Climate Change SCIENCE INSTITUTE

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

Quarterly Newsletter

LETTER FROM CCSI LEADERSHIP

Greetings from Oak Ridge, Tennessee,

After a long, hot summer, fall is in the air…finally. According to the National Oceanic and Atmospheric Administration, summer of 2012 was the third hottest on record and the period of January through August was the warmest first eight months of any year on record. Drought affected over half the nation and it was another big year for wildfire out west. Will this trend continue and what will be the impacts on an increasingly warmer world? CCSI conducts a wide array of interdisciplinary research to answer that question. This newsletter and our website (http://ccsi.ornl.gov) will highlight on-going high impact research being conducted at our facilities at Oak Ridge National Laboratory.

For FY2012, CCSI researcher made significant contributions to the scientific literature. CCSI productivity included:

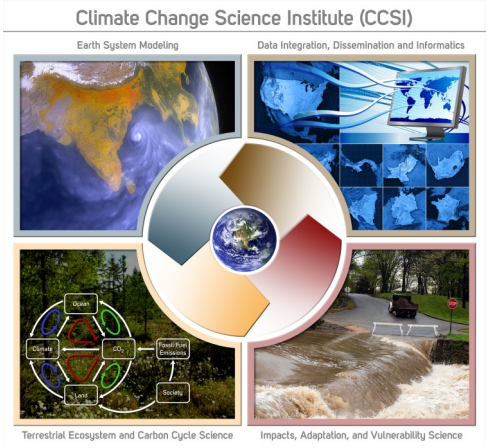
136 Peer-reviewed publications
178 Scientific presentations/posters
80 Conference or workshops organized or attended
38 Leadership roles in national and international planning related to climate change science

Another achievement was the recognition of Paul Hanson as a UT-Battelle Corporate Fellow (see page 3). This distinction is given to ORNL scientists who have made outstanding contributions to science and technology throughout their careers. In addition to Dr. Hanson, CCSI boasts three additional Corporate Fellows: Drs. Virginia Dale, Richard Norby, Thomas J. Wilbanks.

Sincerely,
Jim, Gary, Ben, & John

MISSION STATEMENT

To advance the understanding of the Earth system, describe the consequences of climate change, and evaluate and inform policy on the outcomes of climate change responses



CCSI on the Web

The Climate Change Science Institute website can be found at http://ccsi.ornl.gov. Website content is currently being updated. Please check the website for new information in the coming weeks.

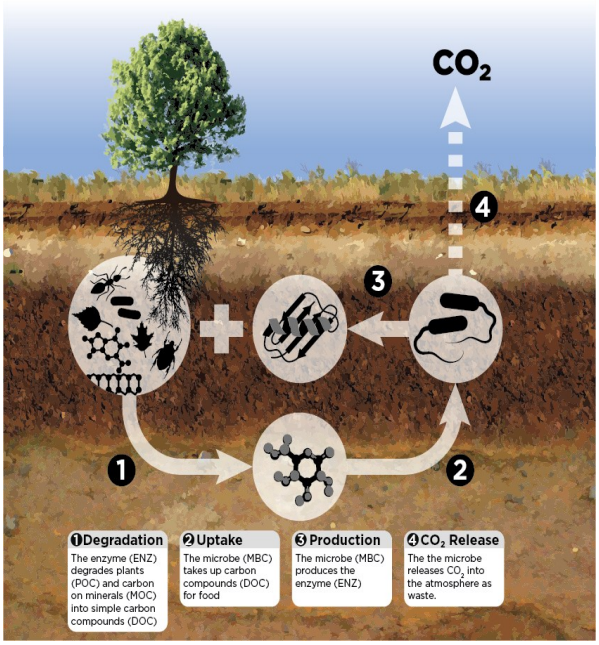
CCSI on Facebook

The Climate Change Science Institute can now be found on Facebook. Facebook will be used to highlight CCSI research as well as other noteworthy climate change news. Please 'like' us and join the conversation

CCSI LEADERSHIP TEAM: James J. Hack, Director; Gary K. Jacobs, Operations & Business Development Manager; Benjamin L. Preston, Deputy Director; John Sanseverino, Project Manager. **For more information:** E-mail us at climatenews@ornl.gov or call 865-576-9093.

CCSI Researchers Develop Improved Soil Carbon Cycle Model

A new carbon cycling model developed at ORNL's Climate Change Science Institute better accounts for the carbon dioxide-releasing activity of microbes in the ground, improving understanding of the role soil will play in future climate change. In a paper published in Ecological Applications (doi: 10.1890/12-0681.1.), the journal of the Ecological Society of America, authors Gangsheng Wang, Wilfred Post, and Melanie Mayes, integrated data from scientific literature on carbon degradation in soil to form the Microbial-Enzyme-mediated Decomposition, or MEND, model that improves upon previous models.



Predicting climate change depends heavily on the cycling of carbon dioxide, which is found in four main reservoirs: the atmosphere, biosphere, oceans and soil. ORNL's model was designed to replace traditional soil carbon cycling models.
"Soil is a big reservoir of carbon," said co-author Melanie Mayes of CCSI and ORNL's Environmental Sciences Division. "Most of the soil carbon cycling models in use today are so vastly simplified that they ignore the fact that decomposition is actually performed by microbes. Our MEND model does a better job of representing the mechanisms of soil carbon decomposition than existing models," Mayes said.

