Purdue Climate Change Research Center

ANNUAL REPORT 2009-2010

PURDUE UNIVERSITY
Discovery Park

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

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Cover photos from left to right: National experts Barry Rabe, Karen Palmer, Mark Trexler, and Don Fullerton discuss key policy design issues at the 2010 PCCRC Emissions Trading Workshop; Paul Shepson stands in front of an autonomous buoy he co-developed and built to measure atmospheric chemistry in the Arctic. The buoy deployed in the Beaufort Sea on October 7, 2009 at approx. 76N, 138W; Ojibwa Tribal College student Michelana Barret works with Purdue graduate student Sara Top on sample collection to study how invasive invertebrates impact the carbon dynamics of tribal forests.

Message from the Director

Over the past year we have seen a shift in the public's perceptions about global climate change. While little has changed in our state of knowledge, we have progressed over the year from a climate bill addressing the issue being passed in the U.S. House of Representatives to having states pass legislation that climate change does not exist and is not the result of human activity. This mirrors a pattern of changing public opinion. Given this, we see our responsibility at Purdue to continue to do the best climate science that we can and to convey this science not only to our peers, but also to the public and to policy makers. We are finding that the intersections between climate and other real concerns that people do have are becoming increasingly important to our work and to the utility of the information that we can convey. We are devoting more effort to the intersections between climate and areas like food security, water, energy, and the environment. This is something that we have already been doing, but highlighting and discovering more about these very real interactions is increasingly going to be a focus for our Center. By no coincidence, this occurs as we grow into the new institutional arrangement under Purdue's Global Sustainability Initiative which now includes other centers with such interests.

We have been increasing the reach of the Center in terms of additional faculty joining the Center, both in terms of number and in terms of allied interests. This gives us the opportunity to broaden the application of the work that we do, but also presents challenges. The PCCRC began as a small number of individuals coming together to work on a limited set of climate issues. As the size of the group expands it is difficult to maintain the esprit-de-corps and sense of common interest that drove the Center at its inception. Maintaining these is critically important.

The 2009-2010 year was remarkable across many areas especially in light of our relatively modest size and modest resource base. Some of the highlights included Kevin Gurney winning the national Sigma Xi Young Investigator Award and Ernie Agee receiving the Cleveland Abbe Award. Tom Hertel became President of the Agricultural and Applied Economics Association, and many others of our group were recognized for their contributions professionally and personally. Cognizant of our education responsibilities, we sent students to COP 17 in Copenhagen where they learned that international agreements may founder even when many have good intentions. Our students did field work in the Atacama Desert and were involved in flights over the Pacific studying hurricane formation. The PCCRC gives fellowships that help allow departments to recruit exceptional graduate students and this year we graduated our first fellow. We continue to encourage the development of courses across the University that involve climate science and issues and the center continues the tradition of its own "Lit Club" seminar for students, visitors, and staff.

This report reflects only the surface of the research and discovery efforts by our faculty and students. While you will find this exciting, much of what happens is below the radar in the day to day activities of a group of talented people across a tremendous range of activities. It is the energy in this work that keeps all of us going. Our faculty produce an increasing number of high-profile reports and scientific publications that you will see described here. The PCCRC faculty continue to bring in outside research funding on major projects – over seven million dollars during this period with over five million staying at Purdue. There is an increasing amount of collaborative work with other institutions and between Purdue's own schools and departments that involve the Center. We have nine new research projects as part of the twenty five projects now underway associated with the Center. We funded eight new seed projects to help faculty initiate new work, capitalize on existing efforts, and help involve students in activities that would enhance their experience at Purdue.

Finally, there were several outstanding outreach efforts this year. Leigh Raymond put together and brought off a workshop on emissions trading that attracted remarkable private sector and academic participation. Videos and materials from this can be viewed at our website. Daniel Aldrich hosted a conference on resilience and recovery that considered climate and non-climate events and drew international interest and participation. As an example of the important climate/energy intersection, Wally Tyner has been prominent in assessing alternative policies to stimulate sustainable biofuel production, his assessment of variable subsidies for ethanol being the best known of these.

Whether by luck or by design, we have a remarkable group of people; faculty staff, students, and others associated with the Purdue Climate Change Research Center. They are the ones who make the effort both rewarding and successful.

Otto C. Doering, III

Professor and Director

Earlier this year the Purdue Climate Change Research Center sponsored a non-partisan workshop of the many issues related to emissions trading policy design. A summary report highlighting some of the main lessons learned from the day's presentations and discussion, along with full video from all the presentations are available as an on-line resource.

In the photo above, national experts from the private sector and academia join public stakeholders from academia, government, environmental groups, and industry to discuss key policy design issues at the 2010 PCCRC Emissions Trading Workshop.

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Professors Richard Grant and Cliff Johnston are developing a course entitled 'Climate change and Africa' with the objectives of broadening student perspective on both the science and realities of climate change, and the people affected by the changes. The seminar course will be offered in the fall semester and will culminate in an overseas experience in Nouakchott and Rosso, Mauritania.

Fishing using these longboats is a major source of food and the primary export of Mauritania. Increasing sea temperatures and overfishing threaten the fishery .

DISCOVERY

The PCCRC seeks to encourage, in the broadest possible way, the application of scientific knowledge to address fundamental questions related to the Earth's changing climate system. Our faculty, students, postdoctoral researchers, and visiting scientists are expanding the boundaries of our knowledge through interdisciplinary, integrative projects; in this section we invite you to explore our most recent research projects and latest scientific papers.

