Purdue Climate Change Research Center

2014 ANNUAL REPORT



PURDUE UNIVERSITY
Discovery Park

The **Purdue Climate Change Research Center** (PCCRC) is a faculty-led, university-based research center on the campus of Purdue University. The PCCRC serves to increase scientific and public understanding of the causes and impacts of climate change through fundamental research and effective learning and engagement.

The PCCRC receives financial support from Purdue's Colleges of Agriculture, Engineering, Science, and Liberal Arts and the Office of the Executive Vice President for Research and Partnerships.

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Cover photographs: LEFT: Nepali children near Mount Makalu (Gerald Shively); MIDDLE: The Kangerlussuatsiaq Fjord in the Sukkertoppen region of western Greenland. This picture was taken while scouting potential sites for sampling dead vegetation for traditional radiocarbon dating and adjacent bedrock for *in situ* cosmogenic ^{14}C exposure/burial dating. Sites emerging from the edges of small, cold-based, retreating ice caps can help to study when the ice caps were last as small as they are at present. The cold-based ice preserves the vegetation killed by the previous ice advance, while the in situ ^{14}C in adjacent quartz-bearing bedrock enables one to model a cumulative burial/exposure history through the Holocene and latest Pleistocene (Nat Lifton); RIGHT: Slingshot leaf sampling at Morgan-Monroe state forest in Martinsville, IN (Nick Smith).

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Jeffrey S. Dukes
Professor and Director

Message from the Director

In 2014, as the PCCRC quietly celebrated its 10th anniversary, climate science advanced and the consequences of greenhouse gas emissions became clearer than ever. At the same time, emissions in the U.S. were in gradual decline, emissions in China rocketed upwards (largely fueled by the production of goods for export to other countries), and researchers at Purdue and around the world worked on solutions to the growing challenge of climate change. Climate policy in the United States advanced, with major new developments such as the announcement of the Clean Power Plan, and of an international agreement between the U.S. and China that could eventually slow the rate of growth of greenhouse gas emissions—but that would not come anywhere near solving the problem of rising greenhouse gas concentrations.

Complex global problems like climate change cut across many disciplines, and demand interdisciplinary solutions. In the 10 years of the PCCRC's existence, it has become clear that society will not sufficiently reduce emissions of greenhouse gases in time to protect people and the planet from major climatic shifts, and this point was punctuated when 2014 was named Earth's "hottest year ever." Indeed, the PCCRC's entire existence has come during the warmest period ever documented by humans; all of the last 14 years have ranked among Earth's hottest 15 years on record. These temperatures, and the hotter temperatures predicted to come, suggest that adaptation to the ongoing climate disruption will be critically important, and cannot wait. There is much work to be done, on many fronts, to minimize the impacts from these changes.

The members of the PCCRC play important roles in identifying, describing, and solving the problems associated with climate change. In these pages you will see highlights of the work we did during 2014 to understand how the climate is changing, how we can mitigate this problem (through science and policy), what the likely impacts will be, and how we can adapt to them. Our members' activities cross a range of disciplines nearly as wide as the university itself. Our members work to uncover new knowledge, to design new solutions, and to broadly educate our stakeholders about the issue of climate change. The PCCRC furthers this mission by facilitating communication and catalyzing new, interdisciplinary research. Thank you for your interest in the center, and please read on!

AWARDS & HONORS

Thomas Hertel, Purdue University Distinguished Professor of Agricultural Economics, was chosen to receive the inaugural Purdue University Research and Scholarship Distinction Award. The award recognizes university faculty whose recent research or scholarship has made a major impact in their field. Hertel is a leading scholar in analyzing the dynamic environmental and economic conditions of a global economy based on land use. He is the founder and executive director of the Global Trade Analysis Project, a Purdue-based program that helps researchers and policymakers analyze international trade. GTAP maintains data on nearly 1 million trade flows linking 130 economic regions around the world. Under Hertel's leadership, GTAP has become the "common" language for conducting analysis of global policy issues, with over 10,000 users representing more than 150 countries.

Paul Shepson the Jonathan Amy Distinguished Professor, Departments of Chemistry and Earth, Atmospheric, and Planetary Sciences was awarded the 2015 American Chemical Society Award for Creative Advances in Environmental Science & Technology for his work "advancing our understanding of the chemistry of remote and polluted atmospheres through an elegant combination of laboratory, field and modeling studies." In the fall of 2014, Shepson began his appointment as Director for the Division of Atmospheric and Geospace Sciences at the National Science Foundation where he will oversee all grant and cooperative agreement proposals and programs in the atmospheric sciences, including management of the National Center for Atmospheric Research.

Cary Troy, associate professor of civil engineering and member of the PCCRC Executive Committee, and **Jennifer Freeman**, associate professor of toxicology, have been named Purdue's inaugural Exceptional Early Career Award recipients. The award is a new program created by the Office of the Provost to recognize outstanding undergraduate teaching among Purdue's early career, tenure-track faculty.

PCCRC FACULTY & STAFF

Aeronautics & Astronautics: James Garrison

Agronomy: Laura Bowling, Sylvie Brouder, Melba Crawford [1], Richard Grant, Cliff Johnston, Dev Niyogi [2], Ronald Turco, and Jeffrey Volenec

Agricultural & Biological Engineering: Indrajeet Chaubey [2], Keith Cherkauer, Jane Frankenberger, and Sweta Singh

Agricultural Economics: Otto Doering, Alla Golub, Benjamin Gramig, Thomas Hertel, Jacob Ricker-Gilbert, Juan Sesmero, Gerald (Jerry) Shively, Wally Tyner, and Nelson Villoria

Biological Sciences: Kerry Rabenold

Botany & Plant Pathology: Nancy Emery[5]

Building & Construction Management: Kirk Alter

Brian Lamb School of Communication: Ashley Kelly

Chemistry: Paul Shepson [2]

Civil Engineering: Larry Nies, Suresh Rao [4], Amisha Shah, and Cary Troy

Curriculum and Instruction: Dan Shepardson [2]

Earth, Atmospheric and Planetary Sciences: Ernest Agee, Michael Baldwin, Timothy Filley, Alexander Gluhovsky[3], Jon Harbor, Harshvardhan, Nathaniel (Nat) Lifton, Greg Michalski, Wen-wen Tung, Yutian Wu, and Qianlai Zhuang[4]

Economics: Timothy Cason

English: Robert Marzec

Forestry and Natural Resources: Jeffrey Dukes[5], Songlin Fei, Reuben Goforth, Bryan Pijanowski, Linda Prokopy, Guofan Shao, and Robert Swihart

Health & Human Sciences: Jonathan Day, Jennifer Freeman and James McGlothlin

Information Technology: Carol Song and Lan Zhao

Mechanical Engineering: Jay Gore

Political Science: Daniel Aldrich, Leigh Raymond, and Mark Tilton

Statistics: Frederi Viens[7] and Hao Zhang [6]

Executive Committee: Michael Baldwin, Laura Bowling, Nancy Emery, James Garrison, Ben Gramig, Linda Prokopy, Paul Shepson, Cary Troy, and Qianlai Zhuang

Administrative Staff
Jeffrey Dukes, Director
Cindy Fate, Administrative Assistant
Rose Filley, Managing Director

[1]joint appointment in Civil Engineering; [2]joint appointment in Earth, Atmospheric and Planetary Sciences; [3]joint appointment in Statistics; [4] joint appointment in Agronomy; [5]joint appointment in Biological Sciences; [6]joint appointment in Forestry & Natural Resources; [7]joint appointment in Mathematics.

NEW FACULTY

The PCCRC is a faculty-led center. Our strength derives from the scholarship, creativity, and energy of our members. This year we welcomed 6 new members, representing 5 different departments.

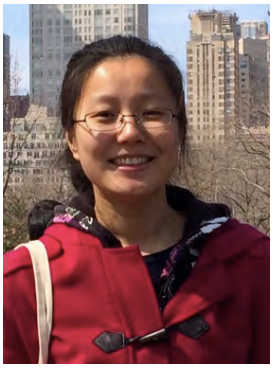
Dr. Jane Frankenberger, Professor of Agricultural and Biological Engineering, works on water quality and agricultural productivity in tile-drained watersheds. Climate change is expected to lead to increases in both excess nitrogen and phosphorus in waterways in spring, and crop stress due to lack of soil moisture in late summer, both due to changing precipitation patterns. In response, she is leading a nine-state project researching potential climate change adaptation strategies that would retain drained water on farms for use by crops. Drainage water can be stored in the soil profile in a practice known as drainage water management, in saturated buffers along ditches and streams, and in ponds and reservoirs providing water for irrigation. This multidisciplinary project will determine environmental and economic benefits and costs associated with these three innovative practices that can address the problems of crop loss from increased likelihood of summer drought and the degradation of water quality from drained farmland.

Dr. Ashley Rose Kelly joined the College of Liberal Arts as an assistant professor in the Brian Lamb School of Communication. Kelly's main areas of interest are in science studies and especially rhetorical studies of science and science communication. Specifically, she is interested in emerging genres of science communication, public participation in scientific research (citizen science), expertise and ethos in grassroots scientific research, and biohacking and hacker participation in scientific research. Prior to coming to Purdue, Dr. Kelly earned her Ph.D. from North Carolina State University in Communication, Rhetoric, and Digital Media in 2014 and her M.A. at the University of Waterloo (Canada) in Rhetoric and Communication Design in 2010.

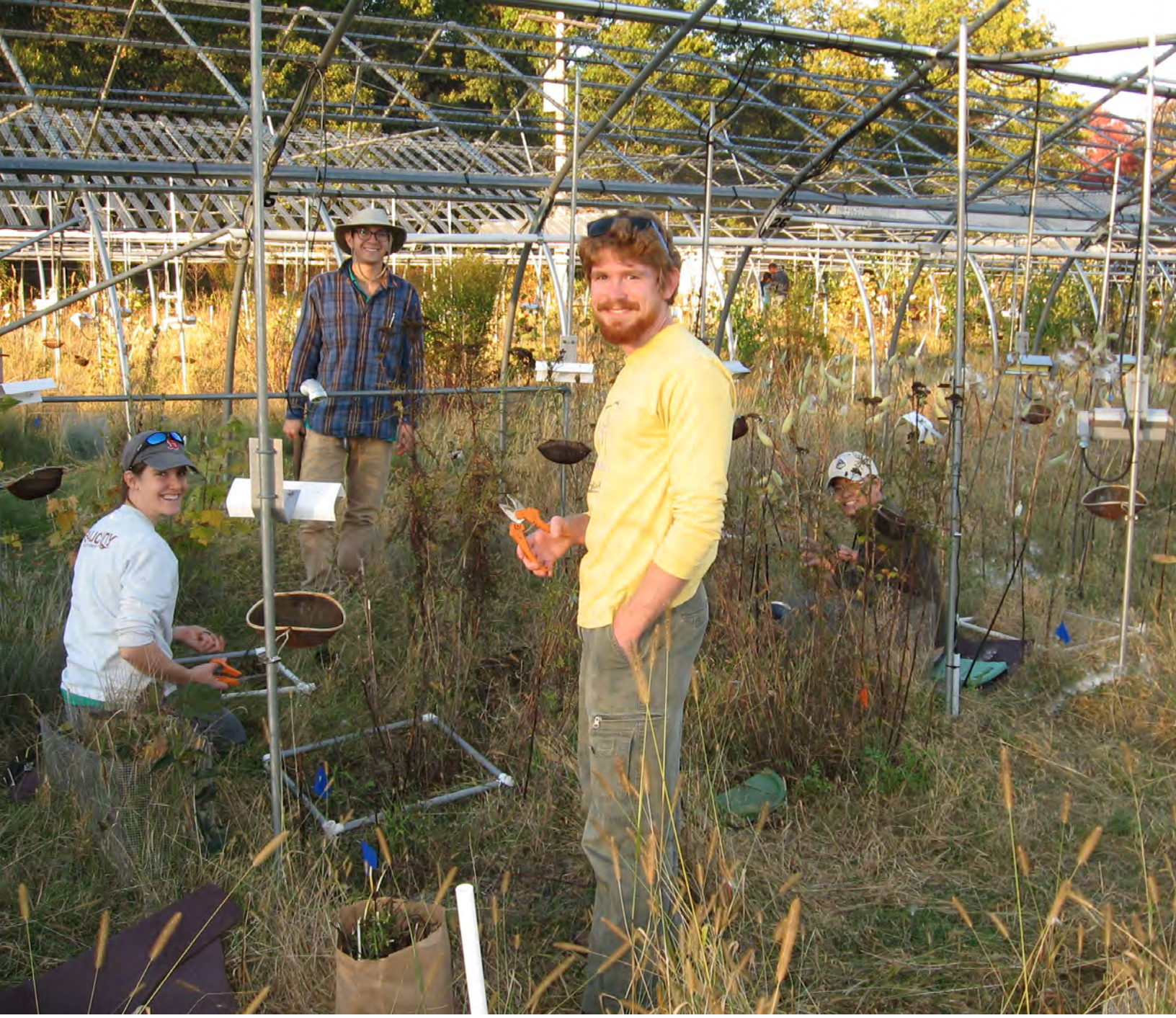
Dr. Robert Marzek is associate professor in the Department of English. His work involves the relationship between historical transformations of humanity's relationship to the environment, and how these transformations inform and affect 1) the event of climate change in today's world, and 2) our reactions to that event. One of the key problems he works to address concerns the chasm that now exists between the human species (especially human subjects living in the global North and West) and the ecosystems humans inhabit. In his interdisciplinary research (which analyzes literary, historical, economic, agricultural, political, legal, and philosophical texts) Dr. Marzek reveals how this split was not always as naturalized as it is today. In his teaching he explores these and other environmental concerns, and the relations between literature, science, environmental ethics, and policy. He teaches courses such as "Science, Literature, and Climate Change"; "Environmental Ethics"; "Postcolonial Ecocriticism"; and "Environmental Issues and Climate Change in Film."

Dr. Amisha D. Shah is an assistant professor in the Department of Civil Engineering. Her interests in the area of climate change primarily focus on understanding how chemical processes in natural waters can effect the overall carbon and sulfur budgets in the atmosphere. One particular area of interest is how indirect photochemical processes of organic sulfur in seawater and freshwater systems can trigger formation of volatile and low molecular weight sulfur compounds that can result in sulfate formation in the atmosphere. Additional interests also include how climate change processes can effect drinking water quality and quantity worldwide. Dr. Shah received her B.S. degree in chemical engineering from Washington University in St. Louis in 2002 and her Ph.D. in Environmental Engineering from Georgia Institute of Technology in 2008. Before joining Purdue, she was a research associate in the Water Resources and Drinking Water Division at the Swiss Federal Institute of Aquatic Science and Technology (EAWAG).