ORNL's comprehensive model accounts for how the different forms of carbon in soil, or "pools," react with extracellular enzymes excreted into the soil by microbes, allowing scientists to understand how quickly carbon is moving through soils.
The model simulates the carbon cycle, beginning after a decaying plant or animal releases carbon-rich materials into the soil. The organic material is degraded by enzymatic reactions, releasing dissolved carbon molecules that can be absorbed by microbes for growth or metabolism. These processes ultimately result in the release of carbon dioxide.

The MEND model is the first model able to track degradation by accounting for most of the relevant processes and by estimating the parameters based on a comprehensive literature review. This model, which is based on the physiological functions of microbes, accounts for how temperature affects the ability of microbes to emit carbon dioxide. Soil can either store or release carbon depending on how rapidly carbon-rich materials in the soil are decomposed. (continued on page 3)

CALENDAR

American Geophysical Union (San Francisco, CA)	3-7 Dec 2012
AMS Annual Meeting (Austin, TX)	6-10 Jan 2013
European Climate Change Adaptation Conference (Hamburg, Germany)	18-20 Mar 2013
1st National Adaptation Forum (Denver, CO)	2-4 Apr 2013
Association of American Geographers Annual Meeting (Los Angeles, Ca)	9-13 Apr 2013

CCSI Researchers Develop Improved Soil Carbon Cycle Model (cont'd)

"What we think will happen is that as temperature goes up, microbial physiology will change, altering their ability to break down carbon chains and release carbon dioxide into the atmosphere," Mayes said. "If our models don't account for this process, then our ability to predict future climate change will be less realistic." For the next six to eight months, Mayes's team will run laboratory-scale experiments to ensure that the MEND model accurately represents the decomposition of carbon compounds in soils. Eventually, team members hope to incorporate their model into the publicly available supercomputing program called the Community Land Model, a module used in the Community Earth System Model that helps researchers predict future climate change.

The study was supported by ORNL's Laboratory Directed Research and Development program, and model development will continue to be funded by DOE's Office of Science.

(Adapted from ORNL Press Release August 16, 2012)

PAUL HANSON NAMED UT-BATTELLE CORPORATE FELLOW

Paul Hanson, member of the Climate Change Science Institute at Oak Ridge National Laboratory, has been recognized as a UT-Battelle Corporate Fellow. ORNL researchers who have made outstanding contributions to science and technological fields over the course of their careers are recognized by this fellowship each year.

Hanson is a distinguished research and development staff member and group leader in ORNL's Environmental Sciences Division and CCSI. He has more than 25 years of experience conducting environmental effects research related to energy technologies and their use, focusing predominately on the impacts of climate change on the physiology, growth and biogeochemical cycles of North American forest ecosystems.

He studies the effect of acid rain, nitrogen deposition, mercury deposition, ozone, and environmental and atmospheric changes on woody plants and ecosystems. The current secondary standards for ozone were influenced by his publications and work at ORNL. Hanson also made the first quantitative measures of the exchange of elemental mercury vapor with plant foliage. In more recent years, his work on precipitation change revealed substantial resilience of common eastern forest tree species to sustained drought. He currently plays a coordinating and leadership role in the SPRUCE project, a whole-ecosystem warming study in high carbon forested-bog ecosystems in northern Minnesota (http://mnspruce.ornl.gov).

Hanson received his bachelor's degree in biology from St. Cloud University, and his master's degree in plant physiology and doctorate in forest tree physiology from the University of Minnesota. He has co-authored over 100 journal articles and book chapters, has co-edited a book, and is an editor of the journal Global Change Biology. He received the Environmental Sciences Division Distinguished Scientific Achievement Award in 1995 and was elected a Fellow of the American Association for the Advancement of Science in 2008. (adapted from ORNL Press Release July 23, 2012).

CCSI WELCOMES NEW STAFF

Santonu Goswami

Santonu Goswami joined the Climate Change Science Institute in September. He is a postdoctoral research associate in CCSI and the Environmental Sciences Directorate at ORNL. His research focuses on the impacts of global change on terrestrial ecosystem structure and functions using remote sensing.

Prior to joining ORNL, Santonu received his Ph.D. in Environmental Science and Engineering at the University of Texas at El Paso (UTEP) in 2011 working with Drs. Craig Tweedie and John Gamon on a large scale ecosystem manipulation study in Barrow, Alaska. Santonu's research focused on studying the impact of changing hydrology on ecosystem dynamics of an arctic tundra landscape using hyperspectral reflectance and a robotic tram system. His research involved three summers of field-work in Barrow, Alaska. In addition, he collaborated with colleagues from Computer Science within the Cyber-ShARE Center of Excellence at UTEP for data management and data quality issues. Santonu's PhD research has significant implications for interpreting satellite imagery and monitoring the productivity of arctic ecosystems as they respond to climate change. During 2007-2008, Santonu was also part of an IPY Antarctic Expedition to the Antarctic Peninsula where he did field work as part of a terrestrial ecology group.