Sponsored Research

The Center facilitates and supports interdisciplinary collaborations, assisting our faculty as they initiate new projects and compete for funding. In this section, read about our newest research grants.

New grants

PCCRC research projects sponsored by external funding totaled approximately $7.1M million in FY2009-2010, with $5.3M at Purdue. Support came from the National Science Foundation, the National Institutes of Standards and Technology, the United States Department of Agriculture and the U.S. Department of Energy.

Collaborative Research: Impacts of Climate Seasonality on Carbon Accumulation and Methane Emissions of Alaskan Ecosystems during the Holocene Thermal Maximum

Qianlai Zhuang, *Departments of Earth and Atmospheric Sciences and Agronomy*, with collaborator Zicheng Yu, *Lehigh University* (Funded by the National Science Foundation)

In recent decades the Arctic has experienced extensive ecological changes and significant warming. The region's last pronounced warm period occurred during the Holocene thermal maximum, about 11000-9000 years ago. The warm and possibly dry climate resulted in unusual ecosystem types and processes, including novel poplar-willow deciduous forests on uplands, and rapid peatland expansion and growth on lowlands.

This project will test the hypothesis that the enhanced climate seasonality at that time played a major role in causing such contrasting ecosystem responses on uplands and wetlands. A novel approach of integrating empirical paleoecological data analysis and ecosystem process modeling will be used to test the hypothesis. The research team will document ecosystem changes from the Holocene thermal maximum across Alaska and will assess the response of hydrological and biogeochemical processes to warmer climate and different seasonality using the Terrestrial Ecosystem Model. The proposed research will make significant progress in our understanding of the effects of changing precipitation seasonality on soil hydrology and ecosystem processes in the Arctic region. This research has important implications for calibrating ecosystem models that are currently used to project the net carbon balance and methane emissions under a changing climate for Alaska, and potentially for Pan-Arctic ecosystems as well.

Development, Improvement, and Assessment of the Accuracy of Aircraft-Based Mass Balance Measurements of the Integrated Urban Fluxes of Greenhouse Gases

Paul Shepson, *Departments of Chemistry and Earth & Atmospheric Sciences*, Kevin Gurney, *Departments of Earth and Atmospheric Sciences and Agronomy* and collaborators Scott Richardson and Natasha Miles from *The Pennsylvania State University* and Colm Sweeny and Jocelyn Turnbul, *NOAA/ESRL* (Funded by the National Institutes of Standards and Technology)

This project seeks to address a key measurement gap in the ability to track the origin and fate of atmospheric greenhouse gases (GHGs), namely, the disconnect and uncertainty in inventory-based methods and emission measurements. The proposed work will seek to reduce the large measurement uncertainties (20% or more) in greenhouse gas fluxes from urban environments on local spatial and temporal scales. The reconciliation of GHG emissions based on bottom-up and top-down methods will help make carbon-control strategies economically viable, and will addresses a generic problem with broad implications to domestic and international commerce. If successful, this work will demonstrate how to significantly reduce the uncertainties in estimates of GHG emissions over regional, metropolitan and local spatial scales. Quantitative results of this type are required to ensure the success of GHG mitigation strategies.

Studying ecosystem services at the Nachusa tall grass prairie reserve.

Ojibwa Tribal College students Annie Johnson and Michelana Barret work with Purdue graduate student Sara Top to study impacts of invasive invertebrates on tribal forest carbon dynamics.

Enhancing ecosystem services from agricultural lands: Management, quantification, and developing decision support tools

Helen Rowe, *Department of Forestry & Natural Resources*, Jeff Holland, *Department of Entomology*, Benjamin Gramig, *Department of Agricultural Economics*, Jeffrey Dukes, *Departments of Forestry & Natural Resources and Biological Sciences* and Joseph Fargione, *The Nature Conservancy* (Funded by the United States Department of Agriculture)

Natural areas in agroecosystems provide important ecosystem services to agriculture and society. In the Midwest, however, there are few patches of native grassland left to provide services: tallgrass prairie is one of the most endangered ecosystems in North America, with less than one percent of its original extent remaining. The leading cause for prairie loss has been conversion of this productive system to row crop agriculture, primarily corn and soybean production. Two of the more valuable services provided by the grassland patches in agricultural landscapes are climate regulation through carbon sequestration and pest control via support of natural enemy populations. This project team will examine how soil organic carbon and natural enemies of soybean aphids vary across seven land management regimes in northwestern Indiana. These include remnant prairie preserves, high diversity grassland plantings, two types of USDA grassland plantings (moderate and low diversity), and soybean fields under three pest management treatments. These comparisons will show how pest management strategies, grassland plant composition, and land use affect natural enemy abundance and carbon sequestration. The team will use field-collected data to parameterize a landscape gradient and diffusion model that will estimate the supply of biocontrol services across the larger agricultural landscape. The spatial relationships identified in the fieldwork and in the landscape model will be used to quantify economic benefits of ecosystem services in the same landscape.