Dr. Shweta Singh joined the Department of Agricultural & Biological Engineering and Environmental and Ecological Engineering in 2014. Her interest in the area of climate change is primarily focused on understanding the impact on resource flows and changing consumption patterns that can affect the sustainability of production systems or urban systems. Her work is aimed at developing a model for coupled natural human systems for nitrogen flows that is targeted to include the impact of climate change on nitrogen biogeochemical cycling. Additionally, Dr. Singh is particularly interested in urban responses to climate change as the world becomes more urbanized.



Dr. Yutian Wu's research group aims at understanding the dynamical processes in the large-scale circulation of the atmosphere and how the processes respond to anthropogenic climate change. One current research project looks at the fastest warming region in the globe—the Arctic. Wu is interested in questions like: what are the processes that cause the Arctic warming, how does Arctic warming affect the weather and climate in North America and Europe, and are we going to suffer more extreme weather events in the future because of Arctic warming? By helping to better understand and predict future climate in North America and Europe, the work will have both scientific and societal importance. Her interests also include the hydrological cycle and the Asian summer monsoon circulation. Dr. Wu received her Ph.D., Department of Applied Physics and Applied Mathematics, at Columbia University. Prior to coming to Purdue's department of Earth, Atmospheric, and Planetary Sciences, she was a postdoctoral Research Fellow at the Courant Institute of Mathematical Sciences, New York University.



Researchers measure plant growth to understand the implications of climate change for ecosystems at the Boston-Area Climate Experiment (BACE) in Waltham, Massachusetts. Pictured from left to right are technicians Hannah Lyons-Galante and Samuel Worley, Purdue M.S. student Zachary Reaver, and Dr. Guoyong Li, a visiting scholar to Purdue from Henan University in China. In operation since 2008, the BACE exposes plots of land to twelve different levels of warming and precipitation. PCCRC Director Jeff Dukes is the principal investigator.

DISCOVERY

NEW SPONSORED RESEARCH AWARDS

Regional and Global Climate and Societal Impacts of Land-Use and Land-Cover Change in Northern Eurasia: A Synthesis Study Using Remote Sensing Data and an Integrated Global System Model

Qianlai Zhuang, *Departments of Earth, Atmospheric, and Planetary Sciences* and *Agronomy*, with collaborators from Marine Biological Laboratory, MIT, and the Russian Academy of Sciences (Funded by the National Aeronautics and Space Administration).

Over the last decade, a significant amount of knowledge and data has been accumulated in the Northern Eurasian Earth Science Partnership Initiative (NEESPI) region. However, there have been very few efforts made to investigate the feedbacks and effects of regional land cover-land-use change (LCLUC) on global climate and human society. This project will focus on work to improve our understanding of how LCLUC, ecosystems and biogeochemical dynamics, climate, and humans have interacted in the region during the last three decades. The improved understanding of established cause-effect relationships among these dynamics will be incorporated into the MIT-based Integrated Global System Modeling framework (IGSM) to reveal potential data and knowledge gaps and to evaluate how future LCLUC will impact the global climate and socioeconomic systems.

While the research focus of this project is on the NEESPI domain, the model analysis will be conducted at the global scale. The multidisciplinary U.S. scientific team includes ecosystem scientists, biogeochemical modelers, climatologists, and economists, including international collaborators from the Russian Academy of Sciences.

Assessing Threshold Benefits of Conservation Tillage During Drought Years: Implications for Nutrient Use Efficiency and Water Quality

Juan Sesmero, *Department of Agricultural Economics* (Funded by the National Institute of Food and Agriculture).

Intensive agriculture in the U.S. Midwest has been linked to various water quality problems in the Mississippi River basin and the expansion of the so-called "dead zone" in the Gulf of Mexico. The problem could become more serious if summer droughts, such as those we experienced in 2007 and 2012, were to become more frequent. During droughts, the use of applied nutrients by growing crops is notoriously low. As a result, large amounts of nutrients remain in the ground at harvest, and these nutrients are typically transferred to streams and rivers (runoff and tile discharge) causing degradation of water quality. Following the 2012 summer drought for example, unusually high nitrate concentrations—2 to 4 times higher than the maximum limit allowed by EPA for drinking water—were recorded in streams draining agricultural watersheds in Iowa, Illinois and Indiana. Many of these streams are sources of drinking water for municipalities in the region.

In this integrated project led by Indiana University, the research team argues that soil quality--achievable with conservation tillage--is the cornerstone of water quality. Compared to conventional tillage, studies have shown that no-till practice results in better crop yield and less residual soil nutrient after summer droughts. They will investigate the effect of tillage management on nutrient cycling, water budget, and crop productivity during drought years, and identify the socio-economic barriers to the adoption of conservation practices in agro-ecosystems. The project will be conducted in the Eagle Creek watershed in Indiana. Satellite images collected (and archived) during the last 10-15 years will be analyzed to determine the distribution of tillage practices throughout the watershed. Landsat images will be used to estimate drought severity every 16 days throughout selected growing seasons (2007 and 2012 as drought years, 2010 as a normal year). The researchers will then identify fields under conventional and no-till practices, and determine how tillage practices determine the response of crops to summer droughts of varying intensity. Using crop yield data and price information, Prof. Sesmero will conduct an economic analysis to determine the climatic, and market conditions under which no-till becomes an economically attractive alternative to farmers. The team will also develop an education and extension program to increase awareness of the links between climate variability, agricultural land management and water quality in the Midwest. Survey instruments will also be developed to collect information on farmers' knowledge regarding key parameters driving net benefits of no-till adoption. Information will also be collected to assess farmers' understanding of the potential benefits of no-till, and the risk they perceive with its adoption. Participating farmers will be surveyed twice during the course of the project to assess change in behavior.

NASA Instrument Incubator: Signals of Opportunity Airborne Demonstrator

James Garrison, *School of Aeronautics and Astronautics* (Funded by the National Aeronautics and Space Administration)

Through this recently awarded Instrument Incubator grant from NASA, Professor Garrison and his team will develop a prototype instrument for the remote sensing of Root-Zone Soil Moisture (RZSM). RZSM is the water content in the first meter of soil and an important variable for understanding the transfer of water from the atmosphere to soil and its absorption by vegetation. Although it represents a small fraction of the Earth's total water budget, soil water content is nevertheless an essential variable to consider because it strongly drives interactions between the land surface and the atmosphere. Getting this variable right will improve weather predictions and allow for better Earth system modeling. It will also improve farmers' ability to monitor plant health, predict crop yields, and plan irrigation schedules; and help water resource managers better understand surface runoff and pollution control measures.

In recent years, there has been significant interest in the remote sensing of soil moisture with the launch of the SMOS (Soil Moisture and Ocean Salinity) satellite by the European Space Agency and the pending launch of SMAP (Soil Moisture Active/Passive) by NASA. The instruments on both of these satellites use passive radiometry, measuring the emission of the soil or ocean surface in microwave frequencies, to extract an estimate of the moisture content (and salinity in the ocean). A well-established technique, radiometry is limited to a protected band around 1.4 GHz due to potential interference. This frequency penetrates the soil to only about 5 cm, requiring the application of hydrological models to estimate the moisture profile below that.

Through the use of signals of opportunity or "SoOps" reflectometry, using a strong communication signal between 240 and 270 MHz, the new instrument under development in the Garrison lab has the potential to provide a direct measurement of the moisture content at much deeper levels. The fundamental principle of this comparatively new technique in microwave remote sensing is that geophysical data can be extracted from the signals broadcast from communication satellites by measuring changes in the properties of these signals as they are scattered when they reflect back from the land or ocean surface.

This project was initiated in April 2014 and is scheduled for completion in 3 years with a collection of data from a NASA aircraft over an experimental field instrumented with in situ soil moisture sensors. To date, SoOp measurements using transmissions from a commercial Satellite Digital Radio Service have been collected on several flights of the NOAA P-3 "Hurricane Hunter" aircraft during the 2014 hurricane season. Strong signals were observed during flights through several hurricanes, giving confidence the instrumentation is working well and the team is currently analyzing the data and developing algorithms to extract surface wind speed from the measurements.

Following a successful demonstration, Garrison and his team will begin the design and analysis of a satellite-based instrument. NASA Goddard Space Flight Center and Exelis Inc. are partners in this development project.

Installation of SoOp experiment on NOAA P-3 "Hurricane Hunter" aircraft. In the left photo Purdue University graduate student Nick Rainville tests the receiver following installation. The right photo shows the ocean-view (nadir) antenna for reflected signal reception.

RESEARCH BRIEFS

Sustainable bioenergy production under climate change and variability

The Energy Independence and Security Act (EISA) of 2007 set a goal of producing 36 billion gallons of biofuel by 2022. To meet this bioenergy production target, fast-growing and high-yielding perennial cropping systems such as switchgrass and Miscanthus are expected to be increasingly used, alongside conventional crop residues, as bioenergy feedstocks. The impact of large-scale production of these energy crops on water availability and water quality, impacts that may be exacerbated by climate variability and change, are either unknown or poorly characterized.

In a research project funded by the Department of Energy (DOE), Dr. Indrajeet Chaubey, Earth, Atmospheric, and Planetary Sciences, is leading an interdisciplinary team to assess the sustainability of realistic future bioenergy production scenarios in the Midwest under a range of changing climate scenarios. At the core of the project is an effort to improve the Soil and Water Assessment Tool (SWAT) model using evidence-based parameter values and then using the improved model to simulate impacts of watershed management and climate change scenarios on a series of sustainability metrics including water quality and quantity, soil erosion, crop production, profitability, and aquatic biodiversity.

Preliminary results indicate that streamflow is reduced due to the increased evapotranspiration demands of these fast-growing perennials, but that these bioenergy crops in general improve in-stream water quality compared to conventional cropping systems (maize-soybean). The research team finds that the water quality benefits due to large scale production of perennial bioenergy crops will likely be greater than the effects of climate change and variability.

ABOVE: Professor Chaubey explains the hydrologic and water quality impacts of bioenergy crop production to a group of students.

Why do farmers adopt offset-eligible practices? An experimental investigation of framing effects

In this USDA Economic Research Service grant, the investigators (Professors Leigh Raymond, Political Science; Benjamin Gramig, Agricultural Economics; Rosalee Clawson, Political Science and graduate student Amelia Andrews) asked three central questions about farmers' decisions to adopt conservation tillage techniques that help mitigate climate change by storing more carbon in the soil. In the second year of this grant, the research team worked on analyzing and writing up results from a second field experiment exposing farmers at a large Indiana trade show to three different "frames" for promoting conservation tillage: a "profit" frame stressing the techniques potential to increase farmer income, a "stewardship" frame stressing the technique's benefits for ecosystems, and a "community" frame stressing the technique's potential to improve environmental quality for the farmer's neighbors and local residents. Consistent with the primary hypothesis, the results indicated that different frames interact with a farmer's prior environmental values, making some frames effective in shaping the attitudes and behavioral intentions of only those farmers who support values that correspond to that frame. For example, the "community" frame was uniquely effective on farmers who previously supported the importance of protecting the environment for the benefit of other individuals. These results suggest the continued complexity of framing effects, and that the same frames may have very different effects on different individuals depending on their prior values. They also suggest the potential for frames to influence even "experts" on a subject, such as farmers, contrary to the arguments of some previous work on framing effects.

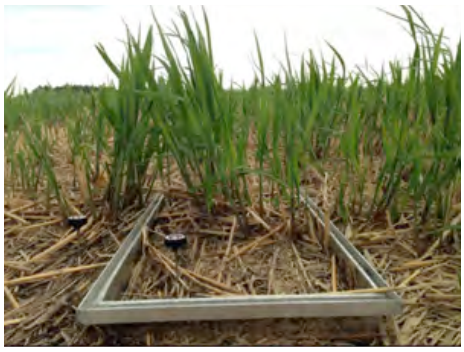
Sustainable production and distribution of bioenergy for the Central U.S.

Greenhouse gas (GHG) emissions from agriculture are contributing to global warming. This contribution comes in part from the high amounts of nitrogen (N) fertilizer applied to row crops, maize, in particular,—the nitrogen that is not taken up by the growing plants is converted to nitrous oxide, a molecule which is approximately 300-times more potent as a GHG than is carbon dioxide. With row crops increasingly used for fuel, it is important to understand how biomass species selection and nitrogen fertilizer impact GHG emissions as well as biomass yield.

To determine the relationship between management of these understudied cropping systems and their environmental footprint, including GHG emissions, biomass plots were established at Purdue University's Water Quality Field Station. The study site includes unfertilized prairie and N-fertilized maize plots as controls that have been in place since 1995, and represent native, unmanaged vegetation and current agricultural practice in the cornbelt, respectively. Sorghum, switchgrass, and Miscanthus were established in 2007/2008 and represent potential biomass production systems.

The N fertilizer rates used in this study reflect best management practices specific to these species when grown on this soil. Unfertilized prairie has very low biomass yield, but also produces very low amounts of nitrous oxide. By comparison, N-fertilized maize produced the highest biomass (grain and stover combined) yield, but also had the greatest rate of nitrous oxide emission. Sorghum yield was lower than maize, and its nitrous oxide emissions also were lower. Switchgrass produced over 7200 kg/ha biomass with no detectable nitrous oxide emissions during the interval of measurement. Miscanthus produced almost as much biomass as maize, and these plots also produced very low amounts of nitrous oxide.

Calculating the biomass:nitrous oxide ratio is one approach to reconciling system differences in both biomass yield and nitrous oxide emission rate. The ratio for maize is the lowest of all systems studied, reflecting the very high nitrous oxide emissions despite having high biomass yield. The high biomass yield of Miscanthus coupled with its low nitrous oxide emissions resulted in a very high ratio suggesting this system is efficient at producing biomass with minimal GHG emissions. During the period of measurement in this study switchgrass did not produce nitrous oxide; however, previous work indicates that this species often produces GHG at rates similar to Miscanthus and the native prairie. These studies, let by professors Jeff Volenec, Sylvie Brouder, and Ron Turco, Agronomy; and post-doctoral researchers Mary-Jan Orr and Ryan Dierking, are on-going.



TOP PHOTO: Frame inserted into the soil of a switchgrass plot during greenhouse gas sampling. BOTTOM PHOTO: Lids placed over the frames seals the soil-plant system and permits periodic sampling of gasses evolving from the soil using a syringe. These gasses are characterized by injecting the mixture into a gas chromatograph in the laboratory.

TABLE: The table presents data from the Water Quality Field Station experiments comparing biomass yield and GHG emissions from controls (praire and maize) with Sorghum, Switchgrass, and Miscanthus cropping systems.