While at ORNL, Santonu is involved with Dan Hayes's Dept. of Energy funded early career project: "Model-data fusion for retrospective and predictive assessment of the pan-arctic scale permafrost carbon feedback to global change". Santonu will also help with aspects of the Next Generation Ecosystem Experiment (NGEE) project, especially those that relate to the use of satellite imagery in modeling terrestrial processes in the Arctic.

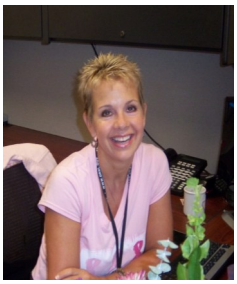
Anna Jensen

Anna Jensen originally comes from Denmark but has lived in Sweden for many years. She received a masters degree in biology (plant physiology) at Lund University and then moved to the Swedish University of Agricultural Sciences where she obtained a Ph.D. in Forest Management. Her dissertation focused on facilitation and competition interactions between young oaks and shrubs.

At CCSI, Anna is working with Jeffrey Warren on the SPRUCE project. Her research seeks to identify and quantify ecophysiological processes in black spruce and shrubs that may restrict (or facilitate) growth and competition capacity in a potentially warmer and CO_2 enriched future climate. Currently, Anna is studying tree variation of the photosynthetic capacity in black spruce. Mapping and understanding this variation gives us valuable insights into how different shoot flushes (needle cohorts) at different vertical positions contribute to the total carbon budget of the tree. In addition, she expects to gain an initial understanding of the between flush plasticity of black spruce.

When not working, Anna enjoys listening to music, hiking and picking mushrooms (however being new to the United States, she needs to learn how to separate the good from the not-so-good mushrooms!).

Teresa Hurt



Teresa is CCSI's new administrative assistant. She has more than 20 years' experience in corporate administration including meeting planning and coordination, implementing program/office start-ups, trade show exhibits, training programs, human resources, and budget planning. Teresa will be working with CCSI's project manager. In her spare time, Teresa and her husband enjoy traveling, the great outdoors, and University of Tennessee Volunteer football.

CCSI WELCOMES NEW STAFF (CONTINUED)

Victoria Sloan

Victoria Sloan joined ORNL as a post-doctoral research associate in the Environmental Sciences Division in May 2012. She holds a BSc in Ecology and Earth Science from the University of Durham, UK, and an MSc in Environmental Resource Assessment from the University of Newcastle, UK. Her PhD is in Arctic plant ecology from the University of Sheffield, UK, where her research focused on plant roots and their role in ecosystem carbon and nutrient cycling in the Scandinavian Arctic.

At ORNL, Victoria will be working on the Next Generation Ecosystem Experiment (NGEE) - Arctic project, within the Vegetation Dynamics Team led by Richard Norby. Her current research aims to link plant community structure and function to geomorphic units in Arctic landscapes, thus improving representation of vegetation dynamics in models at multiple scales. She also continues to investigate root traits of Arctic plants and their links to the above-ground component.

When not working, Victoria likes to run, cook, read and grow vegetables. She is an enthusiastic botanist and learning about new flora in the U.S. Back the UK, she volunteered for a number of conservation groups doing fundraising, public education, field survey work and running a biological records service. Victoria brings this spirit to the Volunteer state.

This past summer, Victoria spent her 4th full field season in the Arctic – actually living there for 3-4 months of the year. She has had many great experiences in Sweden, Finland and Alaska including eating whale meat to spending all night watching the northern lights.

Anthony Walker

Anthony Walker is from the United Kingdom. Originally from Swindon, home of the Magic Roundabout and to many of the UK's Research Councils, he moved to Sheffield to study for his Bachelor's degree in Plant Science. Since completing his Bachelors in 1999, Anthony worked in environmental management and landscaping with time out to study for a Master's degree in Sustainable Agriculture at Imperial College and to travel. He recently received a PhD from the University of Sheffield in model data comparison using data, from the FACE experiments at ORNL and Duke University, to inform and develop global scale carbon cycle models.

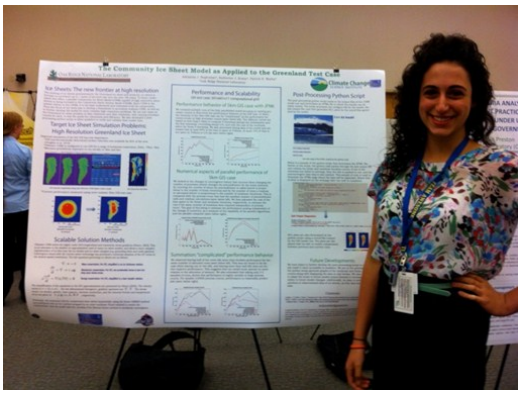
Under the supervision of Rich Norby, Anthony will be working to develop models of carbon allocation and root distribution within CLM, based on data from the FACE and PiTS projects. Anthony will also be working on the next round of FACE data model synthesis in an effort to analyze a number of carbon cycle and ecosystem models and further their development using data from ecosystem CO_2-manipulation experiments.

