Climate Change SCIENCE INSTITUTE

Newsletter

DECEMBER 2010 VOLUME 1, ISSUE 8

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE U.S. DEPARTMENT OF ENERGY

LETTER FROM CCSI LEADERSHIP

Happy New Year Everyone!

In many ways, the birth of the Institute was similar to that of a baby elephant—it starts at a very high level, there's a lot of stomping and screaming involved, and it takes two years to get any results.

In a perfect world, we would have developed a strategy, codified it in a plan that involved a broad spectrum of people across the Institute, vetted it with our external advisors, revised it based on their feedback, and then developed a business plan to execute the strategy. As we all know, ORNL is not a perfect world, but neither is any institution. Meshing our plans with those of the Directorates and Laboratory, which are simultaneously undergoing a major re-organization, is bound to produce considerable chaos. Despite all of this confusion, the staff of the CCSI continue to excel at meeting commitments to current and new sponsors, which underpins our hopes for the future.

We continue our steady progress to build a stronger and broader foundation for climate science research at ORNL. Our portfolio of projects from our principal sponsor, DOE-BER has increased dramatically, and ORNL is leading two new major multi-lab initiatives for BER. In addition, our collocation continues to provide opportunities for integration and collaboration.

We are starting 2011 off with an Institute all-hands meeting followed by a CCSI leadership retreat to review our progress, develop plans to address some of the issues which the Institute faces and embark on a path to execute the potential of this great organization.

Thanks to everyone for a great year.

RECENT *NATURE GEOSCIENCE* PUBLICATION HIGHLIGHTS DOE BER FOSSIL-FUEL CO_2 EMISSION ESTIMATES

Each year the Carbon Dioxide Information Analysis Center (CDIAC) at ORNL quantifies the release of carbon from fossil-fuel use and cement production at global, regional, and national spatial scales. The CDIAC emission time series estimates are based largely on annual energy statistics published at the national level by the United Nations (UN). The latest updates based on UN data estimate the global release to be 8.37 billion tons of carbon for 2007 (http://cdiac.ornl.gov/trends/emis/overview_2007.html).

CDIAC also projects fossil-fuel CO_2 emission estimates for two additional years based on data published annually by British Petroleum for select countries. As stated in the Friedlingstein et al. (2010) correspondence to the editor piece of *Nature Geosciences* (http://www.nature.com/naturegeoscience), the growth in CO_2 emissions closely follows the growth in Gross Domestic Product (GDP) corrected for improvements in energy efficiency. The contraction of GDP due to the global financial crisis that began in 2008 resulted in a 1.3% decrease in global fossil-fuel CO_2 emissions from 2008 to 2009. Despite this drop, the 2009 global fossil-fuel and cement emissions were the second highest in human history at 8.4 $\pm$ 0.5 Pg C, just below the 2008 emissions. The global decrease from 2008 to 2009 hides large regional differences. The largest decreases occurred in Europe, Japan, and North America (e.g., USA -6.9%, UK – 8.6%, Germany -7%, Japan -11.8%, Russia -8.4%), whereas some emerging economies recorded substantial increases in their total emissions (e.g., China +8%, India + 6.2%, South Korea (+1.4%).

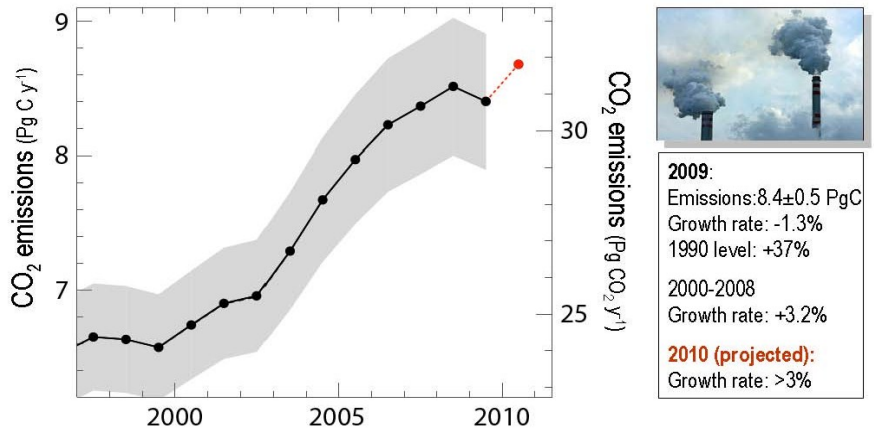

Figure 1. Global CO_2 emissions since 1997 from fossil-fuel use and cement production. Friedlingstein et al (2010)