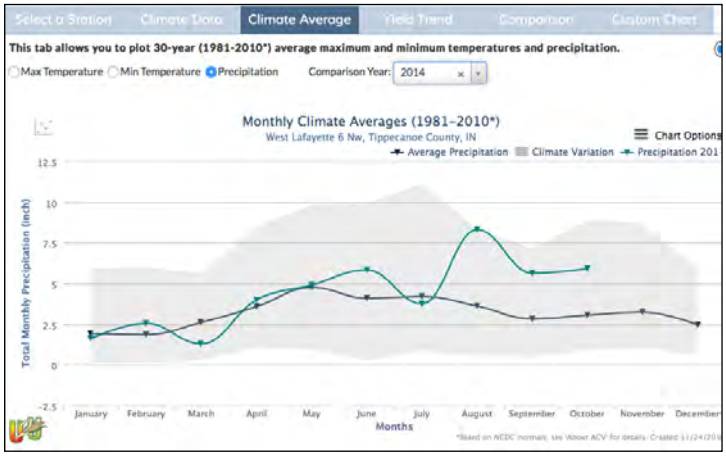
Biomass Species	N Fertilizer, kg/ha	Total Biomass Yield, kg dry matter/ha	Nitrous Oxide (N_2O), mg/h/m2	Biomass:N_2O Ratio
Prairie	0	4285	0.007	6.1×10^5
Maize	160	23179	0.151	1.5×10^5
Sorghum	160	14640	0.068	2.2×10^5
Switchgrass	50	7233	0	not determined
Miscanthus	50	22787	0.009	25.3×10^5

Useful to Usable (U2U): Transforming Climate Variability and Change Information for Cereal Crop Producers

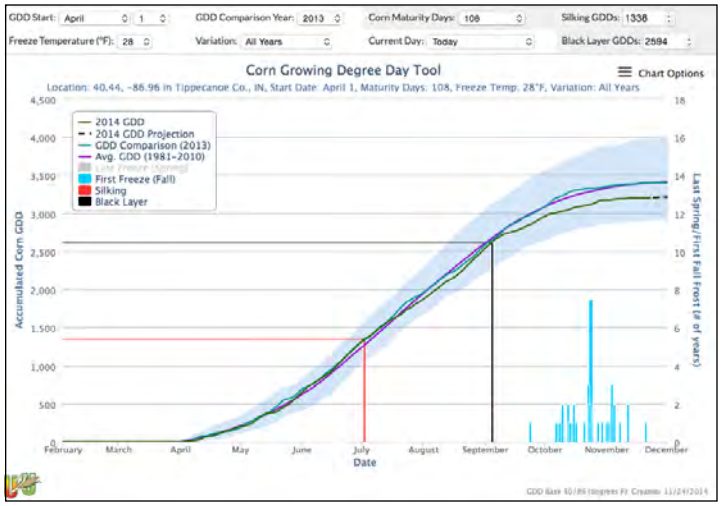
U2U is a five year USDA-funded research and extension project focused on improving the use and uptake of climate information for Midwestern agricultural production. The interdisciplinary U2U team, led by Professor Linda Prokopy, Department of Forestry and Natural Resources, with co-PIs Otto Doering, Ben Gramig, Dev Niyogi, and Carol Song, relies on both biophysical and social science research to inform the development and effective dissemination of user-driven decision support tools (DSTs). The team includes five Purdue faculty members, 20 Purdue employees, as well as participants at eight other universities.

At Purdue, climatologists, crop modelers, agronomists, and IT specialists are working together with agricultural economists and other social scientists to assesses how short-term management decisions and long-term investment planning by corn producers will affect financial, production, and environmental outcomes under different climate scenarios. This interdisciplinary approach, coupled with ongoing engagement of key stakeholder groups, has allowed the team to effectively bridge climate science with on-the-ground decision making. Moreover, through these well-established, integrative partnerships, the team is able to make collaborative, iterative improvements to decision support tools, training materials, and implementation approaches resulting in several innovative and strikingly effective climate-related decision support tools, such as those highlighted here. For more about U2U: www.AgClimate4U.org.

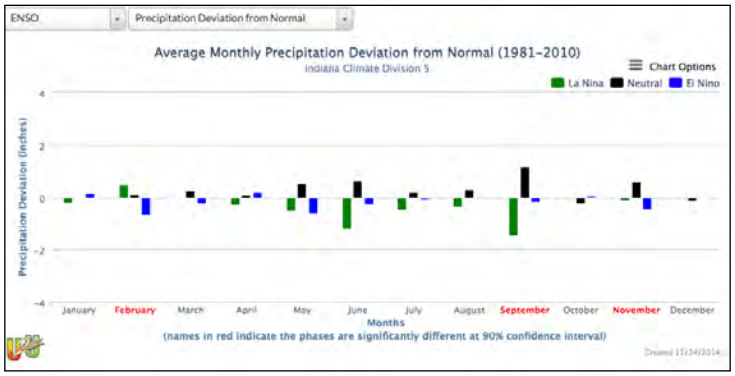
Dr. Linda S. Prokopy is an Associate Professor of Natural Resource Social Science in the department of Forestry and Natural Resources. Her research focuses on the human dimensions of land use change, climate change, and water resource management.



AgClimate ViewDST provides convenient access to customized historical climate and crop yield data. Users can view and download graphs of monthly temperatures and precipitation, plot corn and soybean yield trends, and compare climate and yields over the past 30 years.



Corn GDD DST allows users to track real-time and historical growing degree day (GDD) accumulations, assess spring and fall frost risk, and guide decisions related to planting, harvest, and seed selection. This innovative tool integrates corn development stages with weather and climate data for location-specific decision support tailored specifically to agricultural production.



Climate Patterns Viewer DST helps users see how global climate patterns like the El Niño Southern Oscillation (ENSO) and Arctic Oscillation (AO) have historically affected local climate conditions across the U.S. Corn Belt. Climate Patterns Viewer provides simple maps and charts to determine when and where specific phases of ENSO or AO have influenced temperatures, precipitation and crop yields.

Impact of the 2012 Drought on Farm Advisors' Perceptions of Climate Risks

By: Melissa Widhalm, U2U Project Manager

Understanding the impact of extreme events on peoples' climate risk perceptions has important implications for developing effective communication strategies, motivating people to take action, and improving disaster readiness. However, the relationship between extreme events and changing beliefs and attitudes is inherently difficult to study in part due to the unpredictable nature of weather disasters.

With support from the NOAA Sectoral Applications Research Program (SARP) we are leveraging survey research conducted by the USDA-funded Useful to Usable (U2U) project with additional social science research to gain a unique perspective of how the 2012 drought influenced the farming sector. In this ongoing, two-year effort we specifically focus on agricultural advisors in the U.S. Corn Belt since they are highly influential members of the agricultural community, and farmers rely heavily on their expertise to support on-farm management decisions.

Our research seeks answers to the following questions:

- Did the 2012 drought change advisors' perceptions of risk associated with climate change?
- Did the 2012 drought change advisors' beliefs about the existence and/or causes of climate change?
- Did the 2012 drought change advisors' willingness to respond to climate change?
- Are agricultural advisors ready to use climate information in their decision making?

Survey Research

We used results from two surveys conducted before and after the record-setting 2012 Midwestern drought to determine if/how the drought affected agricultural advisors' risk perceptions, climate change beliefs, and/or adaptation attitudes. This opportunistic natural experiment included responses from 864 advisors in Indiana, Iowa, Michigan, and Nebraska who participated in both surveys and experienced varying levels of drought severity in their region.

Our preliminary analysis revealed that advisors' climate change beliefs did not significantly change after the 2012 drought. Additionally, attitudes towards climate change adaptation and advisors' willingness to use climate information did not significantly change after the 2012 drought. However, we found that risk perceptions did change. Specifically agricultural advisors reported increased concern with drought, heat, weeds, insects, and disease. They reported decreased concern related to flooding, ponding, and nutrient runoff.

From these early findings we conclude that for sectors regularly affected by weather variability, such as agriculture, a single event like the 2012 drought may not be enough to cause a shift in climate change beliefs and, subsequently, adaptive behaviors. However, heightened risk perceptions after an extreme event may present an opportunity to build readiness toward specific climate impacts.

Interviews

Agricultural systems are complex and weather/climate is just one of many factors that influence risk perceptions, planning decisions, and farming success. To capture these intricacies and provide context to our survey research we conducted 57 in depth- interviews with agricultural advisors between December 2013 and April 2014. Participants included Certified Crop Advisors (CCAs), staff at conservation agencies, agricultural bankers, and university Extension personnel located in Indiana, Iowa, and Nebraska.

These interviews used a series of open-ended questions to broach a diversity of interrelated, yet distinct, topics (climate beliefs, financial considerations, Farm Bill impacts, etc.). Analysis is ongoing and results will be used to improve our understanding about how attitudes and perceptions are formed in an individual and to gauge advisors' readiness to use climate information.

Looking Ahead

With future climate projections pointing to likely increases in the frequency of extreme events there is interest in learning how we can rally support for mitigation and adaptation efforts, and whether such events result in specific challenges or opportunities for influencing behavior. Early analysis shows a complex connection between extreme events and climate risk perceptions. Our project team is continuing to explore the many facets of this issue with final results expected in 2015 at the conclusion of our project.

Research Team: Linda S. Prokopy, Nick Babin, Stuart Carlton, Michael Dunn, Amber S. Mase, Melissa Widhalm, Cody Knutson, Tonya Haigh, Lois W. Morton, Jean McGuire, Chad Hart, Maria C. Lemos

This article first appeared in the Fall 2014 issue of Dry Times, the National Integrated Drought Information System Newsletter.

Arctic Sensitivity to Climate Perturbations and a Millennial Perspective on Current Warming Derived from Shrinking Ice Caps

Professor Nat Lifton, Earth, Atmospheric, and Planetary Sciences, graduate student Casey Beel, and collaborators from the University of Colorado and the University of Buffalo, have worked for the last two summers to study Holocene records of the fluctuations of small ice caps in eastern Baffin Island and western Greenland. The ultimate goal of this research is to evaluate whether currently observed Arctic warming is outside the range of long-term natural variability. This goal will be addressed with powerful datasets derived from radiocarbon-dated vegetation preserved beneath cold-based (non-erosive) ice caps for centuries to millennia, but now being exposed annually by current ice-margin retreat across northeastern Canada and West Greenland. These chronologies define the pattern and timing of abrupt summer coolings in the recent past and place current warming in a millennial context. ^{14}C dating of vegetation will be complemented by measuring in situ cosmogenic ^{14}C inventories in recently exposed rock surfaces, providing essential temporal constraints on the duration of ice-covered and ice-free conditions throughout the Holocene. The researchers are also using the longer-lived in situ cosmogenic ^{10}Be and ^{26}Al pair to assess exposure and cover histories under cold-based ice at glacial-interglacial time scales. Initial results from Purdue's PRIME Lab for $^{10}Be/^{26}Al$ from deeply weathered high plateau surfaces in western Greenland indicate only minor ice cover over the last 1-2 glacial cycles. This surprising finding contrasts with previous $^{10}Be/^{26}Al$ results from similar surfaces on Baffin Island indicating long periods of burial by cold-based ice.

ABOVE: Dr. Nat Lifton collecting a bedrock sample at the edge of a small, unnamed ice cap near Qátqatsiaq in the Søndre Isortoq region of western Greenland for in situ cosmogenic ^{14}C analysis. This sample is adjacent to the ice margin where a corresponding sample of dead vegetation was collected. The two types of samples will provide a view of the Holocene advance and retreat history for this cold-based (non-erosive) ice cap as well as similar ones in western Greenland.

Reconstructing Timing and Patterns of Past Glaciation in Central Asia.

Professors Nat Lifton, Jon Harbor, and Marc Caffee, graduate student Robin Blomdin, and visiting scholars Natacha Gribenski and Jingdong Zhao are part of an international research team working to reconstruct the timing and pattern of past glacial expansion across major highlands in Central Asia, including the Tibetan Plateau, Tian Shan mountains, and Altai mountains. Fieldwork in Kyrgyzstan, Mongolia, Russia and China in 2014 was focused on refining mapping of landforms made by past glaciers, and collection of samples that are now being processed for age dating at Purdue's PRIME Lab. The work to date has resulted in new understanding of the timing and pattern of past glaciation that provides new insight into paleoclimate drivers in central Asia.

BELOW: Reconstructing past glaciation in the Altai Mountains, Mongolia. In the background are field research sites with glaciers and areas where glaciers used to be. The foreground shows the Ger (yurt) and cheese drying platform of a family involved in nomadic goat and yak grazing.

Reconstructing the past 1000 years of global mean temperatures

Understanding recently observed and projected future climate changes within the context of the natural variability and dynamics of the climate system requires reconstructions of past climate. Because instrumental temperature observations extend back to only about the 1850s, researchers must turn to the noisy and sparsely distributed paleoclimate record to characterize natural climate variability on longer time scales. Natural proxies for past climate include tree rings, corals, ice cores, lake floor sediments cores, and measurement of speleothems. While these studies have substantially increased our understanding of past climate, limitations remain in terms of the statistical treatment and uncertainty quantification of the data.

Recent work by Professor Frederi Viens, Department of Statistics, with collaborators Luis Barboza (University of Costa Rica), Bo Li (University of Illinois), and Martin Tingley (Penn State University), undertook the first ever reconstruction of the past 1000 years of global mean temperatures by using data both from climate proxies and from natural external forcings. Three main external forcings influencing global temperatures were considered: the concentration of greenhouse gases (particularly CO_2), solar irradiance (intensity of radiation), and volcanic activity. The data were analyzed using a hierarchical Bayesian technique, including a linear model for the proxies given the temperature (data level) and a linear model for the temperature given the external forcings (process level). The Bayesian analysis using the dual-model hierarchy produced high-quality reconstructions of the global temperatures from year 1000 to year 1899, with narrow uncertainty bands and with the added benefit of providing a full uncertainty profile on every parameter in the models. Of particular note is the linear coefficient of the CO_2 term in the temperature model, which the team reinterpreted, after appropriate scaling, as the so-called Transient Climate Response (TCR). The TCR is a measure of the temperature response over a medium-term period (e.g. 70 years) to a doubling of atmospheric CO_2 concentration, before the ocean-atmosphere system has a chance to come into equilibrium.