In his spare time Anthony enjoys hiking, playing football (soccer) and listening to live music so any suggestions for hikes, soccer teams or places to listen to blues or bluegrass would be much appreciated!

CCSI Hosts Students

The Climate Change Science Institute hosted 13 undergraduate and graduate students this past summer. Students learned climate research first hand working directly with staff scientists on several research projects. At the end of the summer, all students presented a poster of their research at ORNL's Annual Graduate Fair and Poster Session open to all staff.

Name	College/Major	Mentor	Project Title
Adrianna Boghozian	University of Tennessee, Knoxville Mathematics	Kate Evans	Building a verification and validation capability in the Community Ice Sheet Model
Brian Conlon Graduate Student	University of Tennessee, Knoxville Environmental Studies	Ben Preston	Multi-criteria Approaches to Adaptive Coastal Development
Wenting Fu Graduate Student	The University of Texas at Austin Geological Sciences	Forrest Hoffman	Applying Computationally Efficient Schemes for BioGeochemical Cycles
Deborah Higdon Undergraduate	University of Tennessee, Knoxville Biomedical Engineering	Sue Heinz	DAAC Dataset Ingest
Tianyu Jiang Ph.D. Candidate	Georgia Institute of Technology Earth & Atmospheric Sciences	Kate Evans	The Role of Atmospheric Rivers in Linking Weather Extremes: East Asian Coldwave and High Impact Precipitation over the West Coast United States
Julie Leifeld Graduate Student	University of Minnesota Mathematics	Salil Mahajan	Statistics of Climate Extremes: Observations and High-Resolution Global Climate Models
Allison Mihalczo Undergraduate	University of Tennessee, Chattanooga Environmental Science/Biology	Jeff Warren Joanne Childs	Field collections, lab processing and analysis of plant & soils samples for the Partitioning in Trees and Soils experiment
Munir Nayak Graduate Student	Cornell University Civil & Environmental Engineering	Moet Ashfaq	Drought projections in the 21st century under RCP 8.5
Jorge Poco Graduate Student	Polytechnic Institute of New York University Computer Science & Visualization	Bob Cook	Application of Advanced Visualization Tools for Data Exploration Associated with Terrestrial Biosphere Models
Deeksha Rastogi Graduate Student	University of Illinois, Urbana-Champaign Atmospheric Sciences	Moet Ashfaq	South Asian summer monsoon in CMIP5 GCMs
Vishwas Hebbur Venkata Subba Rao Graduate Student	Virginia Tech Computer Science	Richard Archibald Kate Evans	Emulation to simulate low resolution atmospheric data
Kai Wang Graduate Student	University of Texas, Austin Geological Sciences	Mac Post Jiafu Mao	Evaluation of CLM4 FPAR with Remote-sensing Products
Christopher William Wesh, Jr. Undergraduate Student	University of South Carolina Pre-Med	Tom Boden	Evaluation of AmeriFlux site information and biological data before inclusion in the CDIAC AmeriFlux RDBMS



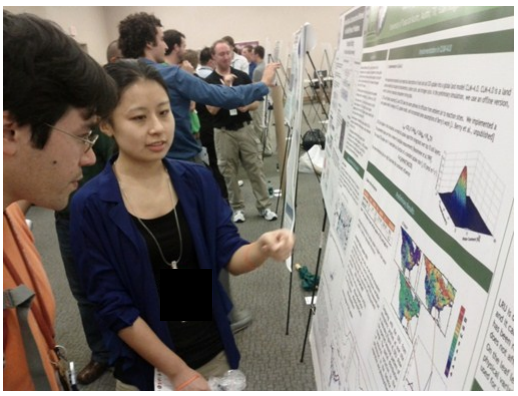


Figure 1. Adrianna Boghozian (left), an undergraduate student at the University of Tennessee, Knoxville, and Wenting Fu (right) displaying their summer research under the mentorship of Drs. Kate Evans and Forrest Hoffman, respectively.

Recent Research Highlights

NEWS FROM THE SPRUCE PROJECT

Investigators from the SPRUCE project descended on Grand Rapids, Minnesota, this past August to collect hundreds of peat samples for analysis. The SPRUCE project, or Spruce and Peatland Responses Under Climatic and Environmental Change, is an experiment to assess the response of northern peatland ecosystems to warming and elevated atmospheric carbon dioxide concentrations. Ultimately, large-scale open-top experimental chambers to control temperature and CO_2 will be built on-site. This sampling trip, led by Paul Hanson, Colleen Iversen, and their many colleagues from ORNL, along with collaborators from the USDA Forest Service, Chapman University, Georgia Tech, Florida State University, Iowa State University, the University of Oregon, and the University of Minnesota, spent a week in Minnesota collecting 3-m deep peat cores from the SPRUCE experimental plots. Meanwhile, construction of the experimental chambers is in the design phase, with anticipated completion in 2013. This timetable is contingent upon the cooperation of the weather in northern Minnesota as well as funding availability.