A new regional paleo-precipitation proxy: oxygen isotopes in desert nitrate

Greg Michalski, *Departments of Earth & Atmospheric Sciences and Chemistry* (Funded by the National Science Foundation)

An important unanswered question facing climatologists, policy makers, and humanity at large is how will global warming impact regional rainfall patterns? Our best tools for assessing how precipitation patterns in arid regions are likely to change in a warmer world are proxy validated global and regional climate models. This project will demonstrate how ^{17}O isotopic anomalies in soil nitrate can be used as a sensitive new proxy of mean annual precipitation in ^{36}Cl dated Atacama Desert soils that are ~ 1,000,000 years old. This new proxy will be used to assess El Nino climate anomalies over the past million years at approximately 3,000 year resolution. This resolution is fine enough to capture climate change impacts arising from orbital precession and axial tilt, and at the same time it is lengthy enough to capture the last 5 orbital eccentricities (the full Milankovitch cyclcle). This work links atmospheric chemistry to climatology and will provide real data to assess coupled chemical transport-meteorological models such as WRF-Chem. The project will advance our understanding of how regional precipitation might change with the anticipated global warming in the coming decades.

Collaborative Research: Impacts of urbanization on nitrogen biogeochemistry in xeric ecosystems

Greg Michalski, *Department of Earth & Atmospheric Sciences and Chemistry* with Stevan Earl, Nancy Grimm, Kathleen Lohse, *Arizona State University* and Paul Brooks, *University of Arizona* (Funded by the National Science Foundation)

Urbanization dramatically modifies the movement and transformations of nitrogen compounds. In particular, nitrate contamination of drinking water is a growing concern in urban areas, especially in arid and semi-arid environments, where urban runoff is actively-managed to recharge groundwater and augment water supplies. Water managers and urban planners, however, lack information on what ecosystem characteristics are most important in controlling the quality of this recharged water, especially its nitrate concentrations. This project will quantify how sources, transport, and fate of nitrate in storm

runoff vary with the density and type of urban land use in Tucson and Phoenix (CAP LTER), Arizona watersheds. Seasonal patterns of nitrate export will be characterized, and new isotopic tracer techniques will be used to understand nitrate sources and mechanisms controlling nitrogen transformations along semi-arid urbanization gradients. These mechanisms will be modeled and integrated into interactive visualization products that will aid in decision-making regarding urban development patterns and storm water management approaches. This project coordinates local (Tucson, Phoenix), state (Arizona), and federal (National Atmospheric Deposition Program/Environmental Protection Agency) resources to focus on a problem that has local, regional and global implications.

Highly Resolved, Process-Driven Fossil Fuel Carbon Dioxide Inventory to Advance Carbon Science, Climate Science and 21st Century Decisionmaking and Public Engagement

Kevin Gurney, *Departments of Earth and Atmospheric Sciences and Agronomy* (Funded by the National Science Foundation)

Quantifying the global fossil fuel carbon dioxide (CO_2) flux at high space/time resolution has emerged as a critical need in both carbon cycle and climate change science. The Vulcan Project led by Kevin Gurney has recently completed such an inventory for the United States at <10 km/hourly scales with mechanistic detail. In this project, Gurney plans to build a global fossil fuel CO_2 emissions inventory that more accurately allocates emissions in space/time than is currently available. The project will combine the recently-constructed global power plant database, monthly energy supply/demand statistics, digital road atlas data, and NASA 'nightlights' observations to build this inventory. With the improved global Vulcan emissions as a key boundary condition, the project will generate new inverse estimates of the non-fossil net carbon exchange. This information will be hosted online in an open, visual, web-compliant domain. The project will also build the 'Footprint' Lab, a virtual learning environment where students 'adopt' a country/U.S. state and collaborate with researchers, instructors and the public on discovery, verification, application, and other activities that immerse them in a long-term, collaborative research network. The virtual lab will consist of a geographic information system (GIS)-based, Google Earth-like, interactive, collaborative environment. The 'placed-based' nature of the research offers a compelling entry point for students of diverse geographic, ethnic, and intellectual backgrounds in addition to offering a web-based platform for public engagement and education.

Collaborative Research: Integrating proxies and Earth System Models to elucidate water cycle dynamics: Did global warming cause an enhanced hydrological cycle in the Eocene?

Matthew Huber and Gabriel Bowen, *Department of Earth & Atmospheric Sciences*, with Mark Pagani, *Yale University* (Funded by the National Science Foundation).

The early Eocene climate was characterized by repeated fluctuations between warm and hyperthermal climate conditions superimposed on a gradual warming trend that culminated in the Eocene Thermal Maximum. This project will enlist a number of isotopic and sedimentological proxies to reconstruct how global patterns of aridity and moisture varied in associated with these climate transitions. Data on climatic wetness from continental sections in North America, Asia, and South America will be integrated with marginal marine records documenting runoff to develop a picture of the spatial structure of the atmospheric water cycle and identify differences between warm and hyperthermal climate states. These will be compared with fully coupled GCM simulations of the Eocene climate to identify robust features of the modeled water cycle and test the large-scale dynamics of the model reconstructions. The resulting synthesis will lead to an improved understanding of the dynamics and impacts of early Paleogene climates and also test predicted large-scale changes in the future water cycle against data from the geological record of greenhouse climates.