The TCR uncertainty profile was estimated under several models and an uncertainty interval was reported at the 95% credible (Bayesian confidence) level with a mean value of 2.5 degrees Celcius, by mixing the two aforementioned preferred models. This is in somewhat sharp contrast to the IPCC's 5th Assessment Report in which a consensus is drawn that TCR uncertainty profiles should be peaked below 2.0 degrees, but is consistent with the same report's finding that TCR is very unlikely to be above 3.0 degrees Celsius. From a statistical standpoint, the biggest improvement coming from the techniques introduced by Viens and his colleagues is a large reduction in uncertainty levels, including for the TCR estimate, which they attribute to a much wider use of data than in previous studies.

Helping Marina and Harbor Operators Respond to Climate Change

Private marinas and small municipal harbors are struggling to fund needed improvements. The recent trend towards low lake levels and increased storm surges caused by climate change only amplify this economic hardship. Though a variety of climate adaptation tools are available, they can be overwhelming to marina and harbor managers. Information overload and uncertainty about future lake levels can result in a lack of confidence and may deter responsive actions. With funding from the Great Lakes Integrated Sciences and Assessments Center (GLISA) this project, led by Michigan Sea Grant, will assist marina and harbor operators in sector-specific problem identification, decision making, and planning related to climate change adaptation.

The project team, which includes Professor Jonathon Day, Department of Hospitality & Tourism Management, is focused on the development and dissemination of scientifically accurate, reliable and unbiased educational content; the usefulness of the educational content for our targeted audience (marina and harbor operators); and the integrity of the final educational resources produced. A key deliverable for this team will be an online training module that will be introduced through a series of workshops. The training module will be hosted through an existing online training resource, made available across the Great Lakes to inform operators of best practices in planning for and adapting to climate change impacts. Providing content and outreach support for these deliverables are core team responsibilities.


Mackinaw City, MI

The GEOSHARE Project: Geospatial Open Source Hosting of Agriculture, Resource and Environmental Data for discovery and decision-making

Those grappling with the complex, dynamic nature of the relationships among climate change, resource use, and agricultural production are faced with the added challenge of incompatible datasets, which limits analysis that integrates across these domains. Working with colleagues from across the globe, Professors Thomas Hertel and Nelson Villoria, Agricultural Economics, piloted a new information infrastructure— GEOSHARE—to support researchers working in this area. The post-pilot workshop for GEOSHARE was held in Discovery Park, on September 10-11, 2014 with support from Purdue, CIMSANS, DFID, DEFRA and USDA. The purpose of this event was to take stock of the efforts undertaken over the past three years and determine whether the project should be scaled up into a long term effort, and, if so, what form this activity should take.

International participation

Seventy-five people attended the workshop, coming from Europe, Africa, Asia, Latin America, Australia and across North America, with affiliations in private, public, non-profit, international, and academic organizations. After an overview of the case studies undertaken during the pilot project, the workshop pursued four major themes: Cyber-infrastructure, Institutional Design, Data Endorsement, and Data Fusion. Each of these was accompanied by breakout sessions in which small groups could engage in deeper discussions. Reports from the rapporteurs, along with all of the accompanying presentations, are available on the GEOSHARE HUB: www.geoshareproject.org.

The high level of participation in this event, and the enthusiastic response to the presentations, suggests that there is indeed a need to scale up GEOSHARE to a long term, global activity. Participants affirmed there is currently an absence of platforms for obtaining and modifying high-quality, reproducible, geospatial data products for analysis of food, agriculture, and environmental issues at global scale. Existing efforts are typically one-off, insufficiently documented, one-way (not allowing modification), and incompatible with other efforts.

There is also a great deal of inefficient duplication of effort. Participants see great potential in adopting the HUBZero architecture developed at Purdue as a vehicle for sharing data and analysis tools, and connecting diverse communities of practice in order to allow for more integrated analysis of global sustainability issues. Indeed, in the wake of this workshop, a number of data sets and tools are already being uploaded or under development by workshop participants for use on the HUB.

Implementation

Despite this great potential, participants also recognized the challenge posed in funding such an effort. This led naturally into discussions about how to design the institutional structure of GEOSHARE. It was generally agreed that an Advisory Board comprising major stakeholders in this field is an essential ingredient. This Board would have responsibility (via annual subscription) for providing funding for core activities. It would set the strategic direction for the project, approving new 'nodes' (each representing communities of scholars, practitioners and users specializing in various aspects of the global data base), endorsing the GEOSHARE data bases, and ensuring that GEOSHARE's activities complement existing efforts already underway.

The leaders of each node would be selected by the relevant community of practice, in consultation with the Board, and these node leaders would form the Scientific Committee of GEOSHARE which would set standards, determine the specification of workflows, and generally ensure that the resulting data bases and analysis tools are of the highest possible quality. Activities of the nodes would be funded as part of their ongoing research efforts, with grants and contracts facilitated in some cases by the Board members. Support for the core activities (HUBZero, management and coordination) would be funded by the Board members' annual fees.

Next Steps

In the wake of the workshop, a number of organizations have expressed interest in serving on the GEOSHARE Advisory Board. Once we have obtained five members, we will schedule the first meeting of the Board and the Scientific Committee. The near term goal is ten Board members, which would allow the project to move ahead with confidence. In the longer run twenty Board members will be required to maintain this activity at the level envisioned by participants in this workshop.

G · E · O · S · H · A · R · E

Linking Satellite Remote Sensing and Household Survey Data to Assess Nutrition Response to Environmental Change


Nepali children near Mount Makalu.

Climate change may threaten the ability of current agricultural systems to keep up with demand for adequate food, clean water, and the provision of other ecosystem services. At a population level, human health is affected by changes occurring across multiple geographic and time scales. Dr. Gerald Shively, Agricultural Economics, has been working with a number of colleagues, including NASA scientists, to develop methods that make use of satellite remote sensing and demographic data to better understand the drivers of individual-level human health and nutrition outcomes. By bringing these diverse datasets together, the connection between environmental change and human health outcomes can be described.

In a recent paper published in the journal *Population and Environment* [see Brown 2014, page 23] the research team describes how remotely sensed data were incorporated in their study of agriculture and child nutrition outcomes in Nepal. In Nepal, sources of nutrition are often determined by local agricultural conditions because poor infrastructure, harsh terrain and high transportation costs frustrate efforts to redistribute food from food surplus to food deficit areas.

Satellite remote sensing data on vegetative health were matched to data from the 2011 Nepal Demographic and Health Survey (DHS). The combined data were used in analyses to evaluate whether interannual variability in weather and its impact on food production was correlated with a child's probability of being stunted or wasted. The nationally representative sample included 1,412 children who were above the age of 24 months at the time of the DHS survey. Data from two satellite radiometers were used to calculate normalized difference vegetation index (NDVI) values as anomalies, i.e., the differences between monthly values and the long-term average NDVI for that month computed over a longer period (in this case July 2002 to May 2012). NDVI values provide a measure of the greenness of the ground cover, which can be used as a proxy for the productivity and yield of a cereal crop. Then, to more carefully connect NDVI values to the critical period in a child's development, they were matched to children according to local, crop-specific agricultural calendars.

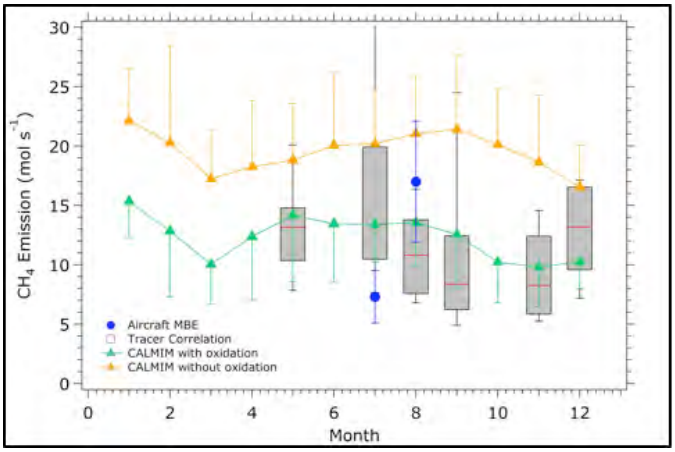
Results from models that included a full set of control variables measured at the child, household and community levels indicated that when crops grew well (positive NDVI anomalies) for harvest months during the time a child was in utero there was a modest, but statistically significant, reduction in the probability of stunting. The results suggest that remote sensing data, with their high levels of geographic specificity could improve targeting of development and intervention programs focused on reducing rural poverty. Going forward, researchers will need to find ways to incorporate variables such as food prices, food quality, and measures of isolation and risk to better understand the impact of an environmental stressor (e.g., drought) in a specific location.

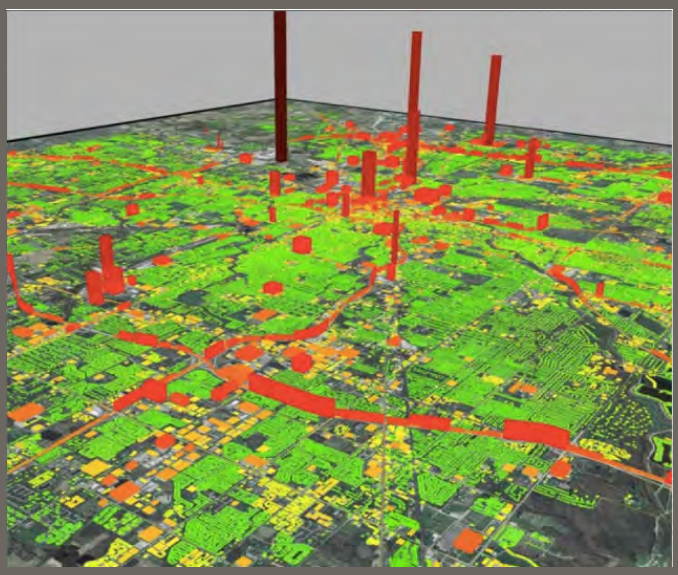
LEFT: Transporting livestock fodder the hard way. Credit for both photos on this page, Gerald Shively.

Measuring carbon dioxide and methane emissions in Indianapolis, Indiana

Professor and PCCRC founding director, Paul Shepson, Departments of Chemistry and Earth, Atmospheric, and Planetary Sciences, along with postdoctoral researchers Obie Cambaliza and Alexie Heimburger and PCCRC graduate fellow Olivia Salmon, continue their work on the Indianapolis Flux Experiment (INFLUX). Funded by the National Institute of Standards and Technology, the INFLUX project is developing improved methods to measure city-wide greenhouse gas (CO_2 and CH_4) emission rates as well as more spatially and temporally-resolved fluxes. The ultimate objective is to reduce the measurement uncertainties to a point (e.g. ~10%) where they are useful for comparison with measured trends from satellites such as the Orbiting Carbon Observatory 2. The INFLUX project involves integration of multiple methodologies, including bottom-up inventories (Kevin Gurney, Arizona State University), inverse modeling (Ken Davis, The Pennsylvania State University), radiocarbon measurements (NOAA), and the aircraft mass-balance measurements conducted by the Shepson group.

A challenge for the INFLUX group is methane. The team has found that methane emissions in Indianapolis amount to 165 tons of methane per day. In "CO_2 equivalent" terms, this methane accounts for 34% of the total greenhouse gas emissions from the city. Approximately one-third of the total methane derives from one urban landfill, with the remaining two-thirds coming from the city's natural gas infrastructure. Because landfills are such a large methane source, the research team has been working on evaluating the uncertainty in direct measurements of landfill emissions. They are also using models to evaluate understanding of the environmental controls on landfill CH_4 emissions. An example data set for the Twin Bridges landfill that sits just west of the Indianapolis city limits is shown in the figure above. The figure illustrates results from tracer release experiments (gray bars), aircraft mass balance measurements (blue points), and the CALMIM landfill emission model (triangles; green points are with bacterial oxidation of methane in the cover soil, and yellow points are without that oxidation). While there is general agreement in the emission rates, the uncertainties are about 30%. The Shepson team is working on making them smaller.





Quantification of fossil fuel CO_2 emissions in Indianapolis. Credit: Bedrich Benes & Michel Abdul-Massih/Purdue University.

The Hestia Project, led by Prof. Kevin Gurney (now at ASU) and launched through the PCCRC, is the first to use bottom-up methods to quantify all fossil fuel CO2 emissions down to the scale of individual buildings, road segments, and industrial/electricity production facilities on an hourly basis for an entire urban landscape.

The researchers gather data from various sources, including local air pollution data, traffic reports, and tax assessment parcel information, which is then incorporated into a modeling system that quantifies carbon dioxide emissions of individual buildings and streets. The system is general enough to be applied to any large U.S. city and holds tremendous potential as a key component of a carbon-monitoring system in addition to enabling efficient greenhouse gas mitigation and planning.

To date the system has been applied to Indianapolis, Indiana, and data collection is in progress for the cities of Phoenix, Arizona, Los Angeles, California, and Salt Lake City, Utah. The ultimate goal is to use Hestia to map carbon dioxide emissions of all major US cities, which collectively are responsible for approximately 25% of carbon dioxide emissions globally.

The Center for Global Soundscapes joins Discovery Park

This year, Professor Bryan Pijanowski, Department of Forestry & Natural Resources, through the newly created Center for Global Soundscapes (CGS), continues his work on several ongoing soundscape research projects. In one example, the center is examining how soundscapes can be used to assess ecosystem recovery after an enormous wildfire event, the Horseshoe II of April 2011 which took place in the Sonoran Desert. Passive acoustic sensors and miniature digital meteorological sensors were placed in the Chiricahua National Monument across seven life zones, from hot desert to pinyon pine, and across three burn severities and areas that were not burned.

In a second research effort, Pijanowski traveled to the Kuala Belalong Forestry Biological Station in Borneo, where, over a 3-month stay, he collected over 15,000 hours of recordings from sensors located near a Smithsonian Tropical Forest Biodiversity study that has yielded the highest plant species richness on Earth (over 1250 species in a 25 ha plot). Dr. Pijanowski also traveled to Denali to record the dawn chorus patterns a few weeks prior to the summer solstice. This study will help develop baselines for determining how photoperiod drives soundscape dynamics during different parts of the year.

In May, studies commenced on soundscapes of estuaries through a partnership with the Wells National Estuarine Research Reserve in Maine. Passive acoustic sensors were placed from ocean beachfronts through estuarine river systems to upland forested landscapes. Hydrophones were used to record long-term soundscapes in vernal and tidal pools. Recordings of these sites also examined the impact of invasive species (Japanese barberry) on soundscape composition. Continuous recordings occurred from May 4 through November 8, 2014.

The Chicago Wild Sounds project was continued for its second year with recordings of soundscapes taking place in coastal, urban nature reserves near the downtown area. Studies here are attempting to determine whether megacity noise interferes with animal communication.