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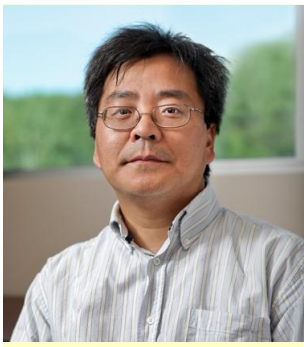
Highlighted Researcher

LIANHONG GU



Growing up in the Jiangsu province of China, Lianhong Gu loved to read, but one book particularly impacted him in his childhood and played a significant roll in the choice of his career path. *What is Life?* by physicist Erwin Schrödinger (famous for winning the Nobel Prize in 1933 for Schrödinger's equation for quantum mechanics) focused on how chemistry and physics could be used as tools to understand life on Earth. The concept was not lost on Lianhong. He went on to receive a BS in physics, but his interest in life never waned.

"I wanted to understand how organisms—how life—operate. I figured that physics or mathematics might be useful in that regard." Thus, Lianhong transitioned from physics to ecology for his MS, but the transition was not immediately straightforward for his mathematical mind.

"If a physicist wants to understand a system, he takes the system apart and examines the parts separately. In ecology, you can't do that. You need to understand how the parts work together to create phenomena at the system level. Physicists don't use words like 'maybe' or 'perhaps.' Ecologists do." Ultimately, Lianhong earned his MS in ecology and traveled to the U.S. to earn his PhD in environmental science before joining ORNL in 2002.

When he is not measuring atmospheric carbon uptake or referring for a scientific journal, Lianhong enjoys listening to traditional Chinese music (he hopes to learn to play one day) and writing.

Lianhong Gu is a senior research and development staff scientist in the Environmental Sciences Division. He received his BS is physics from Xuzhou Normal University in China in 1986, continuing on to obtain his MS in ecology from the Chinese Academy of Sciences and his PhD in environmental sciences from the University of Virginia (UVA) in 1989 and 1998, respectively. Prior to his appointment at ORNL, Gu held the position of project scientist/associate specialist at the University of California-Berkeley's Department of Environmental Sciences and research associate in the Department of Environmental Sciences at UVA.

Gu possesses expert knowledge in a number of environmental and meteorological instruments such as portable photosynthesis systems, soil chambers, trace gas/isotopic analyzers, sonic and cup anemometers, hygrometers, radiometers, spectroradiometers, infrared thermometers, leaf area meters and data loggers. He is proficient in C, C++, and Fortran programming languages, as well as Windows and Linux operating systems. Gu is also familiar with the structure and operation of eddy covariance flux tower systems, numerical analysis, statistics, and various software such as MatLab and SigmaPlot. He is experienced with large dataset management and analysis, and knowledgeable in solar power systems, electrical and electronic circuit analyses.

He is a member of Sigma Xi—the Scientific Research Society—as well as the American Geophysical Union and the Ecological Society of America. Gu has not only refereed for more than a dozen preeminent journals including Nature, Global Change Biology, The New Phytologist, and Geophysical Research Letters, he has also authored or co-authored numerous letters for these publications.

Gu's current work includes several collaborative, cross-disciplinary projects, one for which he is the principal investigator (PI).

PI for the Missouri Ozark AmeriFlux site (FY02-Ongoing)

The AmeriFlux network was established in 1996 and includes more than 120 independently funded sites operating across North America, Central America and South America. AmeriFlux sites include tundra, grassland, agricultural crops, tropical forests and temperate coniferous and deciduous forests. The diversity of AmeriFlux sites greatly expands upon the contributions of other regional networks. AmeriFlux sites have provided a sustained set of detailed observations of ecosystem level exchanges of CO_2, water, energy and momentum on an hourly basis, spanning diurnal, synoptic, seasonal, and interannual time scales. These data have provided a wealth of information on how diverse ecosystems respond to changes in their physical environment, and how they affect their environments. Contributions to carbon cycle science include understanding the variation in net carbon uptake with interannual variation in climate and the influence of disturbance on carbon storage and fluxes.