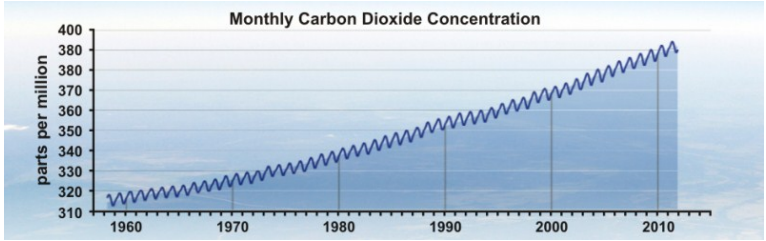
For more information on SPRUCE, please visit http://mnspruce.ornl.gov.

Pictures: Processing samples at the Grand Rapids, MN research site (far right). Peat core sample (right)

CARBON DIOXIDE INFORMATION ANALYSIS CENTER

The Carbon Dioxide Information Analysis Center (CDIAC) had completed its website redesign. The new site has a cleaner look, more intuitive to navigate, and easier to find climate change data of interest. CDIAC is the primary climate-change data and information analysis center of the U.S. Department of Energy (DOE). CDIAC is part of the Climate Change Science Institute located at DOE's Oak Ridge National Laboratory (ORNL) and includes the World Data Center for Atmospheric Trace Gases.

CDIAC's data holdings include estimates of carbon dioxide emissions from fossil-fuel consumption and land-use changes; records of atmospheric concentrations of carbon dioxide and other radiatively active trace gases; carbon cycle and terrestrial carbon management datasets and analyses; global and regional climate data and time series; and analyses of land-cover/land-use change.



CDIAC provides scientific and data management support for projects sponsored by a number of agencies, including the AmeriFlux Network, continuous observations of ecosystem level exchanges of CO_2, water, energy and momentum at different time scales for sites in the Americas; the Ocean CO_2 Data Program of CO_2 measurements taken aboard ocean research vessels; DOE-supported FACE experiments, which evaluate plant and ecosystem response to elevated CO_2 concentrations; and the HIPPO project, which is analyzing the atmospheric carbon cycle and greenhouse gas concentrations from pole to pole over the Pacific Ocean.

CDIAC is supported by DOE's Climate and Environmental Sciences Division within the Office of Biological and Environmental Research (BER).

Recent Research Highlights

GLOBAL FOSSIL-FUEL CO_2 EMISSIONS DATABASE UPDATED

The Global Fossil-Fuel CO_2 Emissions database maintained by the Carbon Dioxide Information Analysis Center (CDIAC) has been updated through 2009. Since 1751, approximately 356 billion metric tonnes of carbon have been released to the atmosphere from the consumption of fossil fuels and cement production. Half of these fossil-fuel CO_2 emissions have occurred since the mid-1980s. The 2009 global fossil-fuel carbon emission estimate, 8738 million metric tons of carbon, represents a slight decline of 0.35% from an all-time high (8769 million metric tons of carbon) in 2008. The slight decline is due to the Global Financial Crisis which began in mid-2008 and had obvious economic and energy use consequences, particularly in North America and Europe.

Globally, liquid and solid fuels accounted for 76.6% of the emissions from fossil-fuel burning and cement production in 2009 (Fig. 1). Combustion of gas fuels (e.g., natural gas) accounted for 17.9% (1568 million metric tons of carbon) of the total emissions from fossil fuels in 2009 and reflects a gradually increasing global utilization of natural gas. Emissions from cement production (413 million metric tons of carbon in 2009) have more than doubled since the mid-1990s and now represent 4.7% of global CO_2 releases from fossil-fuel burning and cement production. Gas flaring, which accounted for roughly 2% of global emissions during the 1970s, now accounts for less than 1% of global fossil-fuel releases.

For more information about CDIAC, please visit http://cdiac.ornl.gov.

