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.

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Cover photographs: From left to right: Mammatus clouds at sunset, following data collection on severe thunderstorms by the Purdue MPEX crew in the Oklahoma Panhandle; Asya Robertshaw, a botany PhD student in Dr. Nancy Emer’s lab, transplanting experimental Anemone acutiloba plants into plots at the Ross Reserve; and Casey Beel, a geosciences PhD student in Dr. Nat Lifton’s group collects samples from West Greenland (photo by Jason Briner).
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Message from the Director

I am writing this letter beyond the date when I thought I would need to do so. Our superb paleo-climatologist, Matt Huber, took over responsibility for the PCCRC in January 2013, but then was hired away last summer. So, I am back as interim until a new director is recruited. Unfortunately, the growing recognition of the potential force and impact of climate change has made our experienced faculty much more valuable to others.

There is increased awareness of the potential impacts from climate change. The new national climate assessment draft (www.assessment.globalchange.gov) coupled with the Fifth Assessment by the Intergovernmental Panel on Climate Change (www.ipcc.ch) as well as such localized events as the continuing drought in California confirm the relevance of many of the areas our faculty are working on. These include;

- assessing climate change impacts on agriculture and forestry and the possible adaptations to it,
- improving our understanding of extreme events,
- improving resilience to climate change and recovery from its impacts, and
- learning more about coupled and interactive systems within and between the atmosphere, oceans, and the land.

In addition, one of the signature hallmarks of our center has been the ability to get our work on the ground in a meaningful way. You will see examples of this in the report from across the areas listed above.

Approaching a decade of operation, we believe we are working on important areas of climate change and are increasingly able to transfer our knowledge to those best able to utilize it. Because of the increased concern with climate change, many of our faculty in critical areas are going flat-out. This makes it imperative to capitalize on where we have both strength and traction, and we are increasing our efforts to make sure what we do is actually useful and usable. This integration from user back to research and discovery requires a strong commitment from researchers for relevance. Increasingly we are being asked to do this internationally, from looking at the impacts of changing climate patterns affecting India to building climate data collection and resilience to climate change impacts in West Africa. One driver of integration is that many major research programs now ask for a climate change impact components and adaptation strategies.

I continue to struggle to best describe the success of our center. Purdue, like many other institutions, has decided that output has to be increased while costs are contained. We are asked; how would the world be different if we
did not exist? I see many more productive efforts where collaborations have occurred that might not have occurred if the center did not exist. My bias is that these collaborative efforts ask better questions and produce results that are more useful. Centers such as ours, in essence, provide a platform for asking the right questions for “wicked” problems that are not subject to straightforward solutions by experts in one discipline. Climate change is not just about climate, but also about the potential disruption of critical societal systems, like food production or transportation.

A well-conceived center can give encouragement to people to organize to begin to answer system based questions successfully. We have also been successful in the development of human capital that can tackle such critical societal questions – something a university should be about. The success of our PCCRC Fellows testifies to this as they have gone out into the world to work on such problems. We are also able to give students and colleagues experience in framing critical societal problems. You will find examples of this in the report.

Our faculty continues to develop cross-cutting courses and learning experiences for our students and the broader community. These effort often relate to the juncture between the science and working on the ground to mitigate or adapt to climate change. Our outreach extends to policy makers, providing unbiased information about the consequence of their actions. We are also adding to the knowledge base of our secondary school teachers in Indiana. These contributions are harder to measure than dollars of research grants or numbers of journal articles. However, these less tangible efforts represent the long term benefit of having a center with core interest in climate that then serves faculty and citizens across the spectrum of societal problems that relate to climate change challenges.
To help better predict where and when spring thunderstorms will form, the Mesoscale Predictability Experiment (MPEX) launched a field study from May 15 to June 15, 2013. MPEX included afternoon launches of weather balloons carrying instrument packages called radiosondes, which will profile conditions around thunderstorms as they develop and move east across the Great Plains. This photo shows the lowered base of severe thunderstorms forming in Oklahoma on 30 May 2013. The inset shows the corresponding radar reflectivity image.
Over the last 9 years, the PCCRC has built a strong foundation of research collaborations and expertise in four areas: coupled biogeochemical cycles; climate change and extreme weather; hydroclimatology; and impacts, adaptation, and resilience to climate change. During this time, our community of natural and physical scientists, engineers, mathematicians, and social scientists has deepened our understanding of the causes and consequences of the Earth’s changing climate system and enhanced the capacity of decision makers to develop effective mitigation and adaptation strategies. In this section of our report we provide a sampling of the breadth and depth of the research efforts of our faculty.
Collaborative Research: The COnvective Precipitation Experiment-Microphysical and Entrainment Dependencies (COPE-MED)

Sonia Lasher-Trapp, Department of Earth, Atmospheric, and Planetary Sciences (Funded by the National Science Foundation).

Convective precipitation is typically characterized by heavy rainfall, hail, and strong winds which can produce hazardous weather including flash flooding and tornadoes. This project will collect a unique, multi-component data set to better understand the initial stages of convective precipitation development, increase understanding of entrainment and cloud microphysical interactions affecting convective rainfall, develop novel data analysis techniques, and develop improved cloud simulation models.

The COPE-MED field campaign is built around the combination of remote sensing capabilities and in situ cloud physics instrumentation on the University of Wyoming King Air research aircraft. These capabilities will be used to observe, in detail, the microphysical and dynamic structure of convective storms in their initial stages of development.

COPE-MED will take place within the broader context of COPE, a U.K.-led field campaign scheduled from June through August, 2013 in Southwestern England. In this geographical location, the cooler cloud bases, lower drop concentrations and relatively predictable convective initiation along convergence lines provide an ideal opportunity to sample developing cumuli as they progress from the warm rain process into ice processes, and the influences of entrainment upon that progression. The remotely-sensed and in-situ aircraft data will be analyzed together with data collected from a COPE UK research aircraft as well as from ground-based radars, radiosondes, aerosol instrumentation, and surface rain gauges. The data will be analyzed in conjunction with high-resolution 3D numerical simulations of the clouds, which can represent the different microphysical pathways and the effects of entrainment, and provide information on cloud features that are otherwise incapable of being sampled by the aircraft.

The novel contributions from COPE-MED will include technical development of the use of attenuation of the in-situ Wyoming Cloud Radar signal by raindrops as a measure of the strength of the warm rain process; the analysis of data collected from a suite of microphysical probes on the aircraft, with post-processing algorithms designed to maximize information and minimize ambiguity regarding quantification of the different water phases in the cloud; and the first direct comparison of flow fields near cloud top derived using dual-Doppler analysis with those from high-resolution cloud simulations, with the purpose of studying entrainment features and improving its representation in large-eddy simulations.

Overall, this project will improve quantitative precipitation forecasting, advance understanding of cloud seeding, and improve prediction of the effects of aerosols and climate change upon clouds and precipitation.

ABOVE: Prof. Lasher-Trapp serving as flight scientist in the University of Wyoming King Air during the COPE field campaign in Southwest England.

BELOW LEFT: View from the cockpit of the top of a developing cumulus cloud as the King Air lines up to pass through it and sample its properties with microphysics probes, the Wyoming cloud radar, and Wyoming cloud lidar, all mounted on the aircraft.
Collaborative Research: Improved Understanding of Convective-Storm Predictability and Environment Feedbacks from Observations during the Mesoscale Predictability Experiment (MPEX)

Robert (Jeff) Trapp and Michael Baldwin, Department of Earth, Atmospheric, and Planetary Sciences (Funded by the National Science Foundation).

The influence of organized regions of deep convection on its environment in both space and time has been recognized for many years. For example, organized deep convective regions are known to enhance upper-level jet streaks. In another example, individual thunderstorms modify the nearby surrounding mass and momentum fields within a few hours, likely assisting in storm maintenance and influencing storm severity. While past observational and modeling studies have documented these nearby and more distant feedback effects, this research represents the first attempt to conduct a careful comparison of model-simulated convective feedbacks with those diagnosed from upsonde, dropsonde, and Microwave Temperature Profiling (MTP) observations taken during the Mesoscale Predictability Experiment (MPEX). The improved capability of numerical weather prediction models and the availability of the NCAR GV airborne observing systems, argues strongly that it is time to understand how deep convection modifies the surrounding environment in much greater detail.

A multi-institutional team with broad expertise has been assembled to pursue the fundamental scientific questions of convective storm-environmental feedbacks and predictability. In particular, the team will seek to quantify the observed environmental modifications and upscale feedbacks from deep convection, and relate these back to the characteristics of the convection; evaluate model simulations of upscale feedbacks from deep convection with MPEX observations; and explore the predictability of convectively disturbed atmospheres. These three objectives will be met using various diagnostic approaches applied to the dropsonde observations, including calculation of heat and moisture budgets; numerical model simulations with ensemble Kalman filter data assimilation at convection-allowing resolutions; and careful comparisons between MPEX observations and model simulations.

Assessment and Recommendations for Using High-Resolution Weather Information to Improve Winter Maintenance Operations

Michael Baldwin and Robert (Jeff) Trapp, Department of Earth, Atmospheric, and Planetary Sciences (Funded by the Indiana Department of Transportation-INDOT).