Figure 2. Missouri Ozark Flux Tower (Photo credit: *Steve Pallardy of the University of Missouri)*

The Missouri site is located in the University of Missouri Baskett Wildlife Research Area, situated in the Ozark region of central Missouri (Figure 2). The site is uniquely located in the ecologically important transitional zone between the central hardwood region and the central grassland region of the U.S. Other CCSI researchers contributing to the Missouri Ozark AmeriFlux site are Paul Hanson, Bai Yang and Stan Wullschleger.

Co-developer of LeafWeb (FY10-Ongoing)

LeafWeb is a SErvice-in-Exchange-for-Data-Sharing (SEEDS) Project. The objective is to develop a global database of biochemical, physiological, and biophysical properties of

single leaves to support studies of plant functions and terrestrial carbon cycle modeling. LeafWeb provides automated numerical analyses of leaf gas exchange measurements. With the approval of the user, the data LeafWeb receives are preserved and captured. This effort is part of ongoing research and data management activities in the area of climate change science at Oak Ridge National Laboratory.

As investigators use LeafWeb and contribute their data, the resulting "global leaf database" will grow and be freely available from the Carbon Dioxide Information Analysis Center (CDIAC). The value of a particular set of leaf gas exchange measurements depends largely on supporting information about the leaf or leaves. It is crucial to provide not just the gas exchange data but also complementary information necessary to interpret the data and put the leaf in context.

The initial field data used to test LeafWeb's data analysis capability came from the Missouri Ozark AmeriFlux site.

ORNL Climate Change Forcing Program-Extreme Events (FY08-Ongoing)

This project studies the ecological impacts of extreme weather and climate events such as droughts, hurricanes, ice storms and natural fire. When a large meteorological event happens, it requires climate scientists to act rapidly to glean all the information possible about the event, so unlike other projects that follow guidelines set in proposals, this project operates according to the occurrence of extreme events. One of Gu's current efforts involves studying how ice storms affect forest structure. A massive ice storm in southern china in 2008 is his prime model. He and other scientists use remote sensing data to try to understand the impact of that ice storm on carbon uptake in China.

Figure 3. One of the extreme events Lianhong Gu studied. (Photo credit: Zhongmin Wu of Chinese Academy of Forestry)

What role does your research play in climate change research?

"My research contributes to understanding how the climate system operates and how the dynamics of the climate system can be effectively represented in computer codes. Currently, I pursue my research in three related areas. The first is the carbon, water, and energy balances of terrestrial ecosystems. The main tool I use in this area is a powerful technique called eddy covariance which consists of a set of very fast response instruments and measures essentially everything that goes between the Earth surface and the overlying atmosphere. The measurements obtained with this technique are a critical source of information for understanding how ecosystems respond to climate change and for testing land surface and ecosystem models.

The second is to use the latest knowledge gained from detailed process studies to improve climate models. This is done by constantly asking two questions: what important processes are missing in current climate models, and for processes already represented in current models, can they be improved? An example of my effort in this area can be found in leafweb.ornl.gov.

The third area of my research is the ecological impacts of climate and weather extreme events such as droughts, heat waves, cold waves, and freezing rains. My favorite example is our study on the 2007 Easter Freeze which was reported in *Bioscience*."

Who is the customer for your research?

"I always view society as the customer for my research, although DOE provides the direct funding."

Why is it important to you, personally, to become involved in climate change research?

"Curiosity has always been a factor in my research. However, I also feel a sense of responsibility to society as climate is such a defining force for humanity."

In what direction do you see the future of climate change research going?

"The future of climate change research is in climate variables, extreme events, and the impacts on organisms and ecosystems. The evolution of ecological and human systems is shaped not by the change in mean climate conditions, but by fluctuations in climate. It is so much more difficult to study fluctuations than means, but that is what national labs are built for – difficult studies."

Highlighted Research

SEACISM

A SCALABLE, EFFICIENT AND ACCURATE COMMUNITY ICE SHEET MODEL

Continental ice sheet models are currently the 'frontier' of global climate modeling as they are just now being coupled to global Earth system models. For example, a testbed version of the Community Ice Sheet Model (CISM) named Glimmer-CISM (in a nod to the code base, Glimmer, from which it was developed, see http://developer.berlios.de/projects/glimmer-cism) has recently been integrated with the Community Earth System Model (CESM). This version of Glimmer-CISM is serial and solves simplified equations considered important to fully capture ice sheet dynamics. A more complete Glimmer-CISM is being extended by the SEACISM (a Scalable, Efficient, and Accurate CISM) project which is an ORNL-led effort with collaborators at Sandia National Laboratories (SNL), Los Alamos National Laboratory, New York University, and Florida State University. SEACISM is tasked to enable important simulations for the next IPCC (Intergovernmental Panel on Climate Change) report, due out in 2013.