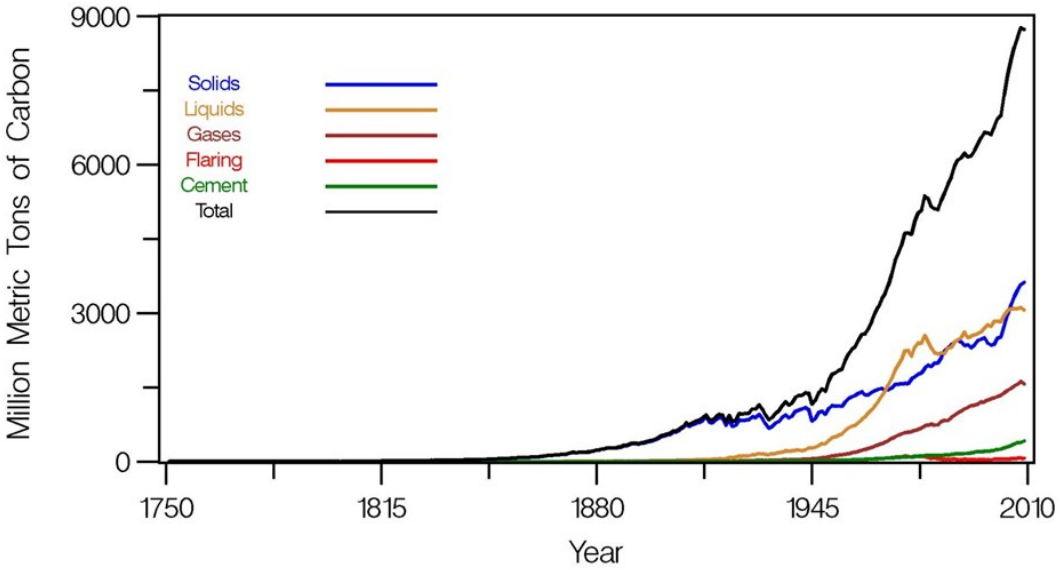


Figure 1. Global carbon emissions estimates (1751 – 2009).

Recent Research Highlights

CCSI Researchers Support Coastal Adaptation in Australia

Benjamin Preston, Deputy Director of the Climate Change Science Institute at ORNL, and Megan Maloney, research associate, traveled 'Down Under' in early September to showcase outputs from their project focused on coastal adaptation to climate change. The project, *Prioritizing Coastal Adaptation Options for Local Government*, is funded through a grant from the Australian Government's Department of Climate Change and Energy Efficiency to the Sydney Coastal Councils Group (SCCG) – a not-for-profit organization supporting education and coastal management in the Sydney region. The SCCG subsequently recruited staff from CCSI as well as the University of the Sunshine Coast (USC) to develop methods for evaluating the utility of different coastal adaptation options as well as a framework for monitoring and evaluating adaptation responses. The project therefore represents the first funded effort under a collaborative memorandum of understanding between ORNL and USC.

On their latest trip, Preston and Maloney traveled to Sydney, as well as two other case study sites included in the project, and presented the initial results of their research. Within the project, they had the responsibility for development of the multi-criteria analysis (MCA) methods for evaluating different coastal adaptation options as well as the geospatial framework for visualizing that evaluation for the three case study landscapes. MCA is an approach to policy analysis that incorporates monetary as well as non-monetary valuation methods for assessing costs and benefits of a particular action. The analytic process involves assessing the performance of alternative management options against decision criteria relevant to decision-makers such as the financial cost of implementation, the potential for environmental externalities, or its acceptance by the community. The visualization tool utilizes GIS maps to identify properties threatened by rising sea levels (Fig. 1). These tools integrated various sources of knowledge, from normative judgments of local experts to the nation's latest coastal hydrodynamic modeling. In so doing, Preston and Maloney were able to demonstrate that the appropriate adaptation options for a given location are contingent upon the time horizon of decision-makers as well as the values attached to different segments of the coast. Nevertheless, they also identify options that appear to be robust and therefore likely to yield benefits across multiple contexts. Local government staff hope to begin using these tools for internal planning regarding coastal risk management policy and screening future development proposals for their consistency with identified risks and community preferences. This research will be submitted for publication this fall.

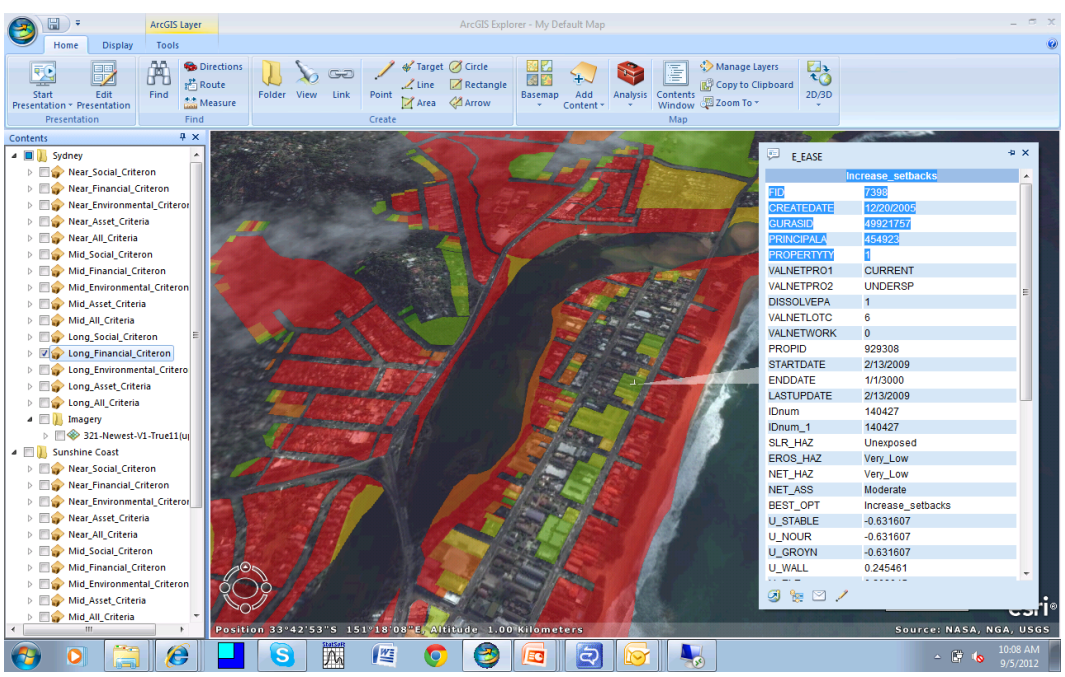


Figure 1. Screenshot of Arc GIS map adapted to highlight threatened coastal areas (green shading indicates relative low risk while red areas indicate relatively high risk). The pop-up table contains information for an individual property regarding relevant hazards, assets, and MCA scores for a suite of adaptation options.

