belowground warming technology that is the basis for the experimental design of the SPRUCE experiment.

E. Capital equipment needs

In FY 2010 $200K of operating funds were transferred for the purpose of purchasing state-of-the-science open-path CO_2 and CH_4 sensors for the development of surface level net efflux measurements, and to pursue the development of new methods for assessing whole-enclosure flux within our new 12-m warming prototype enclosure.

Even though the costs for materials to build the SPRUCE experimental infrastructure are anticipated to be significant over the next two years, we do not anticipate that individual components will require capital equipment funds. If this turns out to be an incorrect assumption, we will pursue the process for translating operation to capital funds at a future time.