This project will provide experimental winter weather forecasting data by developing a prototype high-resolution weather prediction system built upon on-going numerical modeling work. In addition, the project will assess available winter weather forecasting data and evaluate whether more detailed and precise forecast information is beneficial to INDOT.
Ozone and atmospheric particles (also called aerosols) can affect human health, air quality, and climate change. Aerosols can be emitted directly into the atmosphere by various sources such as fires and vehicle exhaust, or through “secondary” mechanisms in which they are formed by chemical reactions in the atmosphere. Organic aerosols that are formed by atmospheric oxidation of biogenic volatile organic compounds (BVOC) represent an increasingly important fraction of the amount of atmospheric particulates, yet we do not fully understand the mechanisms and detailed atmospheric chemistry involved in their production.

Tropospheric ozone is formed by the interaction of sunlight, nitrogen oxides, and volatile organic compounds. During the oxidation of BVOC, organic nitrates are formed, which inhibits the formation of tropospheric ozone by serving as a “reservoir” for nitrogen oxides. In a forest environment, deposition of organic nitrates are also a source of nitrogen that can be used by plants, which could improve our forests’ ability to sequester carbon. However, organic nitrates in the atmosphere can react further to produce secondary organic aerosols in the atmosphere. This study aims to improve our understanding of the role that organic nitrates play as reservoirs for atmospheric nitrogen oxides, and the mechanisms and rates of production of organic nitrates by BVOC oxidation. The research team will also study the role of organic nitrates in the production of secondary organic aerosols. Three BVOC, isoprene, alpha-pinene, and beta-pinene, represent approximately 600 teragrams of emissions per year. The focus of this project is on improving our understanding of the atmospheric chemistry of these three, important BVOC.

An ultimate goal of this project is to improve the representation of BVOC chemistry in Earth Systems Models to gain a better understanding of the interactions and links between organic nitrate chemistry, air quality, and climate change.

Through this project, collaborations will be established with scientists and students at the University of East Anglia in the U.K., and at other partner universities in the U.S, thus creating opportunities to connect graduate and undergraduate students in semester or summer abroad experiences in a number of laboratories.

Local high school students and teachers will be engaged in the science through participation in the Global Ozone Project. Participating students measure ground-level ozone and meteorological conditions outside their schools and upload their measurements to the GO3 database. Through this work, students are effectively building the first global ozone database, while learning about atmospheric environmental problems including: ground level ozone, stratospheric ozone depletion (“ozone hole”), acid rain, and global warming. An ozone instrument will be installed in a rooftop weather station at West Lafayette Junior/Senior High School where an earth science class will interpret data and incorporate their measurements into the GO3 database which will connect their learning to that of other students around the world. Local students will be invited to attend the principal investigator’s group meetings so that high school students can get an advance perspective on how science is conducted in a university research laboratory.

For more information about the Global Ozone Project, and to download lesson plans, see: www.go3project.com.
Invasions of exotic species threaten many ecosystems and can result in significant degradation of our natural resources and economic costs. Research on exotic invasions has been a major topic in the last two decades and much knowledge has been gained from research done on small plots. However, current understanding of the long-term invasion process at regional to continental scales is limited, in part because long-term and large-scale empirical information is lacking.

The project team will use a new research framework constructed using functional traits (for example, life history information) that includes all three major invasion components: the invader, the recipient system, and the drivers that facilitate the invader, all examined across scales of both time and space. The overarching goal of this exploratory project is to establish a network of scientists and practitioners to develop a regional-scale predictive model of invasion dynamics under this new framework.

As this project will examine the role that land use and climate change has in invasive species movement and distribution across the southeastern United States, the research team includes network of ecologists (invasive plant ecologists, community ecologists, ecosystem ecologists, and landscape ecologists), modelers (statisticians and geospatial scientists), conservation biologists, and natural resource practitioners.

The outcomes of the proposed project will position the research team to develop a new generation of accurate predictive models for regional scale invasion forecasting, which will help researchers and natural resource managers examine “what-if” scenarios in the short term (5-10 years) and long term (50-100 years). The new research framework should also be easily applied to invasive species study in other regions and on other continents.
The Midwest is arguably the most economically and environmentally important agricultural ecosystem in the U.S. as it underpins both food and energy security. The overarching goal of this collaborative research project is to determine the productivity potential and environmental impacts of candidate biomass production systems, including input use efficiencies (nitrogen, water) and greenhouse gas (GHG) emissions. Systems based on perennial grasses like switchgrass and Miscanthus, are being compared to annual biomass systems that include maize (for grain and stover) and sorghum. Results of these biomass production systems are being compared to conventional maize-soybean grain production and an unmanaged native prairie (controls).

These studies are being conducted at Purdue’s Water Quality Field Station (a PU “core” facility), and at PU agricultural centers strategically located around Indiana. Four Purdue faculty, Professors Jeffrey Volenec, Agronomy; Sylvie Brouder, Agronomy; Ron Turco, Agronomy; and Indrajeet Chaubey, Agricultural and Biological Engineering and Earth, Atmospheric, and Planetary Sciences, are working with collaborators that have companion studies underway in Illinois, Iowa, Nebraska, Minnesota, and Wisconsin that allows the team to extend the inference space of findings. These collective biophysical data are being used to calibrate the Soil Water Assessment Tool model to further expand inference space and to optimize placement of biomass cropping systems on the landscape. A key factor in determining the net energy balance and environmental footprint of any potential biomass production scheme is the system’s nitrogen (N) economy because it impacts both biomass yield and GHG emissions. The source, rate, and application strategy for N, along with the N use efficiency of the plants and accompanying soil microbial activity can alter biogeochemical cycling of carbon and nitrogen, and this is poorly understood for many understudied biomass systems and especially when these are placed on marginal soils.

Important, novel aspects of this effort include: 1) the explicit focus on the comparative productivity potentials of candidate bioenergy systems as influenced by land capability; 2) the combined study of multiple ecosystem services to identify tradeoffs and tensions among productivity and the maintenance and / or enhancement of soil, air and water quality; 3) the combined analysis of air and water quality for economic and policy implications, and 4) life cycle assessment to identify the break-even scenarios critical to promoting agriculture’s interest in bioenergy crops.
Tracking black carbon through a northern temperate forest soil

Fire is a major controller of carbon cycling in terrestrial ecosystems by converting plant biomass to atmospheric CO$_2$ and by contributing incompletely combusted biomass or “black carbon” (BC) to soils. With funding from the National Science Foundation, Professor Timothy Filley, Earth, Atmospheric, and Planetary Sciences, and collaborators from City College of New York and the University of Michigan are working to clarify the chemical and physical structure of BC materials and their wood precursors and to determine how BC structure relates to its dynamics in natural areas.

This year, the project was expanded to include colleagues from the US-China EcoPartnership for Environmental Sustainability collaboration in an effort to develop complimentary studies in China. Three visiting scholars from China took part in field and laboratory-based projects. This includes two visiting scholars from the Institute of Applied Ecology, Chinese Academy of Sciences (IAE-CAS) from the lab of Professor Jiang Yong. Yong sent PhD student Wang Ruzhen, who is co-advised by Yong and Filley, to investigate if surface oxidation of BC affects how microbes in soils respond to it. Mr. Li Bo, a research scientist from Yong’s group, is tracking the decomposition of 13C-labeled black carbon during long-term laboratory incubations of soil-black carbon mixtures by measuring the amount and isotope composition of CO$_2$ efflux. Additionally, Professor Shenjun Qin from Hebei University of Engineering, is working on measuring changes in soil lignin composition and isotope composition in the soil-black carbon incubations. Each of these visiting scholars works closely with Filley’s graduate student on the project, Ms. Christy Gibson, who is leading the soil incubation aspect of the project. Two field campaigns were conducted in this last year to harvest field mesocosms and soils for use in lab incubations.

Reconstructing timing and patterns of past glaciation in Central Asia.

Professors Jon Harbor and Nat Lifton, Earth, Atmospheric, and Planetary Sciences, and Marc Caffee, Physics and Earth, Atmospheric, and Planetary Sciences, post-doctoral researcher Jakob Heyman, graduate students Robin Blomdin, Christine Kassab and Casey Beel, and visiting scholars Wang Jie and Orkhonselenge 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, Daliija Mountains, Tian Shan mountains and Altai mountains. Fieldwork in the Tian Shan Mountains in Kyrgyzstan in 2012 and in the Altai Mountains in Russia, Mongolia and China in 2013 was focused on checking initial mapping from remote sensing of landforms made by past glaciers, and collecting samples that are now being processed for age dating at Purdue’s PRIME Lab.
The GEOSHARE project, led by Professors Thomas Hertel and Nelson Villoria, *Agricultural Economics*, aims to develop and maintain a freely available, global, spatially-explicit database on agriculture, natural resources, and the environment, accompanied by analysis tools and training programs for scientists, decision makers, and development practitioners.

GEOSHARE has completed the first year of a two-year pilot project designed to demonstrate the feasibility for working across regional and global research nodes through collaborations with IFPRI, IRRI, the University of Bonn and McGill University. Four focus countries include: Tanzania, Ghana, India, and Bangladesh.

External funding for this pilot has come from the UK government (DFID and DEFRA), USDA and the CGIAR’s Climate Change, Agriculture, and Food Security research program. Additional funding from the ILSRI Research Foundation will support development work on Purdue’s HUBzero cyber-infrastructure during the second year of the pilot project. This involves working closely with ITAP and the Rosen Center for Advanced Computing.

The goal is to scale GEOSHARE up to the global level following successful completion of the pilot effort. In this regard, Hertel spent a month this summer at the Rockefeller Foundation’s Bellagio Center, developing the institutional design for the global GEOSHARE effort.