SEACISM, part of the DOE Office of Advanced Scientific Computing Research (ASCR) ISICLES initiative, began in September 2009 to develop Glimmer-CISM to be able to produce simulations that resolve features needed to accurately predict the dynamics of continental ice sheets. One example of smaller scale ice sheet behavior with continental scale influence is the grounding line , which is the line where ice separates from the bedrock and subsequently travels orders of magnitude more quickly. SEACISM is extending a version of Glimmer-CISM that solves more complete ice equations such that the Greenland ice sheet can be simulated at the 1km scale in reasonable time and with demonstrated numerical accuracy of dynamics, including the grounding line. To achieve this goal, the project is implementing distributed parallelism designed for multicore architectures and numerical methods that continue to perform robustly at large computing scales. SEACISM researchers are also developing a new locally refined unstructured finite element grid dynamical core for the scalable Glimmer-CISM to allow local refinement and more accurate results. As an added motivator, SEACISM has promised to deliver the efficiency gains within Glimmer-CISM within the next calendar year so ice sheet scientists can make production runs for the next IPCC report.

Given the simplicity of ice sheet models when the last IPCC report came out, the IPCC AR4 report did not provide an estimate of sea level rise. IPCC projections did include the observed increased ice sheet flow rates from Greenland and Antarctica from 1993 to 2003, but no information about the change in flow rates could be determined. Instead, the summary for policymakers stated that "models used to date do not include uncertainties in…the full effects of changes in ice sheet flow…" and "…understanding of these effects is too limited to assess their likelihood or provide a best estimate or an upper bound for sea level rise." For the next report, the IPCC has tasked ice sheet modelers with the ability to provide predictions and uncertainties of sea level rises due to ice sheet dynamics variations (IPCC cite). With research papers cited by the report due out in 2013, modelers must produce suites of high resolution production simulations in 2011 and run a version of the model coupled to the ocean to be able to make sea level predictions.

The SEACISM project team just presented its midterm report to the DOE ASCR sponsor and the ice sheet modeling community at the CESM's land ice working group meeting in Boulder, CO, January 12-13, 2011. The presentation highlighted test case results from Glimmer-CISM on the Oak Ridge Leadership Computing Facility's Jaguar using a new nonlinear solver within a scalable and flexible framework, Trilinos. Recently submitted to the *Journal of Computational Physics*, a premier journal for computational science developments, SEACISM collaborators demonstrated an order of magnitude reduction of in the number of iterations to reach solutions for a suite of test cases used by the ice sheet modeling community (Figure 4). This translates to a 2-3 times increase in efficiency for the model along with superior accuracy in the ice sheet balance velocities. (Lemieux et al., (2011)). Ongoing efforts to produce solutions at finer resolutions (5km and finer) involve working with the ice sheet community to create new high-resolution input datasets that properly account for the complex and non-smooth terrain of Greenland.

Within CCSI, project member Pat Worley has been analyzing Glimmer-CISM performance characteristics to identify and quantify areas of improvement. "Pat's comprehensive knowledge of the CESM has been invaluable to our efforts to create a robust Glimmer-CISM that will couple easily with the CESM," says Principal Investigator Kate Evans. A more recent addition to the team, postdoctoral research associate Jeff Nichols, has been designing and implementing the distributed parallelism begun by Trey White last year. Evans, of Nichols, reflects that, "its not easy to take over someone else's design and turn it into a working model in such a short time and with great pressure to deliver, but Jeff has delivered a testbed parallel code with great potential for efficient simulation on very large platforms." In addition to efforts by CCSI members, Evans has been working with Andy Salinger at SNL to implement the Trilinos framework so that optimally tuned and scalable numerical methods can be tested and extended. Results from Greenland ice sheet simulations using the Trilinos code base