Acquisition of a Gas Chromatograph-Quadrupole Mass Spectrometer and upgrade to an existing Stable Isotope Mass Spectrometer for Continued Biogeochemical Research

Timothy Filley, *Department of Earth & Atmospheric Sciences* (Funded by the National Science Foundation)

Granted funds will support the acquisition of a new gas chromatograph/mass spectrometer and the upgrade of an existing stable isotope mass spectrometer within Purdue's stable isotope biogeochemistry laboratory. The instrument upgrades will also support the work on forest carbon and nitrogen dynamics that Filley and collaborators from Purdue, Bemidji State University and Leech Lake and Red Lake tribal colleges are conducting on reservation lands. The grant will enable the co-development of a terrestrial biogeochemistry course where students at Purdue and students at Bemidji State and Leech Lake Tribal College will investigate, in parallel, research topics with relevance to understanding the role of soils in climate change and sustainable forestry.

RCN: MSM: ETBC: Integrated Network for Terrestrial Ecosystem Research on Feedbacks to the Atmosphere and Climate: Linking experimentalists, ecosystem and Earth system modelers

Jeffrey Dukes, *Departments of Forestry & Natural Resources and Biological Sciences* with Aimee Classen, *University of Tennessee*, and Peter Thornton, *Oak Ridge National Laboratory*

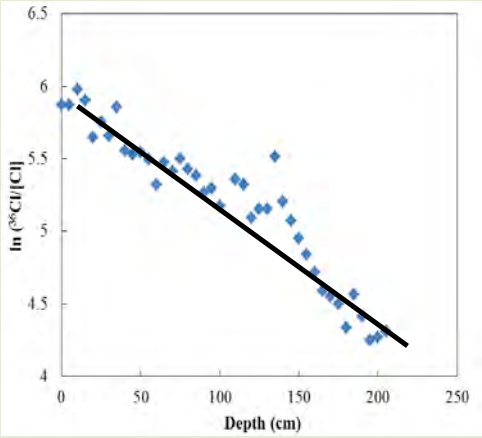
The best available projections of future climate change come from Earth system models (ESMs): complex computer programs that simulate interactions of energy and matter among the atmosphere, oceans, and land. Until very recently, the effects of the land surface on the atmosphere were only incorporated into these models in a limited way. However, recent research suggests that the way in which ecosystems on land respond to changes in atmosphere and climate will itself strongly affect the rate of climate change, and so the responses of these ecosystems must be incorporated into ESMs. Historically, the community of scientists examining these issues has consisted of separate, traditionally non-interactive research groups. A previous

Early Results: Toward a new paleo-precipitation proxy

The Atacama Desert in northern Chile is the oldest and driest desert in the world, despite being located adjacent to the Pacific Ocean. A combination of rain shadow effects from the Andes and Coastal mountains, the cold Humboldt Current, and the southern subtropical high, all lead to meager precipitation and a hyper arid desert that may be as old as 30 million years. Paleosol proxies in this region may hold records of changes in precipitation over time, including how Milankovitch cycles may influence the South American monsoon or El Nino's ability to deliver moisture to the Atacama. However, current surface dating methods provide only the total palesol age, not its age history as the soil develops.

PCCRC fellow Fan Wang and EAS Professor Greg Michalski recently collected soil samples from a 2-meter deep trench located in the Atacama's hyper-arid core (*photo to the right*), and used radioactive chlorine 36 (300,000 year half-life) as a dating constraint. Produced in the atmosphere by cosmic ray reactions with air, ^{36}Cl adheres to aerosol surfaces and is eventually deposited to the Earth's surface as dust. If this chlorine is retained as the soil surface builds up over time, then there should be a linear decay in the natural log of ^{36}Cl activity with depth when normalized to total chlorine content. Measurements of ^{36}Cl concentrations were performed at Purdue's PRIME lab in collaboration with Professor Marc Caffee.

The figure to the right shows exactly the linear decay phenomenon, suggesting the age of this soil profile is 670,000 years old and builds up in a layer-like fashion. Deviations from the expected linear trend are likely due to the movement of soluble chlorine by increases in the frequency of rain events in the Earth's past. Ms. Wang is currently analyzing stable isotope and geochemical data to try and pinpoint the degree of rainfall increases over time and evaluate how changes in the Earths orbital position relative to the Sun over time influences climate over South America.



network brought together researchers doing experiments in the field with researchers who use computers to simulate ecosystem responses to environmental change. A third group, working on land-atmosphere interactions within ESMs, remains largely separate from these other two communities. INTERFACE will facilitate interactions among these distinct groups by bringing them together in a series of international meetings and workshops that are designed to make progress on a set of important, tractable challenges in Earth system modeling and experimentation. Integrating these three groups will advance global environmental change research by 1) incorporating realistic biological responses into ESMs, and 2) facilitating the design of field experiments and computer simulations that are best suited to improving the performance of ESMs. These activities will have the additional benefit of allowing cross-fertilization within, as well as across, these communities of researchers.

IHCDA Home Energy Conservation Program: Technical Monitoring Services

Kirk Alter, *Building and Construction Management* with Mezzetta Construction Services and Scott-Hilliard-Kosene, Inc. (Funded by the U.S. Department of Energy)

With this grant, 10 percent of at least 10,000 Indiana residences receiving weatherization services across the state will be randomly selected for analysis; with particular emphasis on forensic analysis intended to ferret out fraudulent contracting and reporting. The grant will also allow undergraduate students to assist with the field inspections. The team will serve in an inspector general role for IHCDA Low Income Weatherization Assistance Program to ensure that energy audits are performed correctly, that the weatherization construction measures are implemented correctly, and that the program is executed with efficiency and effectiveness. Purdue will perform all of the technical and analytical components of the project, Mezzetta Construction will act as construction manager, and SHK will perform file management and homeowner and sub-grantee interface services. The IHCDA Low Income Weatherization Assistance Program provides weatherization services to Indiana families whose incomes are less than 200 percent of federal poverty guidelines. Energy savings per household are expected to fall between 15-30 percent.