Developing new ways to see and study the Earth

Professor James Garrison, *Aeronautics and Astronautics*, continues his work on development of new methods for Earth remote sensing using microwave reflectometry with signals of opportunity. This emerging new field of microwave remote sensing allows for existing digital signals, transmitted for other purposes, to be re-utilized as sources of illumination. The remote sensing and Earth sciences communities are putting this new technology to the test in a new NASA weather prediction program, the Cyclone Global Navigation Satellite System (CYGNSS). CYGNSS is a constellation of 8 satellites focused on observing the formation of tropical cyclones using ocean-reflected global navigation satellite system signals. CYGNSS team members Garrison and post-doctoral researcher, Nereida Rodriguez-Alvarez, are developing optimal algorithms for ocean surface winds data. Garrison and his students have also been active in field research for testing and validation of reflectometry measurements for various applications. Doctoral student, Rashmi Shah, has collected a year of ocean scattering measurements using S-, L- and Ku-band satellite transmissions from Platform Harvest, off the coast of California. Another graduate student, Nick Rainville, has completed delivery and checkout of an S-band reflectometry receiver to NOAA for flight on the P-3 “hurricane hunter” aircraft in the 2013 hurricane season.
The latest from the Airborne Laboratory for Atmospheric Research (ALAR)

In the past year, the Shepson group has been working on analyzing data collected during their spring 2012 trip to Barrow, Alaska. The data, collected from Purdue’s Airborne Laboratory for Atmospheric Research (ALAR), was used to study the impacts of climate change on sea ice and halogen chemistry in the Beaufort Sea area. In addition to their standard instruments, the ALAR aircraft was also outfitted with a scanning optical spectrometer from the University of Heidelberg. This addition allowed the group to measure the concentration of BrO for direct comparison with satellite measurements of the same compound. BrO is a key species responsible for the extraordinary depletion of ozone and mercury from the polar atmosphere during springtime. The bromine atoms in this important compound are derived from the sea ice surface, and the rates at which bromine is emitted are thought to be changing as a result of large changes in the nature of sea ice. The ALAR flights in 2012 included one day of measurements over Prudhoe Bay, where a great deal of combustion sources exist for the drilling and pumping of oil in the North Slope. That leads to emission of NO₂, which reacts with and removes BrO. Shepson’s team recorded the first observations of the chemical interactions between large-scale oil exploration emissions, and the natural halogen chemistry that occurs in the Arctic.

The Shepson Group also studied the impacts of shale gas drilling on concentrations of atmospheric methane. After a large number of flights in the Marcellus and Bakken formations in Pennsylvania and North Dakota. In the figure to the right, a methane emission plume from a well pad in the Marcellus formation is show that corresponds to a leak rate of 1.6 cubic feet per second of methane, per well. The wells on this pad were in the drilling stage, a stage of operation not previously believed to represent a significant leak risk. The observed leak rates were found to be 100-1000 times greater than what is assumed in the EPA inventory for shale gas operations. This study points out how early we are in our assessment of leak rates from shale gas operations.

Towards a better understanding of extreme weather risk

Professor Hao Zhang, Statistics and Forestry & Natural Resources, traveled to China for two months in the summer of 2013 to work with colleagues on a recent project funded by the Social Science Foundation, “Extreme Weather Events: Spatial Patterns, Temporal Dynamics and National Strategy.” His visit included a collaboration with Professor Zechun Li of the Chinese Academy of Sciences and the China Meteorological Administration to analyze extreme weather events, including drought, in China from the past 60 years.
Useful to Usable (U2U): Transforming climate variability and change information for cereal crop producers

U2U is a USDA-funded research and extension project designed to enhance the usability and up-take of climate-based resources and bolster Extension’s capacity to address agro-climate issues across the Midwest. The project team, led by Professor Linda Prokopy, Forestry & Natural Resources, is developing a suite of tools that will examine the financial, production, and/or environmental outcomes of different climate patterns and farm management strategies.

Slated for release in late 2013, a new Growing Degree Days (GDD) tool will allow corn growers and agriculture advisors to track real-time and historical GDD accumulations, assess frost and heat risks, 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.

Other resources currently under development include Ag Climate View (ACV) – a convenient way to access historical climate and crop yield data for the Midwest, and an in-season nitrogen application tool. Future development will focus on changes in fieldwork opportunities, the cost-effectiveness of irrigation and tiling, and the potential impact of ocean patterns (such as El Niño) on crop yields. The GDD Tool, and other resources, will be available on the U2U website: www.AgClimate4U.org.

Climate change feedbacks from interactions between new and old carbon

By storing and releasing carbon, ecosystems on land influence the rate of climate change. However, in the models used to project future climates, some of the important processes affecting carbon storage are coarsely represented or omitted. This project, led by Professor Jeffrey Dukes, Forestry & Natural Resources and Biological Sciences, and funded by DOE and NSF, examines an omitted process: how plants can affect carbon storage through releases of easily decomposed materials from their roots, and how future conditions could affect the way these “exudates” interact with the carbon compounds already present in soil. The project assesses how changes in soil moisture and temperature affect inputs of new carbon to the soil from plant communities, and the rate of decomposition of older soil carbon once new carbon has been added.

The project takes place at the Boston-Area Climate Experiment. At this site, plots of a meadow-like plant community with tree seedlings are grown under twelve different climatic conditions, with four different amounts of warming and three levels of precipitation. New carbon inputs are being assessed using mesh cylinders of soil that were placed into the ground at the beginning of the experiment, in which roots and fungi (or fungi only, or neither) can grow; these cylinders are later removed and their contents are analyzed. The team is examining decomposition of carbon inputs by slowly injecting known carbon-containing solutions (or water) into the soil at known rates and monitoring the subsequent effects on soil carbon, nitrogen, and phosphorus pools. This exploratory project tests the feasibility of these seldom-tried experimental approaches, and produces initial results indicating how climatic changes can affect interactions between new and old carbon.

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. The research used a national survey to 6,000 row crop farmers investigating how different frames might affect farmers’ interest in conservation tillage, as well as how many farmers were currently using the technique and why they did so.

The results indicate that while adoption varies by geographical region, overall, most farmers are using conservation tillage. In addition, the mention of small payments for environmental services or carbon storage appears to be ineffective in increasing farmer interest in the technique. Most surprisingly, describing conservation tillage using a frame describing its ability to increase a farmer’s profits was also ineffective at increasing farmer interest, actually decreasing interest in the technique among those not currently using it. These results suggest the importance of finding alternative frames to promote conservation tillage, especially in light of the current focus on using a profit frame and financial incentives to promote the technique.
Quantifying climate feedbacks from abrupt changes in high-latitude trace-gas

It has been suggested that climate change and permafrost thaw increase high latitude methane emissions that could potentially represent a strong feedback to the climate system. Using an integrated Earth-system model framework, Professor Qianlai Zhuang, Earth, Atmospheric, and Planetary Sciences and Agronomy, with collaborators at MIT, University of Alaska, Fairbanks, and the Marine Biological Laboratory, are examining the degradation of near-surface permafrost, inundation (lakes and wetlands) induced by hydro-climatic change over time, and subsequent methane emissions and potential climate feedbacks. The research team finds that increases in atmospheric methane and its radiative forcing which result from the thawed, inundated emission sources, are small, particularly when weighed against human emissions. The additional warming, across the range of climate policy and uncertainties in the climate-system response, would be no greater than 0.1 degrees C by 2100. Further, for this temperature feedback to be doubled (to approximately 0.2 degrees C) by 2100, at least a 25-fold increase in the methane emission that results from the estimated permafrost degradation would be required. Overall, this biogeochemical global climate-warming feedback is relatively small whether or not humans choose to constrain global emissions.

New applications of environmental trading programs

Controlling emissions of greenhouse gases is an important goal in environmental protection from pollution and the extreme effects of climate change. With a grant from the U.S. Environmental Protection Agency, Professor Tim Cason, Distinguished Professor and Robert and Susan Gadomski Chair in Economics, with collaborators from the University of Massachusetts, University of Alaska, and Chapman University, are exploring new applications of environmental trading programs. The Purdue-led effort has focused on specific design aspects of emissions trading programs, and alternative mechanisms for promoting cooperation and reducing emissions. Cason and collaborator Professor Lata Gangadharan of Monash University recently studied the relationship between cooperative research and development (so-called “research joint ventures”) to reduce emissions abatement costs, and potential collusion in the market for tradable permits. Although traders often succeed in forming the research joint venture, this cooperation does not spill over to increase collusion in the permit market. This suggests that it may be possible to encourage cooperative efforts in R&D without endangering competition and efficiency in emissions trading.

Cason and Professor Frans de Vries, University of Sterling, also studied investments in R&D to reduce marginal abatement costs, but without research joint ventures. Investment rates and dynamic efficiency are greater when permits are auctioned, compared to when they are grandfathered, although theoretically the allocation method does not influence equilibrium investment.

With Purdue collaborators, Professor Wally Tyner, James and Lois Ackerman Professor of Agricultural Economics and doctoral student David Perkis, Cason evaluates the implications of some alternative “soft” and “hard” price controls that have been proposed for permit trading markets to protect firms from price spikes caused by fluctuations in the demand for permits. Both permit supply adjustments and traditional (hard) price ceilings effectively limit elevated prices, but reserve auctions to implement soft ceilings do not consistently control prices as intended. This study highlights several advantages of hard ceilings for controlling short term price increases.