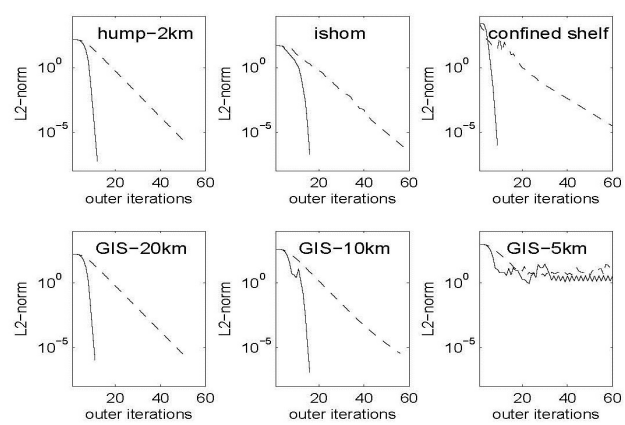


Figure 4. Convergence tolerance versus the number of iterations using the original Glimmer-CISM solution method (dashed line- Picard method) compared to the new Newton-Krylov method, reusing the Picard method as a preconditioner (solid line) for the suite of test cases for model evaluation of the higher-order Glimmer-CISM.

SEACISM (CONT.)

within Glimmer-CISM with 5km and 2km resolution of Greenland were presented at the American Geophysical Union conference this past December by ice sheet modeler and the CESM's Land Ice Working Group co-chair Steve Price of LANL. These simulations showed that, with finer spatial resolution, ice thinning associated with a change in the stress balance occurred more along the ice channel rather than radially propagating outward from the source, which is closer to observations (Figure 5).

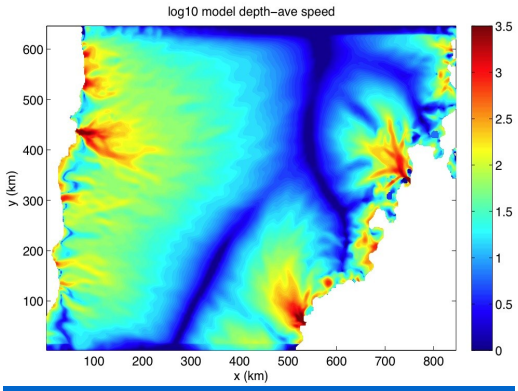


Figure 5. *Balanced velocity norm from a 2km resolution simulation of the Greenland ice sheet using the new Trilinos solver framework. Courtesy S. Price of LANL.*

Concurrent to efforts within CCSI, an effort by postdoctoral research associate Mauro Perego and software engineer John Burkhardt of Florida State is underway to design the next-generation of Glimmer-CISM to incorporate a variably sized mesh finite element version of the code. "It' all about extensibility," explains Evans. "Although we have to deliver for ice sheet science needs in the short term, we want to create an environment for ice sheet model developers to add new complexities relevant at finer spatial scales." SEACISM also designs with a general structure to allow for the methods developed within Glimmer-CISM to be included in other parts of the CESM. The project is grateful for its ASCR funding as well as an ASCR Leadership Computing Challenge (ALCC) Grant for 6 million computing hours on Jaguar and Argonne Leadership Computing Facility's Intrepid to perform this research.

Citations:

IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Lemeiux, J.F., S. Price, K. Evans, D. Knoll, A. Salinger, D. Holland, T. Payne (2011) "Implementation of the Jacobian-free Newton-Krylov method for solving the first-order ice sheet momentum balance" J. Comp. Phys, submitted.