On-going projects

1. **Holocene Water Balance of the Northeastern Great Basin** - Gabe Bowen, *EAS* (NSF)

This project is entering its final year, and the past year saw us complete ~8,000 year long records documenting changes in the chemistry and ecology of the Great Salt Lake. These records were derived from organic and inorganic materials preserved in cores and measured at the Purdue Stable Isotope lab and through collaborations with the University of Utah and Brown University. The results of experimental work demonstrating that lake water and dietary H and O isotope ratios could be inferred from measurements of organic cysts preserved in lake sediments were published in the journal *Geochimica et Cosmochimica Acta*, and graduate student Kristine Nielson is working on a second paper describing her work on radiocarbon dating of lake-floor sediments. Lastly, the project expanded its focus this year to take a closer look at the recent history of human impacts on the lake system. As part of a student research project at the 2010 University of Utah stable isotope ecology short course, Gabe Bowen and 7 graduate students visited the Salt Lake City UGSG regional office to obtain samples from 10 shallow lake cores. Multiple substrates in these samples are being analyzed to identify changes in lake water chemistry and ecology during the period of human habitation of the Great Salt Lake catchment.

2. **Climate Variability and the Poor in Southern and Eastern Africa** - Thomas Hertel, *Agricultural Economics* and Noah Diffenbaugh, *EAS* (World Bank TFESSD).

3. **Changes of Land Cover and Land Use and Greenhouse Gas Emissions in Northern Eurasia: Impacts on Human Adaptation and Quality of Life at Regional and Global Scales** - Qianlai Zhuang, *EAS* and *Agronomy* (NASA)

4. **The Isotope Networks Portal: Data Integration for Biogeochemistry and Ecology Through Web-based Geospatial Modeling** - Gabe Bowen, *EAS* and co-PIs Lan Zhao, *Rosen Center for Advanced Computing*; Chris Miller, *Libraries*; Tonglin Zhang, *Statistics*; and Jason West, *Texas A&M University* (NSF).

The project team is careening towards the release of version 1.0 of IsoMAP, the Isoscapes Modeling, Analysis and Prediction portal. This web-based, GIS-enabled software tool represents a modular framework for implementing spatially explicit models. The initial release of the site, coming in late fall 2010, will allow users to develop and implement models for the spatial distribution of stable H and O isotopes in precipitation. Modeling products for other environmental isotope systems will follow soon after. During the past year, the project supported the publication of an edited book (Isoscapes: Understanding Movement, Pattern, and Process on Earth through Isotope Mapping), review/synthesis articles in the *Annual Review of Earth and Planetary Sciences* and *Eos*, and a research paper in press in the J*ournal of Geophysical Research*. The prototype IsoMAP portal also served as a platform for a tutorial and laboratory research project developed by Gabe Bowen and students of the 2010 University of Utah Stable Isotope Ecology Short Course.

5. **The Boston-Area Climate Experiment: A gradient-based approach for characterizing ecosystem responses to warming and precipitation change** - Jeffrey S. Dukes, *Forestry & Natural Resources and Biological Sciences* (Northeastern Regional Center of the Department of Energy's National Institute for Climatic Change Research, based at Pennsylvania State University)

The Boston-Area Climate Experiment (BACE) exposes old-field ecosystems planted with seedlings of four tree species to twelve different climatic regimes, with the goal of identifying response functions for a variety of ecosystem processes. The experiment is designed to test two basic hypotheses: That ecosystem process responses to changes in precipitation and temperature 1) are not linear, and 2) interact. Preliminary results from the first year of treatments supported both of these hypotheses, at least for some of the measured variables. However, interannual variation in the local climate can cause short-term responses to differ markedly from any long-term average. In addition, some responses can intensify or change over time. Researchers at the BACE, who come from 8 universities, are currently monitoring a variety of variables to see if responses to the different climate treatments change over time.

6. **Impacts of High Resolution Extreme Events on U.S. Energy Demand and CO_2 Emissions in the 21st Century** - Noah Diffenbaugh, *EAS*, and Kevin Gurney, *EAS* and *Agronomy* (DOE).

7. **Risk Assessment of Prairies to Agriculture Conversion** - Bryan Pijanowski, Department of Forestry & Natural Resources (TNC)

8. **Soil-Earthworm-Litter System Controls on the Stabilization of Organic Matter in Forests -** Timothy Filley, EAS, and Cliff Johnston, Agronomy; Melissa McCormick, Smithsonian Environmental Research Center; Kathy Szlavecz, The Johns Hopkins University (NSF).

9. **Using Oxygen Isotopes to Constrain Ozone Sources and Sinks** - Greg Michalski, *EAS* (NSF).

10 **Natural Capital and Poverty Reduction -** Gerald Shively, *Agricultural Economics* (USAID).