Finally, Cason and Gangadharan compare formal and informal mechanisms that influence incentives to improve group cooperation and reduce ambient pollution levels, specifically, they compare a (centralized) group tax mechanism to a (decentralized) peer punishment mechanism. The formal tax mechanism is significantly more effective than informal peer punishment in reducing pollution and increasing efficiency, although peer punishment does improve the performance of the formal group tax mechanism.
Does Climate Change Throw Nature’s Timing Out of Whack?

A PCCRC Seed Grant Update
Climate change is already having impacts on the timing of biological events within natural communities, which may lead to drastic changes in community dynamics if tightly interacting species exhibit different responses to temperature variation. Professor Nancy Emery, Botany & Plant Pathology and Biological Sciences, and her research team are conducting a series of experiments to evaluate the consequences of changing temperatures on the interactions between plants and insects, using the spring ephemeral wildflower community at Purdue’s Ross Biological Reserve. Early spring wildflowers in deciduous forests are predicted to be particularly sensitive to climate change because their life cycles are thought to be closely linked to climatic conditions, and particularly temperature.

The team has initiated a manipulative warming experiment at the Ross Reserve that isolates the effects of elevated soil temperatures on the flowering time and seed production in Anemone acutiloba via interactions with its pollinators and herbivores. In the fall of 2012, they established 25 experimental plots in a naturally-occurring spring ephemeral plant community and manipulated soil temperature using buried heating cables. They have transplanted A. acutiloba into both warmed and control plots and implemented experimental treatments that will allow the team to tease apart the effects of soil temperature on plant-pollinator vs. plant-herbivore interactions, and the consequences of these interactions for plant reproductive success under elevated temperatures. Data from this project will advance our understanding of the complex responses of interacting species to changing climate.

This project has facilitated the graduate training of Asya Robertshaw, a PhD student in the Department of Botany & Plant Pathology, and 8 different undergraduate students from the Departments of Biological Sciences, Botany & Plant Pathology, and Entomology.

The Ross Reserve has for 60 years provided Purdue University with an invaluable teaching and research environment. On the bank of the Wabash River, it is a forest rich in biological diversity and in history of ecological study. The Reserve was established in 1949, thanks to the vision of plant ecology professor Alton A. Lindsey and colleagues, and has been the focus of 30 doctoral dissertations, more than 120 scientific publications, and numerous masters and undergraduate honors theses. It harbors nearly 400 species of vascular plants and more than 100 species of vertebrate animals. When first protected, the Reserve was a patchwork of mature but disturbed forest mixed with agricultural fields and clearings. Rapid regeneration of the clearings and slow maturation of the forest have produced a haven for wildlife that is rare in the Midwestern landscape.
THE YEAR’S PEER-REVIEWED PUBLICATIONS


Agriculture and deforestation account for about one-quarter of global greenhouse gas emissions, with methane from livestock production being the most important type of farm-related emission. Alla Golub, a research economist at the Center for Global Trade Analysis in Purdue’s Department of Agricultural Economics, and Thomas Hertel, distinguished professor of Agricultural Economics and executive director of the Global Trade Analysis Project, modeled policies aimed at reducing emissions from livestock.

Their findings, with co-authors from the FAO, the Electric Power Research Institute and Ohio State University, were published in PNAS. They showed that wealthy countries alone would have limited success in decreasing greenhouse gas emissions from livestock production because it would give poorer countries, with greater greenhouse gas emissions intensities, an incentive to expand production.

This led Golub, Hertel and their co-authors to examine what might happen if emission regulations in wealthy countries were paired with incentives to retain forested land in poorer nations. Without new grazing areas, those poorer countries would not expand their livestock production as much. Their study shows that wealthier countries could provide a subsidy that requires poorer countries to protect forested lands and shift to cleaner technologies, which would support those countries’ output and consumption while reducing emissions.

Adapted from Brian Wallheimer’s Purdue News release, September 27, 2012.


Contributions of individual reactive biogenic volatile organic compounds to organic nitrates above a mixed forest. *Atmospheric Chemistry and Physics*, 12, 10125-10143.


### Photochemical production of molecular bromine in Arctic surface snowpacks

Snow and ice influence the climate and chemistry of the polar atmosphere. Field experiments in Alaska point to the significance of surface snow for polar ozone depletion events. Following the springtime polar sunrise, ozone concentrations in the lower troposphere episodically decline to near-zero levels. These ozone depletion events are initiated by an increase in reactive bromine levels in the atmosphere. Under these conditions, the oxidative capacity of the Arctic troposphere is altered, leading to the removal of numerous transported trace gas pollutants, including mercury. However, the sources and mechanisms leading to increased atmospheric reactive bromine levels have remained uncertain, limiting simulations of Arctic atmospheric chemistry with the rapidly transforming sea-ice landscape.

Kerri Pratt, NSF post-doctoral fellow in the department of Chemistry and Paul Shepson, professor of Chemistry, led a study to examine the potential for molecular bromine production in various samples of snow and sea ice, in the presence and absence of sunlight and ozone, in an outdoor snow chamber in Alaska. They detected molecular bromine only on exposure of surface snow to sunlight, suggesting that the oxidation of bromide is facilitated by a photochemical mechanism. Furthermore, molecular bromine concentrations increased significantly when the snow was exposed to ozone, consistent with an interstitial air amplification mechanism. Their findings suggest that the photochemical production of molecular bromine in surface snow serves as a major source of reactive bromine, which leads to the episodic depletion of tropospheric ozone in the Arctic springtime.
Biofuel, Land and Water: Maize, Switchgrass or Miscanthus?

The productive cellulosic crops switchgrass and Miscanthus are considered as viable biofuel sources. To meet the 2022 national biofuel target mandate, maize cultivation must be intensified and expanded, and other biofuel crops (e.g., switchgrass and Miscanthus) must be cultivated. This raises questions about the use-efficiencies of land and water; to date, the demand on these resources to meet the national biofuel target has rarely been analyzed.

Qianlai Zhuang, William F. and Patty J. Miller Associate Professor of Earth, Atmospheric & Planetary Sciences and Agronomy, and graduate students Zhangcai Qin and Min Chen conducted a data-model assimilation analysis, assuming that maize, switchgrass, and Miscanthus will be grown on currently available croplands in the US. Model simulations suggest that Miscanthus has more than twice the biofuel production capacity relative to maize, and switchgrass is the least productive of the three potential sources of ethanol. To meet the biofuel target, if Miscanthus was substituted for maize, the process would save half of the land and one third of the water. With more advanced biofuel conversion technology for Miscanthus, only nine million hectares of land and 45 km3 of water would probably meet the national target.

In the photo to the right, one-year-old Miscanthus grasses border corn fields near Purdue’s West Lafayette campus.


PCCRC Membership by Department

Aeronautics & Astronautics: James Garrison
Agronomy: Laura Bowling, Sylvie Brouder, Melba Crawford, Richard Grant, Cliff Johnston, Dev Niyogi, Ronald Turco, and Jeffrey Volenec
Agricultural & Biological Engineering: Indrajeet Chaubey, Keith Cherkauer, and Rabi Mohtar
Agricultural Economics: Otto Doering, Alla Golub, Ben 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
Building & Construction Management: Nancy Emery
Chemistry: Paul Shepson
Civil Engineering: Larry Nies, Suresh Rao, and Cary Troy
Earth & Atmospheric Sciences: Ernest Agee, Michael Baldwin, Gabriel Bowen, Timothy Filley, Alexander Gluhovsky, Jon Harbor, Harshvardhan, Matthew Huber, Sonia Lasher-Trapp, Nathaniel (Nat) Lifton, Greg Michalski, R. Jeffrey Trapp, Wen-wen Tung, Qianlai Zhuang
Economics: Timothy Cason
Forestry and Natural Resources: Jeffrey Dukes, Songlin Fei, Reuben Goforth, Bryan Pijanowski, Linda Prokopy, Guofan Shao, and Robert Swihart
Health & Human Sciences: Jennifer Freeman and James McGlothlin
Information Technology: Carol Song and Lan Zhao
Libraries: Christopher Miller
Mechanical Engineering: Jay Gore and Greg Shaver
Political Science: Daniel Aldrich, Elizabeth McNie, Leigh Raymond, and Mark Tilton
Sociology: Martin Patchen
Statistics: Bo Li, Frederi Viens, and Hao Zhang
Executive Committee: Michael Baldwin, Laura Bowling, Jeffrey Dukes, Nancy Emery, James Garrison, Sonia Lasher-Trapp, Bo Li, Linda Prokopy, Paul Shepson, Cary Troy, and Qianlai Zhuang
Administrative Staff
Otto C. Doering, III, Director
Jeffrey Dukes, Associate 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.
Daniel Aldrich spent the academic year 2012-2013 as a Fulbright Research professor at the University of Tokyo where he investigated recovery from the March 2011 compounded disaster. During that year he published a number of articles on the Fukushima nuclear meltdowns that appeared in multiple journals and media outlets including, the *Japanese Journal of Political Science*, *Disasters: The Journal of Disaster Studies, Policy and Management*, *Public Administration Review* and in the *New York Times*. He gave more than 40 lectures and workshops on social capital and resilience throughout Japan, China, Taiwan, and New Zealand.