The center's NSF-funded AISL (Advancing Informal STEM Learning) grant (with Dan Shepardson, Departments of Curriculum and Instruction and Earth, Atmospheric and Planetary Sciences) supported the development of an IMAX Interactive Theater Show which piloted at the Connecticut Science Center in Hartford, CT. The "Big Data, Big Screens, Open Ears" AISL project also presented a new curriculum to students at the Perkins School for the Blind. Another partner, the National Audubon Society, is preparing some of its environmental camps for soundscape-based YELLs (Your Ecosystem Listening Labs). A tablet and low-tech (paper) version of YELLs have been storyboarded and will be released in the spring of 2015. The curricular products being developed are focused on grades 5-7 and conform to the Next Generation Science Standards.

As a project center in the Global Sustainability Institute and affiliated center with the PCCRC and the Center for the Environment, in July of 2014, CGS faculty, students and staff moved into their new space in Mann Hall (Suite B066). The CGS has received funding from NSF Coupled Natural Human Systems Program, the NSF Advancing Informal STEM Learning, and Purdue's Office of the Vice President's Incentive Grant Program and the Department of Forestry and Natural Resources Wright Fund.

Record the Earth

The center's largest activity this year was the "Record the Earth" event hosted on Earth Day 2014. The CGS, along with partners in the ITaP Envision Center, the Center for Environmental Regulatory Information Systems, and the VACCINE program, developed a soundscape recorder app and an associated web site: (www.globalsoundscapes.org). The app asks users to record their soundscape, and answer questions about what they hear (biological, geophysical and human produced sounds) and how these soundscapes make them feel. Visitors to the web site can then map soundscapes in a variety of ways including soundscapes "that make people happy."

Over 1000 uploads occurred on Earth Day. As of November 15, 2014, more than 3,000 uploads have occurred representing recordings from all 50 states, all Canadian provinces, all European countries and nearly 40% of all countries in the world.

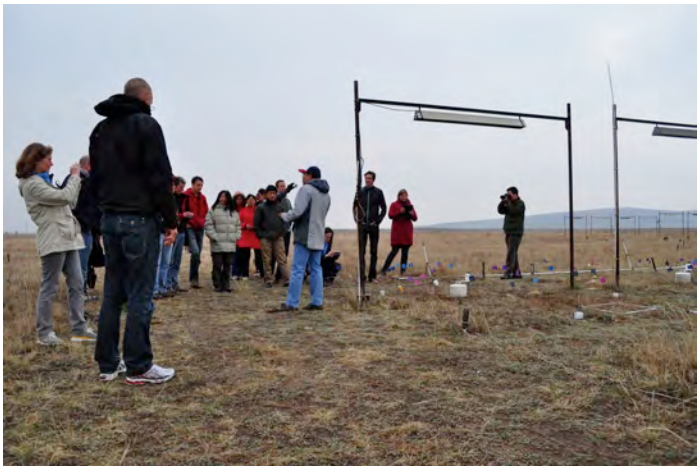
The "Record the Earth" event made national and international headlines, and was the showcase feature on the Today Show. Dr. Pijanowski gave interviews to NPR Science Friday, Wired Magazine, BBC World News Service and Australia National Public Radio.

Dr. Bryan Pijanowski in Denali, Alaska.

An Integrated Network for Terrestrial Ecosystem Research on Feedbacks to the Atmosphere and ClimatE (INTERFACE): Linking experimentalists, ecosystem modelers, and Earth system modelers

As climate models have become more complex, their developers have represented ecosystem carbon uptake (through plant growth) and loss (through decomposition and respiration) by the land surface in increasingly complex ways, and have begun to incorporate a broader set of potential limits to carbon uptake based on resource availability. The NSF-funded INTERFACE Research Coordination Network, led by PCCRC director Jeff Dukes, promotes improvement of the representation of ecosystem processes in climate models by bringing together the modeling community with researchers conducting relevant field experiments. Communication among researchers at these gatherings should lead to incorporation of more realistic process representations in models, and also the development of experiments that are well tailored to addressing critical uncertainties in the current climate models.

In May 2014, INTERFACE brought together 50 researchers from around the world to Beijing, China, to discuss "Using results from global change experiments to inform land model development and calibration." Immediately before the meeting, co-sponsor Prof. Shiqiang Wan of Henan University led the international visitors on a field trip to an experimental field station in Duolun, Inner Mongolia, where several experiments probe the responses of the local grassland to changes in the climate and atmosphere (see pictures to the right). The 50-person meeting was covered in the journals *Nature* and *New Phytologist*.



The Boston-Area Climate Experiment

Several projects continued at the Boston-Area Climate Experiment (BACE), in 2014. This Waltham, Massachusetts-based project, led by PCCRC director Jeff Dukes, exposes an old-field ecosystem with tree seedlings to twelve different combinations of warming and precipitation, to simulate possible future climates. In 2014, Clemson researcher Nishanth Tharayil collaborated with Dukes on NSF-funded research to characterize the responses of tree leaf chemistry to the different climatic conditions, and Indiana University professor Rich Phillips worked with Dukes on a DOE-funded project to measure how the climate treatments affected growth and carbon release by roots and fungi in the soils. In addition, Wellesley College professor Alden Griffith and Babson College professor Vikki Rodgers studied how precipitation affected the success of an invasive species, and Harvard post-doc Daniel Flynn examined the seed output of milkweed species in the different treatments. Finally, Professor Colin Orians at Tufts University used the experiment to test how climate affects the chemistry and quality of tea leaves. In 2015, Purdue Ph.D. student Nick Smith will conduct new USDA-funded research to measure how long-term warming and precipitation change affect the short-term temperature responses of photosynthesis and respiration in tree leaves.

PRICLE; The PRairie Invasion and CLimate Experiment

Ecological Sciences and Engineering Ph.D. student Mike Schuster (insert; left) and Biological Sciences Ph.D. student Nick Smith (insert; center) harvest biomass at PRICLE with Biological Sciences Ph.D. student Alejandro Salazar (insert; right). With help from a PCCRC seed grant, Schuster and Smith (working with PI Jeff Dukes) set up PRICLE at the Purdue Wildlife Area to study how a restored prairie responds to increased variability in precipitation and increased nitrogen deposition. As the climate changes, models suggest that precipitation will come in fewer, larger events. At the same time, fossil fuel consumption and agricultural fertilizer use lead to an unintended "rain" of nitrogen-containing compounds on Midwestern ecosystems. PRICLE simulates these changes and records how vegetation (including invasive plants) and soils respond. The structures pictured below (rain shelter tents with transparent plastic strips) reduced precipitation by half for the plot of land underneath, and once per month researchers watered the sheltered plots to replace that precipitation in a single large event. Thus, these plots and the control plots received the same total amount of rainfall, but in different event sizes.

A PCCRC Seed Grant Update

Are Farmers Willing to Change Tillage Practices to Supply Carbon Emissions Offsets?

Professor Benjamin Gramig, Department of Agricultural Economics, was awarded a PCCRC Seed Grant in 2009 to purchase a license for Sawtooth software to design, collect, and analyze web-based research survey data for the project, "Are Farmers Willing to Change Tillage Practices to Supply Carbon Emissions Offsets?" Professors Linda Prokopy, Forestry and Natural Resources, and Nicole Widmar, Agricultural Economics, are collaborators on this project, which also received critical funding from a Mission Oriented Grant from Purdue's College of Agriculture.

Wide-reaching international agreements like the Kyoto Protocol have thus far failed to achieve significant global greenhouse gas (GHG) emissions reductions. No successor to Kyoto with binding emissions limits has emerged; however, a new model, one in which emissions-reductions goals would be set by each country on its own—tracked under agreed rules—is gaining traction. In this decentralized approach, individual countries are responsible for setting, and choosing how to meet their own emissions targets by, for example, enacting GHG emission limits or imposing a carbon tax to incentivize less use of fossil fuels and development of renewable energy technologies. A common element present in voluntary and regulatory carbon markets has been the inclusion of emission offsets that can be sold by entities outside emission caps or not subject to a carbon tax. One particularly low cost means of sequestering atmospheric carbon involves reducing or eliminating tillage of agricultural soils.

Farmers prefer government conservation payments to market-based payments.

The researchers conducted a choice experiment with corn and soybean farmers in Indiana to measure farmers' willingness to change tillage practices to supply carbon offsets by estimating their willingness to pay or willingness to accept payment related to different attributes of active and proposed carbon markets around the world. Understanding farmers' preferences is vital to ensuring that farmers will participate in such schemes so that carbon abatement efforts around the globe can be achieved in the most cost-effective ways possible. The findings indicate that farmers prefer government conservation payments to market-based payments as a payment vehicle to compensate them for sequestering carbon in farm soils, and that farmers dislike multi-year contracts, regardless of whether they previously adopted reduced tillage. The research team finds that less than 17% of the farmers surveyed who have not previously adopted a form of reduced tillage would be willing to accept payments equivalent to the observed prices for California Carbon Allowances in mid-2014. This suggests that it may be difficult to entice increased adoption of no-till practices, and thus net increases in soil carbon sequestration, to supply carbon offsets.

The greatest potential source of climate change mitigation in agriculture is carbon sequestered in the soils of cropland, grazing land and rangeland. These soils can store 1,500-4,500 million tonnes of CO_2 equivalents per year --CGIAR BIG FACTS

2014 SEED GRANTS

The Seed Grant program funds projects that enhance interdisciplinary research among Purdue researchers in areas related to climate and climate change. The center awards provide seed funding for a wide range of collaborative projects that have high probability of fostering new lines of research and are likely to result in the submission of large-scale extramural funding proposals. This year the center provided 7 seed grants totaling $72,000 to support a wide-range of climate change-related projects.

Linda Prokopy and Stuart Carlton, *Forestry and Natural Resources;* Matthew Huber, *Earth, Atmospheric, and Planetary Sciences*, for: **Measuring attitudes of scientists about climate change** (Project support).

Wally Tyner and Farzad Taheripour, *Agricultural Economics*, for: **Economic Benefits and Costs of Climate Change Mitigation and Abatement** (Graduate student support).

John Harbor, *Earth, Atmospheric, and Planetary Sciences* for: **Educational Initiatives for MAGIC-DML: Mapping/Measuring/Modeling Antarctic Geomorphology and Ice Change in Dronning Maud Land** (Travel support).

Songlin Fei, *Forestry and Natural Resources;* Keith Woeste, *Forestry and Natural Resource;* and Jeff Dukes, *Forestry and Natural Resources and Biological Sciences* for: **Role of early ontogenic environment in acclimation of plants to climate change** (Student/project support).

Rich Grant, *Agronomy*, and Keith Cherkauer, *Agricultural and Biological Engineering* for: **Measurement of CH4 emissions by unmanned aerial vehicles** (Instrument purchase).

Timothy Filley, *Earth, Atmospheric, and Planetary Sciences;* Indrajeet Chaubey *Earth, Atmospheric, and Planetary Sciences and ABE*; Chi-Hua Huang, *USDA Agricultural Research Service*, and Ron Turco, *Agronomy*, for: **Instrumentation Purchase: Revealing the status of watersheds as carbon transformers or carbon transporters through the stable C and N isotope analysis** (Instrument cost-share).

Dev Niyogi, *Agronomy*, for: **Effect of Land Atmosphere Interactions under Nocturnal Conditions** (Travel support).

EARLY RESULTS: The Climate Change Consensus Extends Beyond Climate Scientists

An ongoing concern about climate change is the discrepancy between the public view about climate change and the view of climate scientists. Approximately 97% of active, publishing climate scientists are in agreement that anthropogenic sources of greenhouse gases are leading to a buildup in the atmosphere, which leads to a general warming of the global climate, compared to about 50% of the American public. Contributing to this gap are scientists who are publicly skeptical about climate science and anthropogenic climate change. These scientists often come from fields other than climate science and typically are not currently researching climate issues.

Post doctoral researcher, Dr. Stuart Carlton and mentor Prof. Linda Prokopy set out to investigate scientists' belief in climate change by surveying scientists across biophysical science departments in the Big 10 Conference. Their findings indicate there is a general consensus among biophysical scientists that (1) climate change is occurring, (2) humans are contributing to it, and (3) climate science is a trustworthy, mature, and credible discipline. Scientists who continue to claim otherwise are operating outside of the consensus, not just of climate scientists, but also of scientists as a whole.

THE YEAR'S PEER-REVIEWED PUBLICATIONS

- Agee, E. and S. Childs (2014). Adjustments in tornado counts, F-scale intensity, and path width for assessing significant tornado destruction. J. Appl. Meteor. Climatol, 53, 1494–1505.
- Andrews, A., R. Clawson, B. Gramig, and L. Raymond (2013). Why do farmers adopt conservation tillage? An experimental investigation of framing effects. Soil and Water Conservation, 68(6): 501-511.
- Arbuckle, J. Gordon, Jr., J. Hobbs, A. Loy, L. Wright Morton, L. Stalker Prokopy, J. Tyndall (2014). Understanding farmer perspectives on climate change: toward effective engagement strategies for adaptation and mitigation in the Corn Belt. Journal of Soil and Water Conservation, 69(6): 505-516.
- Aronson, R.B., N. L. Hilbun, T.S. Bianchi, T.R.Filley, B.A. McKee (2014). Land use, water quality, and community dynamics of coral reefs in Bocas del Toro, Panamá. Marine Ecological Progress Series, 504: 159-170.
- Baldos, U. and T. Hertel (2013). Global food security in 2050: the role of agricultural productivity and climate change. The Australian Journal of Agricultural and Resource Economics, (58):1-18.
- Barboza, L., B. Li, M. P. Tingley, F. G. Viens (2014). Reconstructing past temperatures from natural proxies and estimated climate forcings using short- and long-memory models. Annals of Applied Statistics, volume 8 no. 4, pp 1966-2001.
- Blomdin, R., J. Heyman, A. Stroeven, C. Hättestrand, J. Harbor, N. Gribenski, K. Jansson, D. Petrakov, M. Ivanov, A. Orkhonselenge (2014). Glacial geomorphology of the Altai and western Sayan Mountains, Central Asia. Journal of Maps dx.doi.org/ 10.1080/17445647.2014.992177.
- Brown, M., K. Grace, G. Shively, K. Johnson and M. Carroll (2014). Using satellite remote sensing and household survey data to assess human health and nutrition response to environmental change. Population and Environment, 36(1): 48-72.
- Carlton, J.S., J.R. Angel, S. Fei, M. Huber, T. Koontz, B.J. MacGowan, N.D. Mullendore, N. Babin, and L.S. Prokopy (2014). State service foresters' attitudes toward using climate and weather information when advising forest landowners. Journal of Forestry, 112:9-14.
- Chen, M. and Q. Zhuang (2014). Evaluating aerosol direct radiative effects on global terrestrial ecosystem carbon dynamics from 2003 to 2010. Tellus, B 2014, 66, 21808.
- Chen, M., Q. Zhuang, and Y. He (2014). An efficient method of estimating downward solar radiation based on the MODIS observations for the use of land surface modeling. Remote Sens, 6, 7136-7157.
- Caulton, D.R., P. Shepson, R. L. Santoro, J. P. Sparks, R. W. Howarth, A. R. Ingraffea, M. O. L. Cambaliza, C. Sweeney, A. Karion, K. J. Davis, B. H. Stirm, S. A. Montzka, and B. R. Miller (2014). Toward a better understanding and quantification of methane emissions from shale gas development. PNAS, 111 (17) 6237-6242.