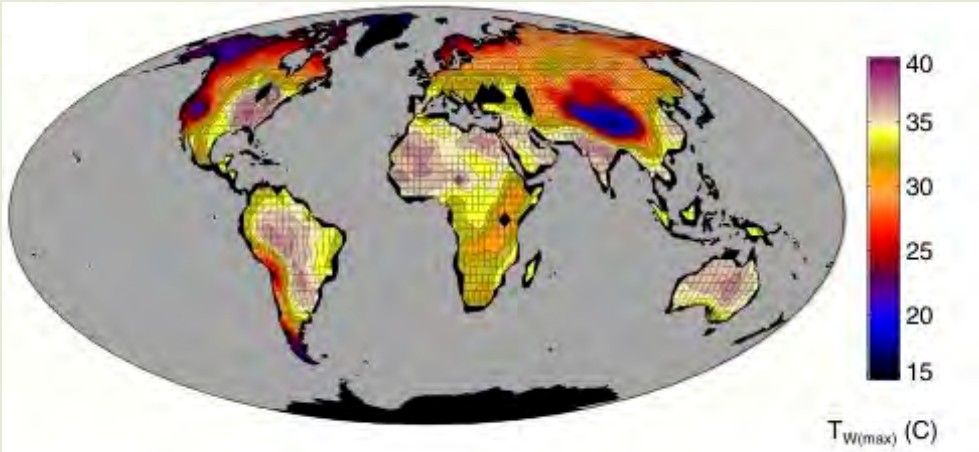
11. **Cosmogenic Nuclides on the West Antarctic Ice Sheet** - Marc Caffee**,** *Physics and EAS* (NSF).

12. **Brown-rot Fungal Mechanisms as a Model for Biomass Saccharification** - Timothy Filley, *EAS*, with Jonathan Schilling and Robert Blanchette, *University of Minnesota* (DOE).

13. **Collaborative Research: P2C2--Understanding the Role of a High-Latitude Convective Cloud Feedback in Equable and Future Climate Dynamics** - Matthew Huber, *EAS* with Eli Tziperman, *Harvard University* (NSF).

The Earth is very sensitive to greenhouse climates. By studying the feedbacks that affect humidity and temperature extremes under extreme greenhouse conditions, the research team and collaborators have found that an Eocene-like warming would render large parts of the Earth uninhabitable for unprotected humans. Specifically, Huber and collaborator Prof. Steven Sherwood of the University of New South Wales, Australia, calculated the highest tolerable "wet-bulb" temperature and found that this temperature could be exceeded for the first time in human history in future climate scenarios if greenhouse gas emissions continue unabated.

Wet-bulb temperature is equivalent to what is felt when wet skin is exposed to moving air. It includes temperature and atmospheric humidity-it is a measure of the lowest temperature an object may be cooled to by the process of evaporation. In a paper published in the *Proceedings of the National Academy of Science*, the investigators find that humans and most mammals, which have internal body temperatures near 98.6 degrees Fahrenheit, will experience a potentially lethal level of heat stress at wet-bulb temperature above 95 degrees sustained for six hours or more. This substantially changes the cost-benefit analysis for global warming in the limit of a large warming, regardless of how far in the future the warming occurs.



This map shows the maximum wet-bulb temperatures reached in a climate model from a high carbon dioxide emissions future climate scenario with a global-mean temperature 12 degrees Celsius (21 degrees Fahrenheit) warmer than 2007. The white land areas exceed the wet-bulb limit

Sherwood, S.C. and M. Huber (2010) An adaptability limit to climate change due to heat stress, *Proceedings of the National Academy of Science*, p.9552, vol. 107.

See also:

Hollis, C., and M. Huber (2009) Evolving Views on a Dynamic Greenhouse Earth, *Eos Transactions*, AGU, p. 194, vol. 90.

Williams, I.N., R. T. Pierrehumbert, M. Huber (2009) Global warming, convective threshold and false thermostats, *Geophysical Research Letters*, vol. 36.

14. **Quantifying Predictability in Nonlinear Multiscale Systems with Applications to Tropical Cyclone Prediction** - Wen-wen Tung, *EAS* with Jianbo Gao, *University of Florida* (NSF).

Graduate student Yi-Chi Wang working with Professor Tung, examined the impacts of high-resolution (<10 km) and cloud-system-resolving regional modeling (CSRM) on the simulation of an intense south Asian monsoon depression (MD) using the WRF-ARW model. The best scenarios were created by the microphysics parameterization (MP) that generated the most robust post-landfall condensation associated with the MD, alone or in combination with the cumulus parameterization that triggered vigorous convection overland in the coarser setup. A sensitivity study of the MP schemes in CSRM suggested that more sophisticated mixed-phased schemes contributed to higher simulation fidelity. Insufficient condensation and weak convection overland might induce spurious low systems over the Bay of Bengal through low-level moisture advection, which further interfered with the MD and degraded several simulations. Read more about this work in their recent publication:

Wang, Y.-C., and W.-W. Tung (2010), Impacts of cloud-system resolving regional modeling on the simulation of monsoon depressions, Geophys. Res. Lett., 37, L08806.

15. **Quantifying Climate Feedbacks from Abrupt Changes in High-Latitude Trace-Gas Emissions** - Qianlai Zhuang, *EAS and Agronomy*, with Adam Schlosser, *Massachusetts Institute of Technology*; Jerry Melillo, *Marine Biological Laboratory*; and Katey Walter, *University of Alaska*, *Fairbanks* (DOE)

16. **Soil Carbon Responses to Atmospheric CO_2 Enrichment** - Timothy Filley, *EAS*; J. Jastrow, *Argonne National Laboratory*; T. Boutton, *Texas A&M*; M-G. Meler and R. Matamala, *University of Illinois, Chicago* (DOE).