Jeffrey Dukes was appointed associate director of the Purdue Climate Change Research Center. As associate director, Jeff will play a key role in helping to shape and develop center initiatives, priorities, and strategic direction. Jeff has been an active member of the PCCRC since joining Purdue’s faculty in 2008. His research group addresses environmental challenges through ecological research and outreach, with a current focus on three themes: understanding how ecosystems respond to climate and atmospheric change, understanding and minimizing the impacts of invasive species on ecosystems, and exploring the ecological consequences of switching our energy supply from fossil fuels to biofuels.

Jennifer Freeman received the Colgate Palmolive Award in Alternative Research from the Society of Toxicology which is a national award that identifies and supports efforts that promote, develop, refine, or validate scientifically acceptable animal alternative models to facilitate safety assessment of exposure to environmental agents.

In spring 2013 Jon Harbor gave a series of presentations in Goa and Raipur, India. His presentations in Raipur, the first ever by a non-Indian at the school and college, led to lively debate on climate change issues and responsibilities in India, and were covered by local print and TV media.

Thomas Hertel, Purdue University Distinguished Professor of Agricultural Economics, was chosen to receive the inaugural Purdue University Research and Scholarship Distinction Award. The 2013 award comes with a $4,000 cash award and $7,000 for his university scholarly activities. Hertel is the founder and executive director of the Global Trade Analysis Project, a Purdue-based program that helps researchers and policymakers analyze international trade.

Sonia Lasher-Trapp received the 2013 Undergraduate Advising Award from Purdue’s College of Science. She was also elected to Purdue University’s Teaching Academy. The Academy is comprised of a dedicated and dynamic network of scholar-teachers committed to the continual improvement of teaching and learning at Purdue University.

Rabi Mohtar was appointed to the Advisory Board for the UNFCC Momentum for Change Initiative, and is a member of the World Economic Forum Global Agenda Council on Climate Change. As the founding executive a Director of Qatar foundation Qatar Environment and Energy Research Institute, he coordinated Qatar Foundation COP18 activities including multiple keynote lectures and special topic sessions.

Bryan Pijanowski was named a Purdue University Faculty Scholar. This program was established by the University to recognize the outstanding accomplishments of faculty who are on an accelerated path for academic distinction.

Leigh Raymond was appointed director of the Discovery Park Center for the Environment (C4E). Established in 2007, the C4E works to catalyze, support, and promote proactive, interdisciplinary work at Purdue addressing important environmental challenges.

Beginning in July, 2013, Professor Jeff Trapp joins the PCCRC as a Discovery Park Research Fellow. During his one-year appointment, Trapp will lead an effort to develop and implement numerical-modeling tools to guide climate variability and change mitigation and adaptation strategies.

Wally Tyner received the Distinguished Graduate Teaching Award for 2013 from the Agricultural and Applied Economics Association.

Hao Zhang was elected a Fellow of American Statistical Association, in recognition of his important work on the asymptotic theory for the estimation of spatial covariance functions and for outstanding contributions to computational methods for the analysis of massive spatial data. Zhang’s exemplary commitment to teaching, mentoring, and outreach activities and service to the ASA were also mentioned.
Professor Jon Harbor led a study abroad “Glaciation in Sweden and Norway” which gave Purdue undergraduate and graduate students (pictured above) a chance to visit sights of past and current glaciation jointly with students from Stockholm University.
LAUNCHING TOMORROW’S LEADERS

The PCCRC supports a learning environment that emphasizes interdisciplinary thinking, collaboration, and a vibrant academic experience. The center offers undergraduate and graduate students mentorship and support to explore new topics, learn new skills, connect with networks, and to advance their research and maximize its impact. In this section of our report, we present a sampling of the intellectual contributions of our students and highlight examples of our faculty’s teaching programs.
Climate change science involves understanding and predicting physical, biological, and chemical changes across many scales and utilizing many approaches. This year’s PCCRC summer internship program offered Purdue undergraduates an opportunity to explore topics in climate change and gain hands-on experience working with climate models using Purdue’s Carter Supercomputer.

Center director Matthew Huber and graduate student Paul Acosta mentored Kehao Zhu, Jake Stevens, and Miles Evans as these bright undergraduates developed their independent research projects. At the end of the summer, the students presented their findings in a poster session. The internships were sponsored by the Discovery Park Undergraduate Research Program and the PCCRC.

Kehao Zhu is a transfer student from Chonqing, China. He is a rising senior, working on a double major in biology and statistics. Zhu said the field of climate change was important to him as it should be for everyone else.

“It’s important to everyone, especially those who not only care about the future of mankind but also the whole planet earth,” he said.

All of the interns were asked to create a climate change model based on a specific situation with a set of variances. A conversation with some of his vegetarian friends about the environmental impact of meat production, prompted Zhu to look into current estimates of greenhouse gas emissions from livestock. Surprised to find that current meat production accounts for approximately 11 percent of global greenhouse gas emissions, Zhu decided to focus his research on the question, what would happen to the climate if the world stopped eating meat?

He specifically looked at the impact this would have on global average temperature over the next 40 years.

Zhu noted a particularly unexpected aspect of his internship was the informal setting where Huber and Acosta work—in the different coffee shops on campus and the nearby community—which made it easier to share ideas, ask questions, and voice concerns.

Livestock emissions arise from the following sources:

- Ruminants (sheep, cattle, goats) release methane during the digestion of food.
- Direct nitrous oxide from livestock manure.
- Indirect emissions come from the production of feed crops, specifically, the production and use of fertilizer on land leads to emissions of carbon dioxide and nitrous oxide.
- Deforestation and conversion of grassland into arable land release significant amounts of carbon dioxide, methane, ammonia, and nitrous oxide from the soil.
- The transport of feed, livestock and animal products also causes emissions, but they are relatively small compared to the other sources.

(adapted from CGIAR Big Facts)
**Country roads and highways inspired Jake’s research**

Jake Stevens is a rising sophomore from Crestwood, Illinois, majoring in computer engineering. Stevens found the inspiration for his research topic thinking about his rides to and from Purdue down I-65, through many farms and fields, and about the massive changes humans have made to the natural environment for food, space, and materials. He decided to focus on the effects of land use change on the climate.

“I got to work with Purdue’s highly ranked supercomputer clusters, which is pretty cool for a computer geek. I also learned a lot more about a field in which I had very little experience,” he said.

Steven’s model looked at how changes in land use, for example transforming farming land into an industrial landscape, would affect the climate. He described his methodology in a blog post for the PCCRC: “To do so, I first ran a default model provided by the National Center for Atmospheric Research (NCAR) that simulates what the climate will be like if the population and carbon emissions continue as at present, with output starting at 2010. The output of this simulation will act as my control case; the land usage is formulated as usual, with no changes. This will be compared to the output of a second, modified version of the default model. The modified version will change the post-2010 landscape to 1850 conditions.”

The amount of computational resources necessary for this kind of research is staggering, as is the amount of data generated.

“It was an eye-opening experience the first time I quickly filled up my 1000GB (1TB, or double a mid-end laptop’s entire storage capacity) quota. To put this in to perspective, 1000GB of data would be equivalent to roughly 256,000 songs,” said Stevens.

**Should we throw salt from the ocean into the air?**

Miles Evans is a rising junior from Bloomington, Indiana. He majors in environmental and ecological engineering, which led him to an internship with the PCCRC. His major specifically looks at how human engineering can affect the environment and its ecosystems.

One of Evans’ climate models included a scenario in which seawater is sprayed into the air to produce a salt aerosol. This is considered a geoengineering strategy and pertains to Evans’ major. The salt aerosol helps reflect light, so when the sunlight is reflected back up into space, it prevents the planet from becoming warmer.

“Strategies to lower the temperature of the Earth without controlling carbon emissions are generally called geoengineering strategies. Many of these strategies can be relatively mundane, such making all roofs white, while others are more exotic, such as floating big, reflective mirrors in the upper atmosphere or firing clouds of dust into orbit to block sunlight,” he said.

Evans also created another model where humans did little to nothing to mitigate carbon emissions that acted a control scenario. Evans said his experience with the PCCRC has allowed him to gain knowledge in the climate change field and some more practical knowledge in terms of running models.
**PCCRC DOCTORAL FELLOWS**

**Nick Smith** is a 2013 PCCRC Fellow, working with Professor Jeff Dukes in the Department of Biological Sciences on a variety of projects designed to examine the response of plant processes to environmental change. His research uses a combination of experimental and modeling techniques to try to predict how plants will respond and feedback to future climate change. Specifically, Nick is interested in quantifying physiological acclimation to future climate change, parameterizing this process for global-scale models, and evaluating its impact on projections of future climate change. In the past year, Smith has presented his findings at the 97th and 98th Annual Meetings of the Ecological Society of America, and the INTERFACE-CLIMMANI joint meeting, and published a paper entitled, “Plant respiration and photosynthesis in global scale models: incorporating temperature acclimation to temperature and CO₂” in *Global Change Biology*.

**Olivia Salmon** is a 2013 PCCRC Fellow starting her graduate work in Fall 2013. She graduated this past May from Marquette University with a B.S. in Chemistry. This summer Salmon had the opportunity to work with Professor Paul Shepson’s atmospheric chemistry group on a collaborative field campaign for the INdianapolis FLUX (INFLUX) project. The field campaign consisted of ground based and aircraft measurements of greenhouse gases (GHG) and thorough investigation of key methane sources to quantify Indianapolis’ GHG emissions. Salmon joined the Department of Chemistry this fall, and is taking classes in atmospheric and analytical chemistry.