HIGHLIGHT: Why do farmers adopt conservation tillage?

In this paper, framing effects are investigated in a new context: farmer decision making about conservation tillage practices. Primary hypotheses include the following: (1) frames (i.e., different arguments about or conceptions of an issue) portraying conservation tillage as "profitable" will generate more interest in the tillage technique among farmers than a control frame presenting only basic information; (2) frames discussing potential payments for "environmental benefits" will generate more positive attitudes than frames discussing payment for "storing carbon (C)" to limit climate change; and (3) framing effects will vary based on subjects' prior beliefs and experiences. These hypotheses were tested using a survey-based experiment administered to a national sample of row-crop farmers. Contrary to expectations, the profit frame and both payment frames had no effect on farmers' interest in conservation tillage across our entire sample. Consistent with the third hypothesis, however, a negative framing effect was found for the profit frame on nonadopters who reported no use of no-till in the past two years. These results support the argument regarding the importance of prior beliefs in reactions to frames. They also suggest the possibility of modest financial payments "crowding out" intrinsic motivations for contributions to public goods such as soil conservation. From a policy perspective, these findings also suggest the relative inefficacy of offers of modest conservation payments or profitability frames in promoting no-till farming, especially among nonadopters, and the need to find alternative frames that avoid reinforcing an argument that nonadopters appear to have already considered and rejected.

- Andrews, A. C., R. A. Clawson, B. M. Gramig, and L. Raymond (2013). Why do farmers adopt conservation tillage? An experimental investigation of framing effects. Soil and Water Conservation, 68(6): 501-511.

HIGHLIGHT: When the atmosphere warms it rains and ice melts: seventh grade students' conceptions of a climate system

Although many environmental and science educators have explored students' conceptual understandings, misconceptions, and knowledge of the greenhouse effect, global warming, and climate change, few have investigated the ways students conceptualize climate as a system or how components of the system influence climate. Therefore, the purpose of this study was to begin the process of understanding how US students conceptualize a climate system. A total of 42 seventh grade students (ages 12–13) from the Midwest completed an open-response task. From the inductive analysis of student written responses, 22 codes emerged that reflected students' conceptions of the climate system. From these codes, three path diagrams were constructed that illustrate these students' conceptions about how a climate system influences climate and how greenhouse gases and global warming impact the climate system. A generalized model of students' conception of a climate system was generated. Students in this study conceptualized a climate system in a unidirectional, linear, cause and effect relationship that emphasized the atmospheric component of the climate system.

- Shepardson D. P., A. Roychoudhury, A. Hirsch, D. Niyogi, and S. M. Top (2013). When the atmosphere warms it rains and ice melts: seventh grade students' conceptions of a climate system. Environmental Education Research, 20(3) 333-353.

- Coulter, D. P., M. S. Sepúlveda, C. D. Troy, and T. O. Höök (2014). Thermal habitat quality of aquatic organisms near power plant thermal discharges: Potential exacerbating effects of climate warming. Fisheries Management and Ecology, 21, 196–210.
- Diffenbaugh, N. S., M. Scherer, and R. J. Trapp (2013). Robust Increases in Severe Thunderstorm Environments in Response to Greenhouse Forcing. PNAS, 2013 110 (41) 16361-16366.
- Dukes, J.S., A.T. Classen, S. Wan, J.A. Langley (2014). Using results from global change experiments to inform land model development and calibration. New Phytologist, 204:3.
- Gao, X., C. A. Schlosser, A. Sokolov, K. W. Anthony, Q. Zhuang, and D. Kicklighter (2013). Permafrost degradation and methane: low risk of biogeochemical climate-warming feedback. Environ. Res. Lett., 8 035014.
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- Hayes, D. J., D. W. Kicklighter, A. D. McGuire, M. Chen, Q. Zhuang, F. Yuan, J. M. Melillo, and S. D. Wullschleger (2014). The impacts of recent permafrost thaw on land–atmosphere greenhouse gas exchange. Environ. Res. Lett., 9 045005.
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- He Y., M. Jones, Q. Zhuang, C. Bochicchio, B. S. Felzer, E. Mason, and Z. Yu (2014). Evaluating CO2 and CH4 dynamics of Alaskan ecosystems during the Holocene Thermal Maximum. Quaternary Science Reviews, 86, 63-77.
- He, Y., Q. Zhuang, J. W. Harden, A. D. McGuire, Z. Fan, Y. Liu, and K. P. Wickland (2014). The implications of microbial and substrate limitation for the fates of carbon in different organic soil horizon types of boreal forest ecosystems: a mechanistically based model analysis. Biogeoscience, 11, 4477-4491.
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- Jorgenson, M. T., J. Harden, M. Kanevskiy, J. O'Donnell, K. Wickland, S. Ewing, K. Manies, Q. Zhuang, Y. Shur, R. Striegl, and J. Koch (2013). Reorganization of vegetation, hydrology and soil carbon after permafrost degradation across heterogeneous boreal landscapes. Environ. Res. Lett., 8 035017.
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- Mase, A.S. and L. Stalker Prokopy (2014). Unrealized potential: A review of perceptions and use of weather and climate information in agricultural decision making. Weather, Climate and Society, 6(1): 47-61.

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HIGHLIGHT: Habitat quality of aquatic organisms near power plant thermal discharges: Potential exacerbating effects of climate warming

Water temperature strongly affects aquatic ectotherms, as even slight temperature changes can have dramatic effects on physiological rates. Water bodies receiving industrial thermal discharges can undergo dramatic spatial and temporal changes in water temperature. To quantify effects on aquatic ectotherms, thermal habitat quality (bioenergetic growth rate potential; GRP) for zebra mussel, *Dreissena polymorpha* (Pallas), rusty crayfish, *Orconectes rusticus* (Girard), walleye, *Sander vitreus* (Mitchill) and smallmouth bass, *Micropterus dolomieu* (Lacepède) was estimated near two power plant thermal discharges on the Ohio River, USA, from 2010 to 2012 using bioenergetics models. These results were then compared with GRP under increased base temperatures representing climate warming. Growth rate potential for all species was low near the discharges during summer and highest in winter, with increasing prey consumption minimizing the negative effects of increased temperatures. In their immediate vicinity, thermal discharges had a more adverse effect on GRP than plausible climate warming but primarily affected GRP over a small spatial area, particularly within 400 m downstream from the power plants. Examining thermal habitat suitability will become increasingly important as rising energy demand and climate change collectively affect aquatic organisms and their habitats.

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- Sarica, K. and W. E. Tyner (2014). Alternative policy impacts on US GHG emissions and energy security: A hybrid modeling approach. Energy Economics, 40, 11, 40–50.

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- Suseela, V., N. Tharayil, B. Xing, and J.S. Dukes (2013). Labile compounds in plant litter reduce the sensitivity of decomposition to warming and altered precipitation. New Phytologist, 200: 122–133.

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- Wang, F., G. Michalski, J.H. Seo, W.S. Ge (2014). Geochemical, isotopic, and mineralogical constraints on atmospheric deposition in the hyper-arid Atacama Desert, Chile. Geochimica et Cosmochimica Acta, 135, pp 29-48.

- Wang, R., T.R. Filley, Z. Xu, X. Wang, M-H Li, Y. Zhang, W. Luo, and Y. Jiang (2014). Coupled response of soil carbon and nitrogen pools and enzyme activities to nitrogen and water addition in a semi-arid grassland of Inner Mongolia. Plant Soil, 381:323-336.

- Zhang, W., B. Liu, Y. Li, J. Feng, J. M. Harbor, L. Liu, Z. Wang, and D. Li (2014). Late Pleistocene glaciations on Qianhu Mountain, Northwest Yunnan Province, China. Geografiska Annaler: Series A, Physical Geography. doi: 10.1111/geoa.12041.

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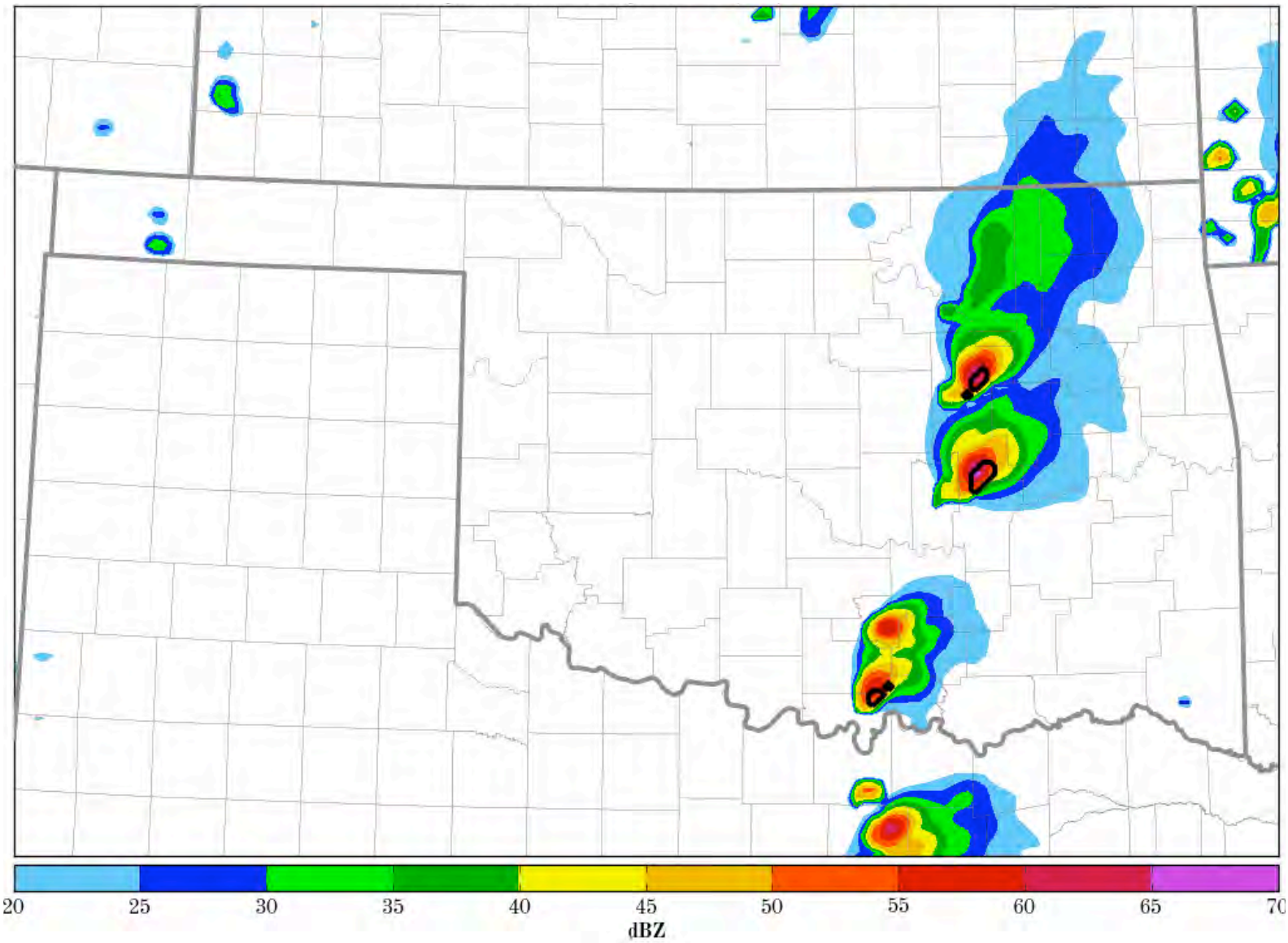
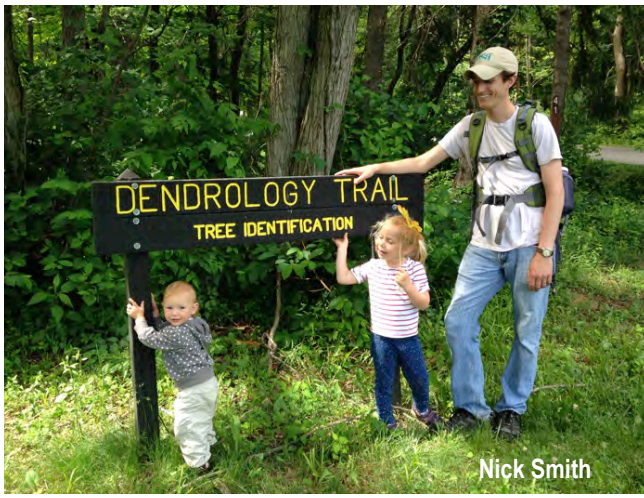


Doctoral candidate Kimberly Hoogewind, Department of Earth, Atmospheric, and Planetary Sciences, studies severe thunderstorm climatology and predictability, and she is particularly interested in the question of how global climate change may affect the frequency and intensity of storms in the future. Hoogewind uses data from global climate model projections to drive high-resolution models to study how changes in large-scale atmospheric conditions in a warming climate might influence the development and characteristics of severe storms. High-resolution simulations allow for storms to be modeled explicitly which in turn provides more detailed information that otherwise cannot be obtained from coarse resolution climate models—with results presented as if on a virtual radar screen. For example, the graphic above depicts results for a simulation in May of 2095. Shown is the simulated radar reflectivity, a measure of storm intensity, with areas of storm rotation illustrated by the black contours. Hoogewind's preliminary results have shown that under a high-emission future climate change scenario, large increases in the mean number of simulated severe storms in the U.S. may occur toward the end of the 21st century, with an increase in interannual variability, and potentially an earlier onset of the severe weather season.