CALENDAR

91st Annual Amer. Meteorological Society Meeting (Seattle, WA)…… 23-27 January 2011
International Land Model Benchmarking Project - ILAMB (Irvine, CA)……24-26 January 2011
Energy, Utility and Environmental Conference 2011 (Phoenix, AZ) …… 31 Jan- 02 Feb 2011
AmeriFlux Science Meeting & 3rd NACP All-Investigators Meeting (New Orleans)…… 31 Jan—4 Feb 2011
ASETSDefense 2011: Sustainable Surface Engineering for Aerospace and Defense (New Orleans, LA)…… 8-11 Feb 2011
Amer. Assoc. for the Advancement of Science Annual Meeting (Washington, DC)……17-21 Feb 2011
1st INTERFACE (Integrated Network for Terrestrial Ecosystem Research on Feedbacks to the Atmosphere and Climate): How do we improve Earth System Models? (Captiva Island, FL)……28 Feb - 3 March 2011
Resilience 2011 (Tempe, AZ)……11-16 March 2011
American Physical Society (APS) March Meeting (Dallas, TX)……21-25 March 2011
The 5th International Conference on Community Based Adaptation (CBA) to Climate Change (Dhakar, Bangladesh) ……24-31 March 2011
Greenhouse 2011 (Queensland, Australia) ……4-8 April 2011
ICARUS-II: Vulnerability and Adaptation: Marginal Peoples and Environments (Ann Arbor, MI) ……5-8 May 2011
Colorado Conference on Earth System Governance (CSU, Fort Collins, CO)……17-20 May 2011
Conference on Adaptation to Climate Change in Low-Income Countries (Washington, DC) ……18-19 May 2011
World Environmental and Water Resource Conference (Palm Springs, CA)……22-26 May 2011
Impact Assessment and Responsible Development for Infrastructure, Business and Industry (Puebla, Mexico) ……28 May - 4 June 2011
Resilient Cities (Bonn, Germany) ……3-5 June 2011
16th Annual CESM Workshop (Boulder, CO) ……20-23 June 2011
2011 SciDAC Conference (Denver, CO)……10-14 July 2011
Federation of Earth Science Information Partners Summer Meeting (Santa Fe, NM)……12-15 July 2011
TeraGrid '11 (Salt Lake City, UT)……18-21 July 2011
19th Conference on Applied Climatology (Asheville, North Carolina)……18–20 July 2011
Third International Conference on Climate Change (Rio De Janeiro, Brazil)……21-22 July 2011
Community Earth System Modeling Tutorial (Boulder, CO)……1-5 August 2011
96th Annual Ecological Society of America Meeting (Austin, TX)……7-11 August 2011
Fifth Intl. Conference on Flood Management (Tsukuba, Japan)……27-29 September 2011
ASA, CSSA, and SSSA International Annual Meetings (San Antonio, TX)……16-19 October, 2011
ICCCGW 2011: International Conference on Climate Change and Global Warming (Venice, Italy)……23-25 November 2011
Partners in Environmental Technology Technical Symposium and Workshop (Washington, DC)……29 Nov–1 Dec 2011
92nd Amer. Meteorological Society Meeting (New Orleans, LA)……22-26 January 2012
AAAS Annual Meeting (Vancouver, Canada)……16-20 Feb 2012
2012 Ocean Sciences Meeting (Salt Lake City, UT)……20–24 February 2012

OAK RIDGE CLIMATE CHANGE SCIENCE INSTITUTE

One Bethel Valley Road
P.O. Box 2008, MS-6301
Oak Ridge, TN 37831-6008

Phone: 865-574-5435
Fax: 865-574-6476
E-mail: climatenews@ornl.gov

We're on the Web!
www.climatechangescience.ornl.gov

RECENT PUBLICATIONS

Chen X, Post WM, Norby RJ, Classen AT. Modeling soil respiration and variations in source components using a multi-factor global climate change experiment. Climatic Change, DOI 10.1007/s10584-010-9942-2

Garten CT, SD Wullschleger, and AT Classen (2011) Review and model-based analysis of factors influencing soil carbon sequestration under hybrid poplar. Biomass and Bioenergy 35: 214-226.

Garten CT, DJ Brice, HF Castro, RL Graham, MA Mayes, JR Phillips, WM Post, CW Schadt, SD Wullschleger, DD Tyler, PM Jardine, JD Jastrow, R Matamala, RM Miller, KK Moran, T Vugteveen, RC Izaurralde, AM Thomson, TO West, JE Amonette, VL Bailey, FB Metting, and JL Smith (2010) Response of "Alamo" switchgrass tissue chemistry and biomass to nitrogen fertilization in west Tennessee, USA. Agriculture, Ecosystems, and Environment (in press).

Kardol P, Reynolds WN, Norby RJ, Classen AT. 2011. Climate change effects on soil microarthropod abundance and community structure. Applied Soil Ecology 47: 37-44.

Schwalm CR et al. (2010) A model-data intercomparison of CO_2 exchange across North America: Results from the North American Carbon Program site synthesis. Journal of Geophysical Research 115: G00H05.

Coming in January

Highlighted Researcher: Patrick Mulholland
Highlighted Research: ARM Archive

Developing and executing programs for the multi-agency, multi-disciplinary climate change research partnerships at Oak Ridge National Laboratory.

CURRENT CCSI JOB OPPORTUNITIES

We seek motivated individuals across a range of educational and professional experience including M.S. through Ph.D. academic qualifications at junior, as well as senior levels of experience to address some of the most pressing questions in global climate change science. You can view complete staff position descriptions and apply at http://jobs.ornl.gov. Postdoctoral and post-master's research position descriptions and online application are at http://www.orau.org/ornl/postdocs/ornl-pd-pm/default.aspx.

- Climate Computational Scientists
- CCSI Administrative Assistant
- Postdoctoral Research Associates