**Casey Beel** is a 2012 PCCRC Fellow, working with Professor Nathaniel (Nat) Lifton in the Department of Earth, Atmospheric and Planetary Sciences. His current research focuses on using *in situ* ¹⁴C from bedrock surfaces emerging beneath ice caps in Arctic Canada and West Greenland to investigate if arctic ice caps are smaller now than during peak warmth of the Holocene Thermal Maximum (HTM). During the summer term of this year Beel spent four weeks in West Greenland collecting rock samples that will be processed and analyzed during this academic year. He is also working on a methods paper that uses paired cosmogenic nuclides to test the sensitivity of a new isochron method for exposure duration calculations of glacial troughs. In the past year he completed a field season in Kyrgyzstan, collecting samples from moraine crests in order to constrain the glacial history of the Inylchek Glacier. These samples were processed and analyzed during the 2012 Fall semester and presented at the 2012 American Geophysical Union Fall Meeting. Beel also presented his Masters research completed at the University of Otago, New Zealand at the 43rd Annual International Arctic Workshop during the spring semester. Beel will present his latest results at this year’s AGU Fall meeting and will sit for his Qualifying Exams in November.

**Wendell Walters** joined the Department of Earth, Atmospheric, and Planetary Sciences in the fall of 2012 as a PCCRC Fellow and works with Professor Greg Michalski. In his first year at Purdue, he took classes in stable isotopes chemistry, air quality and dispersion, particle mass spectrometry, general statistics, and applied linear regression. Walters’ current project focuses on analyzing the stable isotopes of ice-core nitrate to determine the changes in global nitrogen cycling and shifts in oxidation chemistry in response to natural and anthropogenic climate change. He plans on presenting his work at the American Geological Union conference in December 2013. Walters received an NSF graduate research fellowship in March 2013, which will provide financial support for his work for the next three years. He plans to use the funding to explore isotope effects in gas phase reactions in order to help climate modelers incorporate atmospheric isotope effects into the next generation of climate models.
Linyuan Shang is a 2011 PCCRC Fellow and works with Professor Qianlai Zhuang in the Department of Earth, Atmospheric, and Planetary Sciences. His research focuses on developing and using model data assimilation techniques to improve vegetation phenology and representation of the water cycle. In the academic year of 2012-2013, Shang developed a spatially explicit parameterization for Terrestrial Ecosystem Model with Advanced Very High Resolution Radiometer Leaf Area Index data product. Compared with traditional parameterization methods, this new method considers the heterogeneity issue. Shang passed his M.S. exam in July 2013.

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. His current research involves exploring the ability of an existing hydrology and crop growth model (SWAT2009) to simulate yield variability for traditional crops in the Midwestern US with respect to observed climate and soil moisture variability. The model has been calibrated and evaluated. Wang has used the calibrated model to extend the observational record to explore the relationship between climate variability and crop yield. He will also investigate the impact of future changing climate on crop yield by using the General Circulation Model under different emissions scenarios. Wang presented a talk entitled “Estimation of Aeration Stress Effects On Crop Yields in Midwest USA” at the joint ASA, CSSA, and SSSA International Annual Meeting in October 2012, in Cincinnati, OH. Wang will also present his research at the American Geophysical Union Fall Meeting in December, 2013 in San Francisco, CA.

Paul Schmid is a 2010 PCCRC Fellow and a PhD candidate in the Department of Earth, Atmospheric, and Planetary Sciences. In the past year, Schmid’s research has continued its focus on thunderstorm interaction with urban areas. Since 2012, he has also been a NASA Earth Systems Science Fellow. In January 2013, Schmid presented results of his research at the annual American Meteorological Society conference in Austin, TX. During summer 2013, he and his advisor, Professor Dev Niyogi, published results in Geophysical Research Letters detailing land surface interactions with thunderstorms related to city size. The next step in the research is untangling how urban aerosols independently affect thunderstorm development.

Fan Wang is a 2009 PCCRC Fellow in the Department of Earth, Atmospheric, and Planetary Sciences (Professor Greg Michalski, advisor). This year, she has been mostly focusing on writing her PhD dissertation, “The soil formation mechanism in the hyper-arid core of the Atacama Desert in northern Chile,” to wrap up her 4.5 years-long doctoral study at Purdue. For her dissertation work, she has applied a variety of ground truthing, geochemistry, stable isotope, cosmogenic nuclide, mineralogy and numerical modeling approaches to address how the Atacama surfaces have evolved in the near absence of water. This has led to a proposed soil formation mechanism in hyper-arid environments. Wang is expected to graduate in December of 2013.
STUDENT-LED INITIATIVES

Student Sustainability Summit

On February 20, 2013, Purdue held the first Student Sustainability Summit, gathering over 180 individuals from across campus, including students, faculty, staff, and administration, to improve communication and collaboration between those engaged in sustainability projects and initiatives. The summit was created, organized, and hosted by Lindsey Payne and Aaron Goldner, PhD candidates in Earth, Atmospheric, and Planetary Sciences. The summit began with focused presentations from faculty and staff representing sustainability centers and offices across campus, including Purdue’s Climate Change Research Center, Water Community Center for Global Food Security, Energy Center, the Global Policy Research Institute and the Office of University Sustainability. Their presentations were graphically represented by professional graphic artists on a large display board (photo, above). The participants were then asked to form groups to discuss how to enhance the networks and collaborations surrounding sustainability initiatives on campus and in the community. Over 40 student projects and initiatives were highlighted during the Student Sustainability Showcase, which followed the group discussions. At the end of the summit, four new sustainability initiatives were revealed to the audience including the Student Sustainability Council, a Global Sustainability Institute student representative, a student “seed” grant program, and Purdue’s participation as a founding member of the Emerging Leaders in Science & Society program.

Emerging Leaders in Science & Society

Over the course of several months, graduate students Aaron Goldner, Lindsey Payne, and Monique Long campaigned to have Purdue University become one of the founding partners in the Emerging Leaders in Science & Society Graduate & Professional AAAS Program (ELISS). Their efforts were successful, and Purdue joins the University of Washington, University of Pennsylvania, and Stanford University as the program’s founding partners. The program will recruit ~20 graduate and professional students for a pilot class that begins in January of 2014. ELISS fellows will collaborate with a team of students and mentors from different campuses to organize locally embedded, nationally connected dialogues on complex issues in areas such as health and energy.

LEFT: Dr. Aaron Goldner stands with his advisor, Matthew Huber, in the local cafe where many of their scientific discussions took place. Dr. Goldner graduated in the summer, 2013, and will head to Washington, D.C. to begin his AGU Congressional Science Fellowship.
Yini Ma (PhD ’13, 2008 PCCRC Fellow). Dr. Ma’s research is focused on understanding how invertebrates influence the incorporation of above-ground litter into soils and on their influence on soil organic matter stability. Working with advisor Professor Timothy Filley, Ma finished her doctoral thesis, “The Combined Controls of Land Use Legacy and Earthworm Activity on Soil Organic Matter Stabilization and Dynamics in Temperate Deciduous Forests,” and earned her PhD in Earth, Atmospheric, and Planetary Sciences. She published a paper in the journal, *Organic Geochemistry*, titled, “The combined controls of land use legacy and earthworm activity on soil organic matter chemistry and particle association during afforestation.” A second paper titled “Interactions between earthworm community and wood and leaf litter control litter incorporation into forest soil fractions” has been accepted for publication in the journal *Soil Biology & Biochemistry*. After graduation, Dr. Ma will start her postdoctoral work at Nanjing University.

Clay Davis (PhD ’13; 2009 PCCRC Fellow), working with Professor Paul Preckel, completed his Ph.D. in Agricultural Economics early in the Spring Semester of 2013. His thesis is titled “Three Essays on the Effect of Wind Generation on Power System Planning and Operations.” The essays will be individually published as State Utility Forecasting Group studies, with the first now available on the SUFG website. An article based on one of the essays titled “Determining the Impact of Wind on System Costs via the Temporal Patterns of Load and Wind Generation” is forthcoming in the journal *Energy Policy*. Dr. Davis now works for the New York Independent Systems Operator in the Department of Market Mitigation and Analysis.

Jinyun Tang (PhD ’11; 2006 PCCRC Fellow) was recently promoted to research scientist at the Lawrence Berkeley National Laboratory. He has published several papers this last year, including a study of a new equation that mechanistically predicts the impact of top soil moisture on bare soil evaporation and air-soil exchanges of various trace gases including CO2, CH4, H2. Application of these results will lead to a consistent representation of trace gas exchanges in various biogeochemical models and atmospheric chemistry models. In another study he led, ecosystem substrate-consumer dynamics is linked to an equilibrium chemistry model. This led to the first successful model-based explanation that litter decomposition is modulated by both the litter chemistry and microbial physiology, consistent with field experiments. This work also revised the representation of predator-prey systems and a few other biogeochemical issues.

C. Kendra Gotangco Castillo (PhD ’11; 2007 PCCRC Fellow) has taken a position as assistant professor in the Department of Environmental Science at the Ateneo de Manila University, Philippines. Professor Castillo maintains her affiliation with the Manila Observatory as a research scientist working on climate change adaptation and disaster risk management projects.
NEW COURSES

Ecological impacts of climate change
Instructors: Jeff Dukes, FNR/Biol
FNR 589 and Biology 595

This course explores the responses of organisms to past and current changes in climate. The course will loosely follow the topics addressed by Working Groups I and II of the Intergovernmental Panel on Climate Change, starting with an in-depth look at the basic science of climate change, followed by a broad examination of the expected impacts of climate change for natural and managed ecosystems, and an exploration of some (sometimes controversial) strategies for adaptation to climate change. Greatest emphasis will be placed on the impacts of climate change on biodiversity and ecosystem processes in unmanaged or lightly managed systems. The class will also consider ecosystem impacts of related environmental changes, such as increases in atmospheric CO$_2$ concentrations and nitrogen deposition, on ecosystems.