RECENT PUBLICATIONS

Andres, R. J., T. A. Boden, F.-M. Breon, P. Ciais, S. Davis, D. J. Erickson III, J. S. Gregg, A. Jacobson, G. Marland, T. Oda, J. Oliver, M. Raupach, P. Rayner and K. Treanton, "A synthesis of carbon dioxide emissions from fossil fuel combustion", *Biogeosciences*, 9, 1845–1871, 2012 www.biogeosciences.net/9/1845/2012/, (2012).

Allen, M., D. J. Erickson III, W. Kendall, J. Fu, L. Ott and S. Pawson, "The Influence of Internal Model Variability in GEOS-5 on Interhemispheric CO_2 Exchange", *J. Geophys. Res.*, 117, D10107, doi:10.1029/2011JD017059, (2012).

Boden, T.A., G. Marland, and R.J. Andres. 2012. Global, Regional, and National Fossil-Fuel CO_2 Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi 10.3334/CDIAC/00001_V2012

Cheng, C.L., M. Kang, E. Perfect, H.Z. Bilheux, J. Horita, S. Voisin, J.M. Warren and D.S. Hussey. 2012. "Average Soil Water Retention Curves Measured by Neutron Radiography." Soil Science Society of America Journal 76:1184–1191.

Dennis, J.M., M. Vertenstein, P. H. Worley, A. A. Mirin, A. P. Craig, R. Jacob, and S. A. Mickelson, Computational Performance of Ultra-High-Resolution Capability in the Community Earth System Model, International Journal for High Performance Computer Applications, Vol. 26 (1), 2012, p. 5-16, doi:10.1177/1094342012436965.

Dennis, J.M., J. Edwards, K. J. Evans, O. Guba, P. H. Lauritzen, A. A. Mirin, A. St-Cyr, M. A. Taylor, and P. H. Worley, CAM-SE: A scalable spectral element dynamical core for the Community Atmosphere Model, International Journal for High Performance Computer Applications, Vol. 26 (1), 2012, p. 74-89. doi:10.1177/1094342011428142.

Evans, K. J., A. G. Salinger, P. H. Worley, S. F. Price, W. H. Lipscomb, J. Nichols, J. B. White III, M. Perego, J. Edwards, M. Vertenstein, and J.-F. Lemieux, A modern solver framework to manage solution algorithm in the Community Earth System Model, International Journal for High Performance Computer Applications, Vol. 26 (1), 2012, p. 54-62, doi:10.1177/1094342011435159.

Graham D.E., M.D. Wallenstein, T.A. Vishnivetskaya, M.P. Waldrop, T.J. Phelps, S.M. Pfiffner, T.C. Onstott, L.G. Whyte, D. Gilichinsky, D.A. Elias, R. Mackelprang, N.C. VerBerkmoes, R.L. Hettich, D. Wagner, S.D. Wullschleger and J.K. Jansson. 2012. Microbes in thawing permafrost: The unknown variable in the climate change equation. The ISME Journal 6: 709-712. http://dx.doi.org/10.1038/ismej.2011.163

Gunderson CA, Edwards NT, Walker AV, O'Hara KH, Campion CM, Hanson PJ (2012) Forest phenology and a warmer climate – growing season extension in relation to climatic provenance. *Global Change Biology* 18:2008-2025, doi: 10.1111/j.1365-2486.2011.02632.x

Lawrence, P. J., J. J. Feddema, G. B. Bonan, G. A. Meehl, B. C. O'Neill, K. W. Oleson, S. Levis, D. M. Lawrence, E. Kluzek, K. Lindsay and P. E. Thornton, **2012**. Simulating the biogeochemical and biogeophysical impacts of transient land cover change and wood harvest in the Community Climate System Model (CCSM4) from 1850 to 2100. *Journal of Climate*, 25: 3071-3095, doi: http://dx.doi.org/10.1175/JCLI-D-11-00256.1.

Lee H., S.D. Wullschleger and Y. Luo. 2012. Enhancing terrestrial ecosystem sciences by integrating empirical modeling approaches. EOS 93: 237. http://doi:10.1029/2012EO250008

Levis, S., G. B. Bonan, E. Kluzek, P. E. Thornton, A. Jones, W. J. Sacks and C. J. Kucharik, 2012. Interactive crop management in the Community Earth System Model (CESM1): Seasonal influences on land-atmosphere fluxes. *Journal of Climate* 25: 4839-4859.