LEARNING

PCCRC DOCTORAL FELLOWS

Nick Smith (2014 PCCRC fellow) began the year with a trip to Australia to attend a small, exclusive workshop on plant respiration sponsored by *New Phytologist*. Two publication from the workshop have already been published. Nick spent much of the fall and winter performing controlled experiments on a variety of plant species to understand the influence of long-term temperature on leaf gas exchange—data that will ultimately be used to help improve large-scale models. In addition, he spent much of the year writing, publishing two articles, a review paper outlining ways in which data from manipulative field experiments can be used to help improve terrestrial biosphere models, as well as a commentary on how to best test for plant temperature acclimation using multiple datasets (see Journal Articles section). In addition, two papers from previous work are currently in review, including one examining plant community composition shift in response to rainfall variability and nitrogen addition in the field. A seed grant from the PCCRC helped initiate this experiment. The following spring and summer months were spent doing extensive field work, in which Nick traveled from Alabama to Alaska and many places in between measuring leaf gas exchange responses on ~40 plant species from different biomes occurring at the northern and southern end of their range. This data will be used to understand how plant carbon exchange in these species may change under future, warmer conditions. The summer concluded with a presentation of some of his dissertation work at the 99th annual Ecological Society of America meeting in Sacramento.

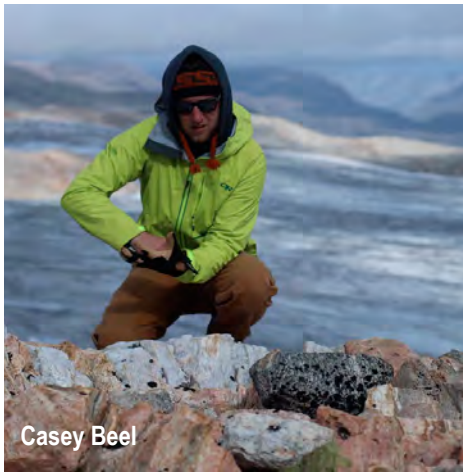


Nick Smith

Olivia Salmon is a 2013 PCCRC fellow and a second-year member of the Shepson research group. Her past year as a PCCRC fellow began with mapping methane (CH_4) leaks at the street level in the city of Indianapolis. After this surface mobile field campaign, she began conducting experiments in the air with the Shepson group's experimental aircraft (ALAR: Airborne Laboratory for Atmospheric Research) to quantify total city CH_4 and carbon dioxide (CO_2) fluxes from Indianapolis. In addition to urban CH_4 and CO_2 measurements, Olivia also looks at net ecosystem exchange of CO_2 in forested environments. This past spring she took part in a field campaign at Harvard Forest in MA, conducting airborne measurements of net CO_2 uptake by a forest canopy. These aircraft measurements were part of a hierarchy of data sets which also combined tower measurements and remote sensing retrievals of ground cover type, elevation, and soil moisture. In July 2014, Olivia was awarded an AmeriFlux scholarship to attend the annual Flux Course held at the University of Colorado, Boulder Mountain Research Station. The Flux Course is a two-week course on ecosystem fluxes which covers topics from carbon assimilation at the leaf level to regional-scale land surface modeling of CO_2 exchange. Her future projects will continue to focus on monitoring surface-atmosphere exchange of greenhouse gases in forested and urban environments.


Olivia Salmon

Casey Beel is a 2012 PCCRC fellow, working with Professor Nat Lifton, Earth, Atmospheric, and Planetary Sciences, and collaborators from the University of Colorado and the University of Buffalo. Casey's research is focused on using *in situ* cosmogenic ^{14}C inventories in recently exposed bedrock surfaces to provide temporal constraints on the duration of ice-covered and ice-free conditions throughout the Holocene in eastern Baffin Island and western Greenland. Casey was recently awarded a Purdue University PRIME Laboratory Seed Grant to expand on the group's current research into using longer-lived in situ cosmogenic ^{10}Be and ^{26}Al pairs to assess exposure and burial histories at glacial-interglacial time scales. The initial findings from this study were presented at the 44th Annual International Arctic Workshop in Boulder, Colorado. Casey has a manuscript in review, titled "How many and from where? Assessing the sensitivity of exposure durations calculated from paired bedrock $^{14}C/^{10}Be$ measurements in glacial troughs" to Quaternary Geochronology. Casey presented this research at the AGU fall meeting with support from a PCCRC Travel Grant. Work on samples collected from the 2013 and 2014 Greenland and Baffin field seasons is ongoing.


Casey Beel

Wendell Walters joined the Department of Earth, Atmospheric, and Planetary Sciences in the fall of 2012 as a PCCRC Fellow, working with Professor Greg Michalski. In the past year, Wendell has analyzed the stable isotopes of ice core nitrate to determine changes in global nitrogen cycling and shifts in oxidation chemistry in response to natural and anthropogenic climate change. Wendell was awarded a PCCRC and a P.F. Low Travel Grant to present this work at the AGU Fall Meeting and at the IU Crossroads Geology Conference. Wendell has also worked on collecting nitrogen oxides (NOx) from various emissions sources and analyzing its nitrogen stable isotope signature in order to partition between NOx sources to assess the effectiveness of NOx reduction technologies. In addition he has worked on understanding the isotope effect of the evaporation of nitric acid, which has important implications for polar environments. Wendell received a GSA Graduate Student Research Grant, with which he plans to further explore NOx chemistry and isotopic effects.


Wendell Walters

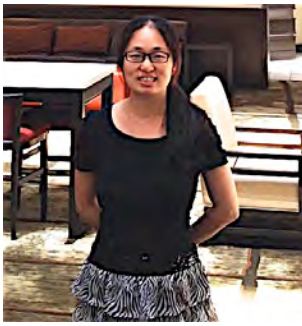
Ruoyu Wang is a 2011 PCCRC Fellow in the Department of Agricultural and Biological Engineering. He works with Professor Keith Cherkauer, with Professor Laura Bowling from the Department of Agronomy serving as co-adviser. In the past year, Ruoyu continued his research on evaluating climate variability and climate change impacts on crop yield and bio-climate stresses in the Midwestern U.S. using an improved ecohydrology model. He tested the model at plot scale, summarized current results in a manuscript, and submitted the paper to the journal *Agricultural and Forest Meteorology*. The main findings of this paper seek to establish the importance of realistic representation of soil moisture dynamics for correct quantification of crop stress. His next step is to extend the model to the watershed scale, where soil moisture calibration is not feasible, and to explore potential CO_2 enhancement effects on crop yield under future climate change conditions. Ruoyu passed his PhD preliminary exam in August 2014.


Ruoyu Wang

ALUMNI UPDATE

Since graduating from Purdue in 2009, **Dr. Joseph Alfieri** (2005 PCCRC Fellow) has worked for the USDA Agricultural Research Service, where his research takes a holistic, highly-interdisciplinary approach both to understand the physical mechanisms controlling the exchange of heat, moisture, and other chemical species between the atmosphere and biosphere and to develop tools to measure and model land-atmosphere exchange processes on local to continental scales. Dr. Alfieri's research has applications to a broad range of issues confronting both the agricultural community and society as a whole. His work investigating the impacts of surface variability on both airborne and in-situ measurements of evapotranspiration and other surface exchange processes has yielded techniques for determining the measurement uncertainty while highlighting the impacts of fine-scale variations in surface conditions on both evapotranspiration and its measurement. Most recently, Dr. Alfieri, working in collaboration with fellow scientists and industry partners, has focused on characterizing the impacts of within-field variability in canopy structure and vegetation density on turbulent transport and evaporative water loss. Dr. Alfieri was honored by Agricultural Research Service as the 2014 Early Career Scientist of Year for the Beltsville Area.

Professor Kendra Gotangco (Ph.D. '11; 2007 PCCRC Fellow) is an assistant professor at the Department of Environmental Science of the Ateneo de Manila University. She was just made permanent, effective June 2014 (similar to the concept of tenure). Gotangco's projects and courses revolve around human-environment dynamics, systems thinking and resilience to disasters and climate change. She is also a member of the Working Group of Regional Climate of the World Climate Research Programme, and will be a Junior Associate of the Abdus Salam International Centre of Theoretical Physica (ICTP) starting next year.



Dr. Fan Wang After completing her doctoral studies in October, 2013, Fan Wang (2009 PCCRC fellow) has been working for the US-China Ecopartnership for Environmental Sustainability (USCEES)-Purdue Project as the project coordinator. Her main responsibilities are to lower the barriers to research communication and promote mutual trust and understanding between Chinese and US scientists and students, as well as assisting Director Tim Filley (Earth, Atmospheric, and Planetary Sciences) foster bi-national research and education efforts and the transfer of Purdue technologies related to environmental and economic sustainability in China. At the same time, Wang is still actively engaged in many academic activities, such as participating in research proposals, making presentations at conferences, and writing papers.

Dr. Jinyun Tang (Ph.D. '11; 2006 PCCRC Fellow) now with the Lawrence Berkley National Laboratory, was awarded honorable mention for the Gene E. Likens outstanding publication award by the Ecological Society of America (ESA). This award is granted to only one scientist and one honorable mention per year. The paper presented a new approach to modeling resource competition in networks involving many components, such as microbial decomposition of soil organic matter and nutrient competition between microbes and plants. Dr. Tang also published his recent work examining how parameterization of decomposition temperature sensitivity (Q10), microbial carbon use efficiency, and mineral surface reactions contribute to the large uncertainty in soil carbon-climate feedback predictions. The paper 'Weaker soil carbon–climate feedbacks resulting from microbial and abiotic interactions," demonstrated that these three parameters, as used in most existing soil biogeochemical models, misinterpret empirical experiments; misinterpretation that could lead to over-prediction of soil carbon-climate feedbacks. This discovery represents a serious call for reformulating many existing terrestrial biogeochemical models. The work was published in *Nature Climate Change*.

Dr. Aaron Goldner (Ph.D., 2013) currently is serving as a science and technology fellow at the Department of Energy, where he is focusing on domestic climate and energy policy. He is working on several parts of the Climate Action Plan put forth by the President in 2013. Projects include working with Environmental Protection Agency on the soon-to-be-finalized Clean Power Plan rule; working with DOE program offices to integrate climate change strategies in their workflows/ projects; and energy modeling of the necessary emissions reductions to meet the mitigation targets for post-2020 decision making.

STUDENT AWARDS

Graduate students Amber Mase, Forestry and Natural Resources, and Paul Schmid, Earth, Atmospheric and Planetary Sciences were recipients of Best Oral Paper awards for their respective presentations at the 2014 Annual Meeting of the American Meteorological Society. A recording of their presentations is available from the AMS conference website.

Amber Mase's award-winning presentation was titled: **Climate Change Risk and Adaptation: Perspectives of Midwestern Agriculturalists.** As the climate changes, farmers must cope with impacts, such as more frequent extreme weather events and less reliable conditions, which will create challenges for crop production. When making decisions, U.S. farmers typically rely on advisors with specialized expertise for guidance. Little research has been done on agricultural advisors' views on climate change, and how this affects advice they give to farmers. Amber's talk described results from two 2012 surveys of 4,778 farmers across the 11 Corn Belt states and 2,087 Midwestern agricultural advisors in Michigan, Indiana, Iowa, and Nebraska. Advisors surveyed included Certified Crop Advisors, Extension agents, Natural Resource Conservation Service (NRCS) Employees, Ag bankers and more.

Paul Schmid won for his presentation, **Modeling the Influences of Local Urban Aerosols on a Derecho in Birmingham, AL**. Paul's study used the Regional Atmospheric Modeling System (RAMS) to simulate a derecho (a widespread, long-lived, straight-line wind storm that is associated with a land-based, fast-moving group of severe thunderstorms) that crossed the Birmingham, AL metro area on June 14, 2009. The observed derecho modified significantly as it passed over the urban center: 1) the core of the storm split around the city and 2) the entire mesoscale system turned southward after passing over the urban area. The RAMS bin-emulating microphysical parameterization, with two urban aerosol modes, was coupled with an air quality model to produce local urban sources of cloud-nucleating aerosols near and downwind of Birmingham. The local sources produce a realistic, heterogeneous aerosol distribution compared to observations made by satellite.

TEACHING INNOVATIONS

Access to top-flight supercomputer for atmospheric science students

A partnership between Professor Mike Baldwin, Earth, Atmospheric, and Planetary Sciences, and Stephen Harrell, Information Technology at Purdue, facilitated some innovative teaching by integrating high-performance computing into weather modeling and forecasting classes at the undergraduate and graduate levels. The partnership gave students practical hands-on training in high-performance computing that included learning skills to automate tasks and coax the software to take fuller advantage of one of the world's most powerful supercomputers.

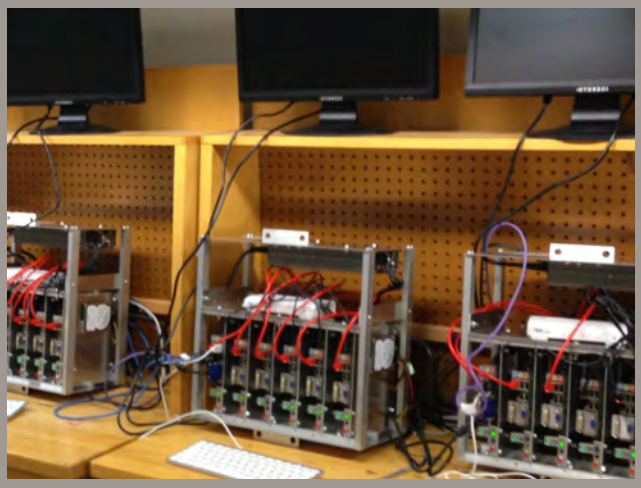
The students use the Carter community cluster, which made the TOP500 list of the world's most powerful supercomputers two years running. ITaP Research Computing (RCAC), which operates five community clusters for Purdue researchers, has set aside a portion of Carter, dubbed the Scholar Cluster, for any instructor with a need to incorporate high-performance computing in classes.

With high-performance computing systems now integral to weather forecasting—and many other fields—developing these skills is important for students. Some things Baldwin has his students do, such as ensemble forecasting using multiple models to gauge not only a forecast's accuracy but its uncertainty, would be difficult, if not impossible, to do without using a supercomputer—so would running the state-of-the-art Weather Research and Forecasting (WRF) model.

The photo below, left, shows a series of small cluster computers that the students built in the EAPS 391 "Scientific Computing" class, another collaboration between Baldwin and Harrell. Purdue undergraduates taking the course built these machines from the ground up, installed the operating system, compilers, built the WRF model, ran it and pulled useful forecast variables from the output.

The photo below, on the right, shows students that participated in the Student Cluster Competition at the SC14 Supercomputing conference in New Orleans in November, 2014. Harrell served as the team's coach and Baldwin as faculty adviser. The team called themselves 'Calderero,' the Spanish term for 'Boilermaker' to honor the inclusion of students from Purdue's sister school, Colombia's Universidad EAFIT, on the team. The students built their own cluster computer, brought it to the conference, and ran four scientific applications on their machine (including ADCIRC, a hydrology model used for hurricane storm surge, among other things) for a 48 hour period, attempting to get as much accomplished as possible.