Ecological Principles in Building
Instructors: Kerry Rabenold
Biology 595

The objectives of this course are to share expertise across campus and to develop a community of people with interest and skills in “green” building who can collectively promote sustainability and more efficient infrastructure both on campus and beyond, and who could apply this knowledge to teaching, planning, construction practice, and a model building at the Ross Biological Reserve (artist rendition below). A series of presentations and discussions will cover most of the ground outlined in the contents of the book, Sustainable Construction – green building design & delivery, stepping through rationale (societal need), assessment rubrics like LEED, design and ecological principles, sites and landscaping, energy and water conservation, materials options, interior design and function, construction strategies, educational and outreach missions, and economic analysis. Each week’s leader introduces their experience and expertise, identifies a frontier of potential progress in the field, focusing on local application and Purdue projects, and sketched wider implications.

Study Abroad: Glaciation in Sweden and Norway
Instructor: Jon Harbor

Professor Jon Harbor led a study abroad “Glaciation in Sweden and Norway” which gave Purdue undergraduate and graduate students (pictured above) a chance to visit sights of past and current glaciation jointly with students from Stockholm University. Highlights of this two-week field experience included field investigations of landforms produced by a large ice sheet that formerly covered Scandinavia, visiting an active glacier in Norway, and the cultural experience of living and working in teams with Swedish undergraduate and graduate students.

Sustainable Global Collaborations
Instructors: Kirk Alter
IDIS 491/591

This seminar course explores the intersection of human interactions in systems: social, technical, scientific, cultural, political, economic, historical, through a holistic approach to sustainable human experience. It introduces transdisciplinary approaches to global sustainable collaborative development, and addresses the principles, practices, and strategies of development in a global context.

Global Land Use Change to 2050: Implications for Food Security and the Environment
Instructors: Thomas Hertel and Uris Baldos
AGECON 596

The first meeting during each week of this course introduces a new dimension of global land use, food and environmental security, starting with a guest lecture and followed by student-led discussion of the readings. The second meeting of each week emphasizes the economics underpinning how this particular dimension of the problem affects the global supply and demand for land, environmental quality, and nutritional outcomes. In addition, lab assignments, based on the SIMPLE economic model of global land use change, will allow students to obtain a hands-on assessment of the relative importance of the different forces bearing on the long run supply and demand for land, as well as the implications for food security and the environment.
This new textbook, *Mesoscale-Convective Processes in the Atmosphere*, by Robert (Jeff) Trapp, *Earth, Atmospheric, and Planetary Sciences*, seeks to promote a deep yet accessible understanding of mesoscale-convective processes in the atmosphere. Mesoscale-convective processes are commonly manifested in the form of thunderstorms, which are fast evolving, inherently hazardous, and can assume a broad range of sizes and severity.

Modern explanations of the convective-storm dynamics, and of the related development of tornadoes, damaging “straight-line” winds, and heavy rainfall, are provided. Students and weather professionals will benefit especially from unique chapters devoted to observations and measurements of mesoscale phenomena, mesoscale prediction and predictability, and dynamical feedbacks between mesoscale-convective processes and larger-scale motions.

Each year, natural disasters threaten the strength and stability of communities worldwide. Yet responses to the challenges of recovery vary greatly and in ways that aren’t explained by the magnitude of the catastrophe or the amount of aid provided by national governments or the international community. The difference between resilience and disrepair, as Daniel P. Aldrich, *Political Science*, shows, lies in the depth of communities’ social capital. Professor Aldrich’s *Building Resilience* highlights the critical role of social capital in the ability of a community to withstand disaster and rebuild both the infrastructure and the ties that are at the foundation of any community. He examines the post-disaster responses of four distinct communities—Tokyo following the 1923 earthquake, Kobe after the 1995 earthquake, Tamil Nadu after the 2004 Indian Ocean Tsunami, and New Orleans post-Katrina—and finds that those with robust social networks were better able to coordinate recovery. In addition to quickly disseminating information and financial and physical assistance, communities with an abundance of social capital were able to minimize the migration of people and valuable resources out of the area.

**Contributing book chapters**

Keith Cherkauer, Laura Bowling and Bibi Naz contributed a chapter on how the unique features of periglacial hydrology and the unique vulnerabilities of watershed systems are dominated by cold-season processes. The chapter appears in *Treatise on Geomorphology*, John F. Shroder (Editor-in-chief) San Diego: Academic Press.

Doug Gotham contributed a chapter on the vulnerability of the electricity and water sectors to climate change in the Midwest, and Dev Niyogi and Vimal Mishra wrote the chapter on Agriculture Vulnerability Assessment for the Midwestern United States in *Climate Change in the Midwest*, a volume edited by S. Pryor, Indiana University Press.
Participants from the 2013 Dynamics of Climate Conference discuss options for reducing one’s carbon footprint. This group activity was designed to promote active learning in the fossil fuels and greenhouse gases module.
ENGAGEMENT

The PCCRC works to expand partnerships, share our collective knowledge, and encourage open dialogues that help generate innovative solutions to the complex and on-going challenge of climate change. This builds upon the collegiality and collaboration that were the founding characteristics of the center. In this section, we provide examples of our efforts to connect the scientific community with policy makers, government agencies, industry, and the general public. We have learned it is essential that this connection be two-way to provide us a better understanding of the problems faced by our stakeholders and to allow us to build solutions together.
A RESOURCE FOR SCIENCE-BASED INFORMATION

National and Global Market Implications of the 2012 US Drought

The 2012 drought in the US caused tens of billions of dollars in economic losses, destroying or damaging major field crops in the Midwest, with repercussions that spanned the globe through market interactions. During the summer of 2012, there were numerous calls to suspend biofuels mandates - in a Chicago Council on Global Affairs Issue Brief, Purdue professor, Wally Tyner, James and Lois Ackerman Professor of Agricultural Economics, argued that what was missing from the public debate is an examination of two assumptions driving these calls: 1) that biofuels, not the drought, are to blame for price spikes and 2) that reducing or eliminating the biofuels mandate would quickly lead to price reductions. The brief is available on line and in print.

Climate Change on Capitol Hill

In February 2013, Professors Matthew Huber, Earth, Atmospheric, and Planetary Sciences and Sylvie Brouder, Agronomy, traveled to Washington, DC for Climate Science Day on Capitol Hill. The event, organized by 13 major scientific societies, provides a non-partisan opportunity for scientists to visit with members of Congress in an effort to build relationships with policy makers and their staff. Huber and Brouder met with members of Congress (primarily those representing Indiana) and discussed climate and agriculture, water resources, heat waves, irrigation and soils, among other topics. Fifty scientists from across the country participated in this year’s event.

INTERNATIONAL COLLABORATIONS & PARTNERSHIPS

The Integrated Network for Terrestrial Ecosystem Research on Feedbacks to the Atmosphere and Climate (INTERFACE), led by Professor Jeffrey Dukes, Forestry & Natural Resources and Biological Sciences, serves to bring together experimentalists and modelers within the global change research community to improve the design of field experiments, mechanistic understanding of feedbacks, and realism of Earth system model projections. Throughout the year, INTERFACE co-sponsored several symposia and meetings, including in April 2013, "OpenScienceConference on Climate Extremes and Biogeochemical Cycles in the Terrestrial Biosphere: Impacts and Feedbacks Across Scales" in Seefeld, Austria; and in June 2013, “Scaling climate change experiments across space and time: Challenges of informing large-scale models with small-scale experiments,” held in the Czech Republic, in collaboration with the European "CLIMMANI" network. INTERFACE also sponsored student exchanges, including one by Purdue’s own Yujie He. Ms. He, whose thesis focuses on modeling Arctic vegetation responses to climate change, conducted field work in Alaska with Jennifer Harden (USGS), providing Ms. He with her first opportunity to see the type of vegetation she has been modeling.

James Garrison, Aeronautics and Astronautics, and brought together researchers from around the world (40% from outside North America) to give 29 oral presentations and conduct a Town Hall meeting to define a science and technology roadmap. Prof. Garrison is the guest editor for a special issue of IEEE Journal of Special Topics in Applied Earth Observations and Remote Sensing, containing selected papers from GNSS+R 2012.

The Workshop on Reflectometry using GNSS and Other Signals of Opportunity (GNSS+R 2012) was held at Purdue, October 10-11, 2012. An international conference, jointly sponsored by the IEEE-Geoscience and Remote Sensing Society and NASA, GNSS+R 2012 was chaired by Professor

Each year over 200 of China’s leading professors, postdoctoral researchers, and graduate students are hosted by Purdue faculty as visiting scholars. This year Purdue’s U.S.-China EcoPartnership for Environmental Sustainability (USCEES) led by Professor Timothy Filley, Earth, Atmospheric, and Planetary Sciences, established a Chinese Visiting Scholars Network Reciprocal Travel Grant program to provide funding to support the research-related travel of a past Purdue host of a visiting scholar to that visitor’s home institution in China. The program offered awards up to $4500 to support travel for a stay of no less than four weeks. The PCCRC provided support to expand the USCEES program’s reach to include a project led by Greg Michalski related to climate change and the long term atmospheric deposition of nitrate in deserts in China.
The Dynamics of Climate Conference was supported by a National Science Foundation Geoscience Education grant awarded to Professors Dan Shepardson, Earth, Atmospheric, and Planetary Sciences and Curriculum and Instruction and Dev Niyogi, Agronomy and Earth, Atmospheric, and Planetary Sciences. The three day conference, held on May 15-17, 2013 at Purdue’s Discovery Park, was designed to enhance educators’ understanding of global warming and climate change and prepare them to use the activities in the Dynamics of Climate professional development toolkit. The toolkit utilizes various datasets and activities to develop an understanding of how the Earth’s climate is changing. The activities are designed to promote active learning, viewing students as active thinkers who construct their own understanding of scientific concepts and information.