Long, M.S., R., Easter, W. C. Keene, R. Sander, A. Kerkweg, D. J. Erickson III, X. Liu, S. Ghan, "Implementation of the chemistry module MECCA (v2.5) in the modal aerosol version of the Community Atmosphere Model component (v3.6.33) of the Community Earth System Model", *Geosci. Model Dev. Discuss.,* 5, 1483-1501, 2012, www.geosci-model-dev-discuss.net/5/1483/2012/ doi:10.5194/gmdd-5-1483-2012, (2012).

Mao, J., X. Shi, P. E. Thornton, S. Piao and X. Wang, 2012. Causes of spring vegetation growth trends in the northern mid-high latitudes from 1982 to 2004. *Environmental Research Letters* 7(104010): 1-7 DOI: 10.1088/1748-9326/7/1/014010.

RECENT PUBLICATIONS—CONTINUED

Mao, J., P. E. Thornton, X. Shi, M. Zhao and W. M. Post, 2012. Remote sensing evaluation of CLM4 GPP for the period 2000-09. *Journal of Climate* 25: 5327-5342.

McCarthy H.R., Y. Luo and S.D. Wullschleger. 2012. Integrating empirical-modeling approaches to improve understanding of terrestrial ecology processes. New Phytologist 195: 523-525. http://doi:0.1111/j.1469-8137.2012.04222.x

McGuire, A.D., T. Christensen, D.J. Hayes, A. Heroult, E.S. Euskirchen, J.S. Kimball, C. Koven, P. Lefleur, P.A. Miller, W. Oechel, P. Peylin, M. Williams, and Y. Yi (2012), An assessment of the carbon balance of arctic tundra: Comparisons among observations, process models, and atmospheric inversions, *Biogeosciences*, *9*, 3185-3204, doi:10.5194/bg-9-3815-2012.

Measham, T.G. and Preston, B.L. (2012) Vulnerability analysis, risk and deliberation: the Sydney Climate Change Adaptation Initiative. In Locki, S. and Measham R.G. (eds.) Risk and Social Theory in Environmental Management, CSIRO Publishing, Collingwood, pp. 147-157.

Mirin, A.A. and P. H. Worley, Improving the Performance Scalability of the Community Atmosphere Model, International Journal for High Performance Computer Applications, Vol. 26 (1), 2012, p. 17-30, doi:10.1177/1094342011412630.

Rothenberg, D., N. Mahowald, et al., 2012. Volcano impacts on climate and biogeochemistry in a coupled carbon-climate model. *Earth System Dynamics Discussions* 3: 279-323.

Tipping E, Chamberlain PM, Fröberg M, Hanson PJ, Jardine PM (2012) Simulation of carbon cycling, including dissolved organic carbon transport, in forest soil locally enriched with ^{14}C. *Biogeochemistry* 108:91-107, doi 10.1007/s10533-011-9575-1.

Wang, G., Post, W.M., Mayes, M.A., 2012. Development of microbial-enzyme-mediated decomposition model parameters through steady-state and dynamic analyses. Ecological Applications. doi: 10.1890/12-0681.1.

Wang, G., Post, W.M., 2012. A theoretical reassessment of microbial maintenance and implications for microbial ecology modeling. *FEMS Microbiology Ecology* 81, 610–617. doi: 10.1111/j.1574-6941.2012.01389.x.

Wang, G., Post, W.M., A note on the reverse Michaelis-Menten kinetics. *Soil Biology and Biochemistry*, doi: 10.1016/j.soilbio.2012.08.028.

Warren, JM, CM Iversen, CT Garten Jr., RJ Norby, J. Childs, D. Brice, RM Evans, L. Gu, P. Thornton, DJ Weston. 2012. "Timing and magnitude of C partitioning through a young loblolly pine (*Pinus taeda* L.) stand using ^{13}C labeling and shade treatments." *Tree Physiology 32:799-813*.

Weng, E., Y. Luo, W. Wang, H. Wang, D.J. Hayes, A.D. McGuire, A. Hastings, and D.S. Schimel (2012), Ecosystem carbon storage capacity as affected by disturbance regimes: A general theoretical model, *Journal of Geophysical Research*, *117*, G03014, doi:10.1029/2012JG002040.

Weston D.J., P.J. Hanson, R.J. Norby, G.A. Tuskan and S.D. Wullschleger. 2012. From systems biology to photosynthesis and primary production: a conceptual model for integrating multi-scale networks. Plant Signaling and Behavior 7: 260-262. http://dx.doi.org/10.4161/psb.18802

Wullschleger S.D. and D.J. Weston. 2012. Modeling the molecular and climatic controls on flowering. New Phytologist 194: 599-601. http://doi:10.1111/j.1469-8137.2012.04142.x

Xu C., R. Fisher, S.D. Wullschleger, C.J. Wilson, M. Cai and N.G. McDowell. 2012. Toward a mechanistic modeling of nitrogen limitation on vegetation dynamics. PLoSONE e37914. http://doi:10.1371/journal.pone.0037914

Yuen, E.J., Stone-Jovicich, S., Preston, B.L. (2012). Climate change vulnerability assessments as catalysts for social learning: four case studies. Mitigation and Adaptation Strategies for Global Change, DOI 10.1007/s11027-012-9376-4.