Adapted from an article by Greg Kline, science and technology writer, Information Technology at Purdue.



STUDENT TRAVEL GRANTS

The Student Travel Grant program provides funds to students for travel to professional meetings and conferences to present invited papers or posters. The program also funds student participation in workshops that facilitate their on-going research efforts. This year the center provided 8 travel grants totaling over $12,000.

Casey Beel, doctoral student in Earth, Atmospheric, and Planetary Sciences for travel to American Geophysical Union Fall Meeting

Samuel Childs, undergraduate student in Earth, Atmospheric, and Planetary Sciences for travel to American Meteorological Society Annual Meeting

Natalie Chin, ESE doctoral student in Agricultural and Biological Engineering, for travel to the American Geophysical Union Fall Meeting

Amber Mase, doctoral student in Forestry and Natural Resources, for travel to the American Meteorological Society Annual Meeting

David Mase, doctoral student in Earth, Atmospheric, and Planetary Sciences for travel to American Geophysical Union Fall Meeting

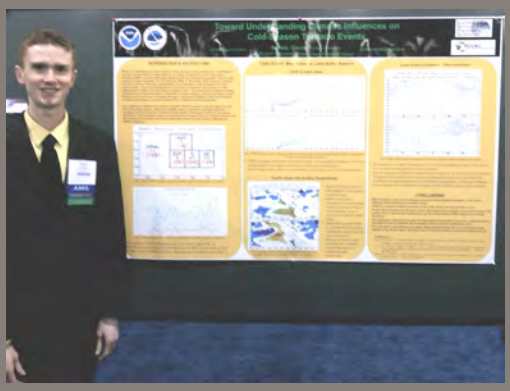
Ian Pope, doctoral student in Earth, Atmospheric, and Planetary Sciences for travel to the Association of American Geographers Annual Meeting

Nick Smith, doctoral student in Forestry and Natural Resources, for travel to the NCAR Land Model Tutorial Workshop

Lili Wang, doctoral student in Agricultural and Biological Engineering, for travel to the American Geophysical Union Fall Meeting

"The conference not only provided a chance for me to present my research project from last summer, but it also opened my eyes to the latest advances in the field and allowed for excellent networking opportunities among some of our field's most storied professionals."

—Samuel Childs,
EAPS undergraduate student



ABOVE: Samuel Childs presenting his research, "Toward Understanding Climatic Influences on Cold-Season Tornado Events," at the AMS Annual Meeting.

Over the next decade and beyond, understanding, mitigating, and adapting to climate change will remain at the forefront of scientific inquiry and public discussion. Teaching about climate and climate change, however, is conceptually challenging. With a grant from the National Science Foundation, Professors Dan Shepardson and Dev Niyogi and their team developed a climate change education program for middle and high school teachers using an Earth systems science approach. The team presented their program to a group of teachers from across the Midwest at a conference held on the Purdue campus in June 2014.

ENGAGEMENT

PCCRC SPECIAL EVENTS

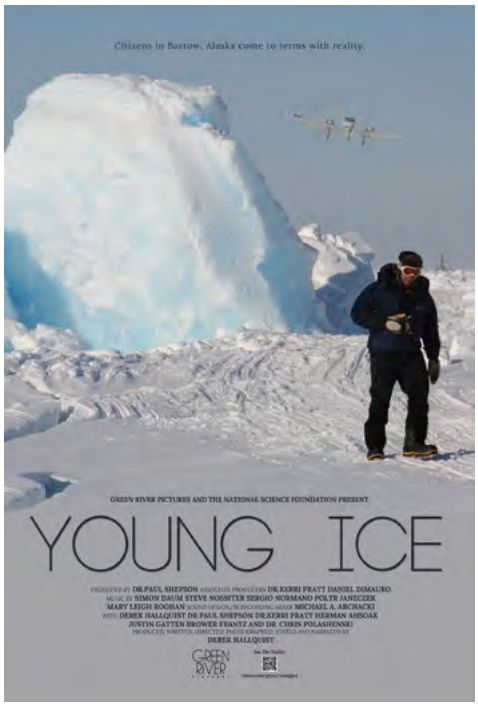
The center hosts public programs throughout the year, offering visitors the opportunities to attend lectures, conferences, and film screenings, and connect with Purdue researchers.

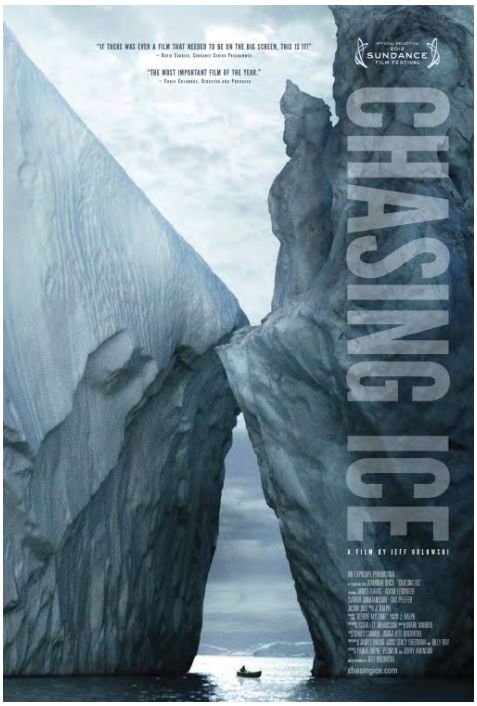
DOCUMENTARY DOUBLE FEATURE

You are invited to the PREMIERE of Paul Shepson's documentary, *Young Ice*, followed by the full-length documentary *Chasing Ice*

WEDNESDAY, APRIL 23 · 6:30 PM

Purdue University, Fowler Hall
Stewart Center





EARTH WEEK 2014

In April 2014, the center was pleased to premiere the short documentary, "Young Ice." Written and directed by filmmaker Derek Hallquist, and produced by Paul Shepson, the documentary is a terrific exploration about how research scientists and local communities learn from each other and together offer a collective voice to respond to climate change.

Following the film, the full-length documentary, "Chasing Ice," was shown. The movie tracks photographer James Balog on his three-year project to document the most visible sign of climate change on the planet today—the Earth's melting glaciers. A Q&A session with Shepson and Hallquist followed the movies.

2014 DYNAMICS OF CLIMATE CONFERENCE

The Dynamics of Climate conference aimed to prepare participants to use a professional development toolkit for climate science education and to provide up-to-date information on climate science.

In a three day conference held on the Purdue campus on June 18-20, 2014, participants were introduced to climate datasets and activities to help develop a deep understanding of the climate system. Small group and individual activities required participants to interpret, analyze, and represent climatic data and use scientific concepts to explain climate events.

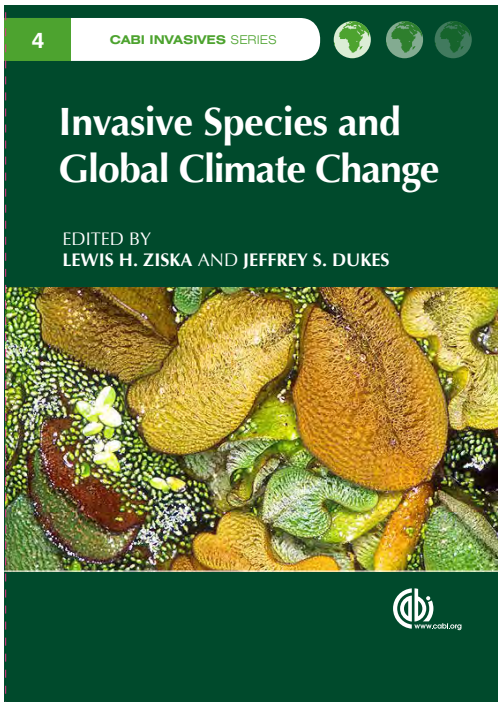
This teacher professional development program and toolkit were developed with a grant from the National Science Foundation's Geoscience Education program with support from the Purdue's departments of Curriculum and Instruction, Earth, Atmospheric, and Planetary Sciences, and Agronomy. The conference attracted 41 teachers from various middle schools and high schools in IL, IN, MI and OH.

Professor Paul Shepson, Chemistry and Earth, Atmospheric, and Planetary Sciences, and Dr. Abigail Derby Lewis from the Chicago Field Museum of Natural History were keynote speakers. They provided scientific data about climate change and its impact on the Earth's climate system from local to global scales. Professor Michael Jabot, SUNY Fredonia, addressed the Next Generation Science Standards and their implication for climate change education. Professor Shepardson overviewed the research on secondary students' conceptions of the greenhouse effect, global warming, and climate change, laying an educational foundation for the need for climate education. The conference also included an interactive panel discussion with Purdue faculty and students. Topics presented included research on:

- the impacts of climate change on severe storm events for tourism destination communities around the Great Lakes region (Natalie Chin, graduate student, Agricultural and Biological Engineering);
- agricultural adaptation to climate change and the IPCC (Otto Doering, professor, Agricultural Economics);
- the role of norms and values in shaping political behavior and policy outcomes; framing climate science (Leigh Raymond, professor, Political Science).

In addition, science teachers Nicole Strickhouser and Joel Wilson discussed how they help students better understand the greenhouse effect, global warming, and climate change. The toolkit is available for download from the PCCRC website.

NEW BOOKS



Climate change is only one of many stresses affecting natural and managed ecosystems around the globe. While the threat from climate change will continue to grow over time, some stressors already cause major problems over widespread areas. Collectively, invasive species, introduced (often accidentally) from other habitats, are such a stressor. Many researchers worry that current pressures on ecosystems from invasive species could be exacerbated as climate change disrupts ecosystems. "Invasive Species and Global Climate Change," co-edited by PCCRC director Jeffrey Dukes and USDA researcher Lewis Ziska, examines this issue from many angles.

The book, published by CABI Press in September 2014, comprises 20 chapters from top invasive species experts around the world. The authors examine how climate change will affect a broad range of organisms across many continents. Chapters focus on the responses of invasive pathogens, plants, insects, marine organisms, and more, in settings from Antarctica to Australia to the National Parks of the United States. Other chapters highlight new tools for addressing invasive species problems. Growing evidence suggests that the increasing CO_2 concentration in the atmosphere, along with warming and precipitation shifts, will present further challenges to managing invasive species. These challenges will be more difficult to address in natural systems than those under more active management. This book provides an overview of the future challenges and the extent to which we may be able to develop solutions.

WORKING PAPERS

The Physical and Social Determinants of Mortality in the 3.11 Tsunami
Daniel P. Aldrich, *Political Science* and Yasuyuki Sawada, *University of Tokyo*

The human consequences of the March 11, 2011 tsunami were not distributed equally across the municipalities of the Tohoku region of northeastern Japan. Instead, the mortality rate from the massive wave varied tremendously from zero to close to ten percent of the local residential population. What accounts for this variation remains a critical question for researchers and policy makers alike. This paper uses a new, *sui generis* data set including all villages, towns, and cities on the Pacific Ocean side of the Tohoku region to untangle the factors connected to mortality during the disaster. With data on demographic, geophysical, infrastructure, social capital, and political conditions for 133 municipalities, we find that tsunami height, stocks of social capital, and demographic conditions strongly influenced mortality rates. Given the high probability of future large scale catastrophes, these findings have important policy implications for disaster mitigation policies in Japan and abroad.

Power to the People or Regulatory Ratcheting? Explaining the Success (or Failure) of Attempts to Site Commercial U.S. Nuclear Power Plants: 1954 - 1996
Eric Berndt and Daniel P. Aldrich, *Political Science*

Between 1954 and 1996, more than 200 nuclear power projects were publicly announced in the United States. Barely half of these projects, however, were ever completed and generated power commercially. Past research has raised a number of potential explanations for the varying siting outcomes of these projects, including contentious political protest, socioeconomic and political conditions within potential host communities, regulatory changes ("ratcheting") and the cost overruns associated with reactors. This article uses a new, *sui generis* data set of more than 210 cases of actual and potential host communities over time to illuminate the regional and national variables which led to successful siting (or failure). Controlling for factors highlighted by past studies, we find that regulatory, collective action, and reactor-specific factors best predict the outcomes of attempts to site nuclear reactors over this time period. These findings have important implications in the post-Fukushima "nuclear renaissance" era when many still hope to revitalize the nuclear industry in the U.S. and abroad.

A RESOURCE FOR SCIENCE-BASED INFORMATION

Wally Tyner

Farzad Taheripour

The PCCRC works to bring objective, science-based information to the policy making process. Our faculty engages in multidisciplinary analysis to provide information tools for researchers, students, elected officials, and the public.

In a policy brief published by the National Agricultural & Rural Development Policy Center (NARDeP), Drs. Wally Tyner and Farzad Taheripour, Department of Agricultural Economics, evaluate the economic and environmental impacts of simultaneous expansion of shale oil and gas resources and policies aimed at reducing greenhouse gas (GHG) emissions. They use a computable general equilibrium (CGE) model (GTAP) to perform the analysis. A computable general equilibrium model is simply one that has all the economic sectors and factor markets included within its scope.

The GTAP model is a global CGE model with as many as 113 regions and 57 sectors, although it is commonly simulated with greater aggregation to simplify the analysis. The main reason for using a CGE model is that one can examine all the interrelationships within an economy. They report on several simulations of the impacts of the shale oil and gas technology with no environmental measures in place, with a carbon tax, and with environmental regulations on the electricity and transportation sectors in the United States. You can read the policy brief from the NARDeP website.

NARDeP
National Agricultural & Rural Development Policy Center
A Regional Rural Development Centers Initiative

POLICY BRIEF
BRIEF 21/MAY 2014

UNCONVENTIONAL SHALE OIL AND GAS PRODUCTION AND GREENHOUSE GAS REDUCTION: CAN WE HAVE BOTH?

By Wallace E. Tyner and Farzad Taheripour (Purdue University)

The U.S. Department of Energy projects that by 2030 North America will be self-sufficient in petroleum due to the shale oil and gas revolution. We estimate that shale technologies will provide a welfare increase of about $300 billion/year. We evaluate what happens to this gain if we "spend" part of it on reducing greenhouse gas (GHG) emissions. A carbon tax that achieves a 27 percent reduction in GHG emissions reduces the gain by 41 percent, and a policy of regulating transportation and electricity takes about half the gain. In both cases, we can retain a large part of the shale dividend while at the same time reducing GHG emissions.