The conference included panel discussions, expert presentations, breakout sessions (for modeling and guided practice in using the toolkit), and informal networking activities. All activities and materials used a climate system approach to understanding how the Earth’s climate is changing.

The conference attracted 45 individuals from various formal and informal educational institutions and organizations from the East, Midwest and Southern states, including participants from the Chicago Academy of Sciences, Saint Joseph’s College, University of Tennessee at Martin, SUNY Fredonia, National Weather Service, NUVO/Indiana Living Green, Penn State University, Delaware State University, Sustainable Indiana, Great Lakes Research and Education, Midwest Regional Climate Center, Captain Planet Foundation, Purdue University, and Jasper County CES. Next year’s conference will focus on middle and high-school teachers and is scheduled for June 18-20, 2014.

“Couldn’t have asked for a better combination of science content, education strategies, and networking. Thank you!”

“This was great for getting activities to teach people about climate and climate change.”

“I can use the toolkit in my undergrad class and with teacher inservice.”

“One of the best. I was engaged from start to finish. The toolkit is excellent!! Job well done.”
DISTINGUISHED LECTURE SERIES

Each year the PCCRC brings outstanding scholars and other thought leaders to Purdue to catalyze lively, university-wide discussion of climate change issues and to encourage Purdue’s creative potential in this area. This year we were pleased to welcome Professor David Archer and Dr. Jay Gulledge.

In May 2013, Professor Archer presented a lecture on the impact of fossil fuel combustion on Earth’s carbon and methane cycles to an audience of conference attendees, faculty, students, staff, and members of the Greater Lafayette community. Included in his presentation was a demonstration of several on-line, simple interactive models he has designed to help non-science undergraduates, as well as the general public, better understand global warming and climate change forecasts.

Inspired by his visit to Purdue as a PCCRC distinguished lecturer and the keynote speaker for the Dynamics of Climate Conference, Archer, in collaboration with Jill Archer, offers his take on how credible, scientifically sound disagreements in climate change science should take place: with both sides in the same ring.

David Archer is a professor in the Department of the Geophysical Sciences at the University of Chicago and a Fellow of the American Geophysical Union, publishing on Earth’s carbon cycle and its interaction with global climate. He has written a series of books on climate change, including “Global Warming: Understanding the Forecast,” a text for non-science major undergraduates now in its second edition and “The Long Thaw: How Humans are Changing the Next 100,000 Years of Earth’s Climate.” He teaches classes on global warming, environmental chemistry, and global biogeochemical cycles, and is a regular contributor to the climate science blog site realclimate.org.
Clouds’ Effect on Climate Change

Clouds have an enormous effect on the climate, but how they will behave in a warming climate is uncertain. Professor Sonia Lasher-Trapp, Earth, Atmospheric, and Planetary Sciences, shares her thoughts on the state of the science.

The amount and types of clouds that may change as regional climates change still remains one of the largest unknowns in climate prediction. Clouds can be our “friend”, as increases in highly reflective clouds over regions that greatly absorb solar radiation, like stratocumulus layers over the warmer oceans, can effectively help cool the earth and offset greenhouse gas warming. Clouds can also be our “foe”, as increases in cloud cover in the upper atmosphere, like vast expanses of cirrus clouds, can act like an insulating blanket, redirecting some of the earth’s emitted radiation (a cooling effect) back to the surface. Archer’s cartoon highlights climate change skeptics articulating the main uncertainty in climate models, and the criticism is accurate!

Our representation of clouds in climate models is poor, and the world’s scientists are racing to mitigate this problem in multiple ways. On one side, a lack of basic knowledge at the smallest cloud particle scales (micrometers) can influence the clouds at the macroscales (tens, even hundreds of kilometers), affecting precipitation and cloud longevity, both important for predicting climate change. Thus basic research on cloud and precipitation is still desperately needed. On another side, current climate models cannot even represent the knowledge we presently have at the smallest scales, due to the limited resolution (large grid spacing and long time steps) in climate models. Thus other scientists are tackling the problem of better representation of current cloud physics knowledge in the models through parameterization of their effects. Advances on both fronts are being made, but the progress is slower than we’d like, because the problems involve nonlinear interactions over a huge expanse of time and spatial scales. I often feel the need to tell say in my classes that “cloud physicists aren’t slackers; we’ve just taken on one of the most difficult problems out there”!

The over-arching philosophy of Prof. Lasher-Trapp’s group is that advances in our understanding of cloud microphysics are best made with observational and numerical modeling analysis done in unison thus using two approaches to investigate every problem. The group’s successes in the last decade include demonstrating when giant aerosol particles are (or are not) important in warm rain formation, how the productivity of the warm rain process may change in a future warmer climate, the importance of variability resulting from entrainment and mixing upon accelerating or preventing warm rain formation, and the behavior of clouds as shedding thermals that thus entrain air through their leading edges.

The group has also contributed to the development of tools for visualization of ground-based and airborne radar data and high-resolution numerical simulations of clouds, evaluated the performance of aircraft-mounted cloud microphysical probes, and tested microphysical parameterizations in larger-scale cloud models.

Dr. Lasher-Trapp’s group also contributes to science education through studies to improve undergraduate understanding of the nature of science, and the development and evaluation of research-based laboratories for undergraduates in atmospheric science.
Q&A

with Distinguished Lecture Series Speaker, Dr. Jay Gulledge

Jay Gulledge, Deputy Director of the Environmental Sciences Division and a member of the Climate Change Science Institute at Oak Ridge National Laboratory, spoke as a distinguished lecturer in November 2012, sharing his thoughts on scientific uncertainty and climate change policy. PCCRC media intern, Kirsten Gibson, reached out to Gulledge for an update.

"Ignoring the uncertainty systematically biases damage estimates to the low side, making costly climate impacts more likely."

LAST YEAR YOU SPOKE ABOUT THE UNCERTAINTIES OF CLIMATE CHANGE AND HOW THAT WOULD AFFECT CLIMATE CHANGE POLICY. COULD YOU LIST AND DESCRIBE A COUPLE OF THOSE UNCERTAINTIES?

One key uncertainty centers on the local details of climate change impacts: exactly where and when particular types of impacts will affect human systems is unpredictable. Another key uncertainty is the rate at which average global temperature will rise. The pace of warming will determine in part how urgent the problem will become in the next few decades.

COULD YOU DESCRIBE AN IDEAL RISK MANAGEMENT FRAMEWORK FOR CLIMATE POLICY TODAY? ANY NEW REVELATIONS FROM LAST YEAR?

A risk management framework is flexible and adaptable to changing knowledge. Therefore the framework itself does not change as new knowledge is revealed. Instead, it includes mechanisms for updating policies and actions as new information becomes available. Such a framework acknowledges key uncertainties and accounts for the full range of uncertainty. The framework also prices risk appropriately and includes the risk inherent to various policy options, including the risk of not acting (i.e. the risks inherent to unabated climate change), the risk of unintended consequences, and the risk of policy failure. Contingency planning is needed in case science dramatically underestimates damages or in case of total policy failure.

YOU GAVE THE U.S. MORTGAGE CRISIS AND THE OIL SPILL IN THE GULF OF MEXICO AS EXAMPLES OF HOW LACKING A RISK MANAGEMENT POLICY CAN BE CATASTROPHIC. WHAT WOULD BE SOME OF THE CATASTROPHES THAT COULD OCCUR WITHOUT A STRONG RISK MANAGEMENT POLICY FOR CLIMATE CHANGE?

The point of the two examples given (Gulf oil spill and the 2008 mortgage crisis) was that policymakers dramatically underpriced the risk inherent to those events, thus making them more likely to occur. In the case of climate change, "best estimates" of damages ignore the uncertainty inherent to climate impacts. Ignoring the uncertainty systematically biases damage estimates to the low side, making costly climate impacts more likely. This is true of climate impacts to society in general, because underpricing risk leads to under-investment in adaptation measures. Also, high-consequence “tipping points” are more likely—such as the shutdown of the North Atlantic thermohaline circulation, rapid global sea level rise, and species extinctions—because the value of reducing greenhouse gas emissions is underestimated.

HOW WAS YOUR VISIT AND PRESENTATION AT THE PCCRC?

I had a great visit to Purdue. I was most impressed by the open interaction across academic units in the university, the diversity of graduate programs, and the high quality of students. It was an honor to be invited to speak and a pleasure to get to know the good people working on climate change at Purdue.

-Kirsten Gibson is a senior at Purdue studying Spanish and linguistics. She hails from both Lafayette, Indiana, and Wilmington, Delaware. Kirsten has worked at The Exponent, Purdue’s student newspaper, and recently became the PCCRC’s media intern.