The making of an instrumented sled for taking chemical and meteorological measurements from the Arctic Sea ice near Barrow, Alaska.

17. **The Collaborative O-Buoy Project: Deployment of a Network of Arctic Ocean Chemical Sensors for the IPY and Beyond** - Paul Shepson, *Chemistry*; P. Matrai, *Bigelow Laboratory*, J. Bottenheim, *Environment Canada*, U. Frieß, U. Heidelberg, D. Perovich, *CRREL*, and W. Simpson, *University of Alaska, Fairbanks* (NSF).

Chelsea Stephens and Kyle Custard, members of Prof. Paul Shepson's research group, have been working on designing and building an instrumented sled from which to conduct chemical and meteorological measurements from the Arctic sea ice near Barrow, Alaska. This project is an extension of the Ocean-Atmosphere-Sea Ice-Snowpack (OASIS) 2009 field study. The sled, built with the help of the Jonathan Amy Facility for Chemical Instrumentation and the Department of Chemistry Shop, will have the capability of measuring ozone, UV radiation, wind speed and direction, temperature, pressure, and BrOx and ClOx radicals produced photochemically from saline ice and snow surfaces. The aim of this project is to study the occurrence of tropospheric ozone depletion events in Polar Spring and the chemistry associated with them. The sled is set for deployment mid-March of 2011.

18. **The Collaborative O-Buoy Project: Deployment of a Network of Arctic Ocean Chemical Sensors for the IPY and Beyond** - Paul Shepson, *Chemistry*; P. Matrai, *Bigelow Laboratory*, J. Bottenheim, *Environment Canada*, U. Frieß, U. Heidelberg, D. Perovich, *CRREL*, and W. Simpson, *University of Alaska, Fairbanks* (NSF).

19. **Modeling Coherent Structures in Convective Boundary Layers** - Alexander Gluhovsky *EAS and Statistics* and Ernest Agee, *EAS* (NSF).

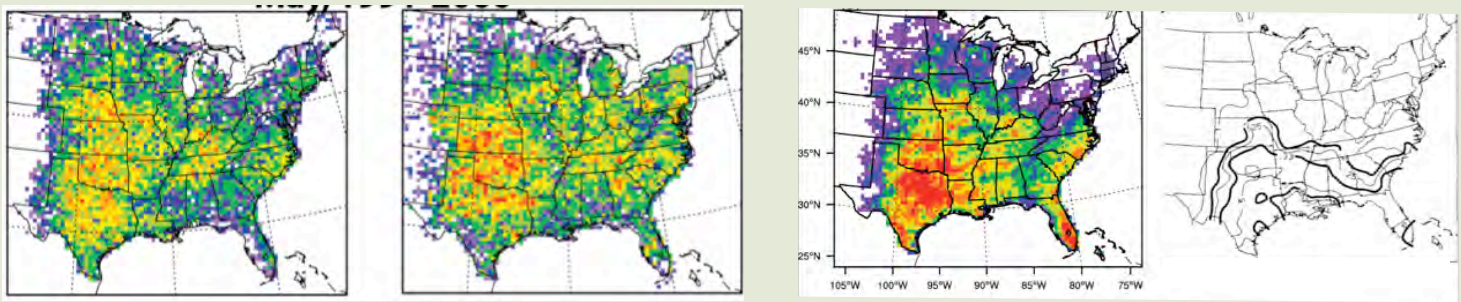
20. **Urbanization Impacts on the Hydrometeorology of the Upper Great Lakes Region** - Laura Bowling, *Agronomy*; Keith Cherkauer, *ABE*; Bryan Pijanowski, *FNR*; and Dev Niyogi, *Agronomy and EAS* (NASA).

The overall objective of this project is to build fundamental knowledge of the role of the spatial arrangement, orientation and connectivity of future urban development on summer thunderstorms and streamflow response at multiple spatial scales. The team's unique approach involves a land cover/land use transformation model, a macroscale hydrology model and a regional atmospheric model that work together in a physically consistent one-way coupling. In this final year of the project, the group is working both individually and collectively to quantify the multi-scale spatial interactions of urban development. FNR graduate student Kimberly Robinson (Pijanowski lab) is developing an innovative dataset to quantify urban topology based on digitization of 38,830 buildings in the Indianapolis Metropolitan Area. Derived statistics such as the distribution of inter-building distances will be used to better describe the energy dynamics of urban areas in the Regional Atmospheric Modeling System (RAMS) model.

Ming Lei, a graduate student in EAS (Niyogi lab), is working to better understand the feedbacks between local scale land cover changes and mesoscale convective weather events. Lei uses multiple land cover scenarios simulated by the Land Transformation Model (LTM) within the RAMS model coupled with the LEAF2 land surface model. Simulated precipitation has shown highly non-linear change with increasing impervious area. Lei is exploring the results by analyzing how surface fluxes lead to changes in convergence and local scale boundary conditions.

Agronomy graduate student Guoxiang Yang (Bowling lab) is also exploring the impact of urban spatial location on flood frequency in the White River basin, near Indianapolis, IN. Hydrology simulations were conducted for seven different land cover scenarios with urban areas located in different zones based on the travel time to the basin outlet. Urban areas located near the basin outlet have a smaller impact on simulated flood magnitude compared to urban areas located in the upper basin, in some cases reducing flood magnitudes. This confirms that the largest impacts of urbanization are not necessarily seen immediately downstream of the development. The remaining challenge for this project is to quantify how uncertainties in each of our key components, transfer to other parts of the simulated cycle.

21. **Exploration of the Mechanistic Relationship Between Improved Regional North American Inverse Carbon Fluxes and Climate Variability/Trends** - Kevin Gurney, *EAS and Agronomy* (DOE).



22. **The Response of Convective Precipitating Storms to Anthropogenically Enhanced Global Radiative Forcing** - Robert (Jeff) Trapp, *EAS*, and co-PIs Noah Diffenbaugh, *EAS*; Michael Baldwin, *EAS*; and Alexander Gluhovsky, *EAS* and *Statistics* (NSF)

The use of high-resolution dynamical downscaling is being explored as a means to simulate the regional statistics, variability, and possible future climatology of hazardous convective-scale weather. Our basic approach differs from a traditional regional climate model application in that it involves a sequence of daily integrations. We use the Weather Research and Forecasting (WRF) model, with global reanalysis data (from the NCEP-NCAR Reanalysis Project; the R1 dataset) as initial and boundary conditions. Horizontal grid lengths of 4.25 km allow for explicit representation of deep convective storms and hence a compilation of their occurrence statistics over a large portion of the conterminous United States. Our procedure is to integrate the model over one day (12 UTC to 12 UTC), reinitialize the model, and then integrate/reinitialize over each subsequent day during warm-season months of 1991-2000.

The resultant 10-y sequence of WRF model integrations yields precipitation that, despite its positive bias, has a diurnal cycle consistent with observations, and otherwise has a realistic geographical distribution. Similarly, the occurrence frequency of short-duration, potentially flooding rainfall compares well to analyses of hourly rain gauge data. Finally, the climatological distribution of hazardous-thunderstorm occurrence is shown to be represented with some degree of skill through a model proxy that relates rotating convective updraft cores to the presence of hail, damaging surface winds, and tornadoes. The results suggest that the proxy occurrences, when coupled with information on the larger-scale atmosphere, could provide guidance on the reliability of trends in the observed occurrences.

Analysis of another set of experiments, in which data from the NCAR CAM3 were used as initial and boundary conditions, are underway.

23. **Experimental Testbeds for New Applications of Environmental Trading Programs** -Timothy Cason, *Economics*; John Stranlund and John Spraggon, *University of Massachusetts*; James Murphy, *University of Alaska*; David Porter, Stephen Rassenti and Vernon Smith, *Chapman University* (EPA).

The laboratory provides a test bed to inform many design choices for emissions permit markets. Experiments are sometimes strongly motivated and structured by specific theoretical models and predictions, but in other cases the experiment itself can be the model of the market and regulatory environment. Professor Timothy Cason delivered a keynote presentation at the workshop "The Use of Experimental Methods in Environmental, Natural Resource, and Agricultural Economics," organized by the Northeastern Agricultural and Resource Economics Association (NAREA) in Burlington, Vermont. Cason presented a review of specific experimental applications that address design issues for permit auction rules, permit expiration dates and banking, liability rules, and regulatory enforcement.

24. **Collaborative Research: Synthesis of Arctic System Carbon Cycle Research through Model-Data Fusion Studies Using Atmospheric Inversion and Process-Based Approaches** - Qianlai Zhuang, *EAS and Agronomy*, with D. McGuire, *University of Alaska, Fairbanks*; J. Melillo, *Marine Biological Laboratory*; and M. Follows, *MIT* (NSF).

25. **Halogen Chemistry and Ocean-Atmosphere-Sea Ice-Snowpack (OASIS) Chemical Exchange During IPY** Paul B. Shepson, *Chemistry* (NSF).

Chelsea Stephens and Kyle Custard, members of Paul Shepson's research group, have been working on designing and building an instrumented sled from which to conduct chemical and meteorological measurements from the Arctic sea ice near Barrow, Alaska. The sled, built with the help of the Jonathan Amy Facility for Chemical Instrumentation and the Department of Chemistry Shop, will have the capability of measuring ozone, UV radiation, wind speed and direction, temperature, pressure, and BrOx and ClOx radicals produced photochemically from saline ice and snow surfaces.

Seed grant program

The PCCRC seed grant program provides a modest amount of funding to encourage research and education activities involving cross-college collaborations and to catalyze interdisciplinary projects that have strong potential for subsequent extramural support.

The Hosts: Mapping the Siting of Nuclear Power Plants in the United States - Daniel P. Aldrich, *Political Science*
Many government decision makers, energy scientists and NGOs envision nuclear power as the best alternative to electrical generators which burn coal, oil, and natural gas. Nuclear power plants, while producing long-lived radioactive waste, emit no carbon dioxide and hence could substitute for the hundreds of thermal plants which do. However, despite predictions of a "nuclear renaissance," more than 20 billion dollars in US government loans to the industry, and approximately 20 applications to the Nuclear Regulatory Commission (NRC) for new plants, we have little knowledge of which communities around the country will volunteer (or refuse) to host the next generation of atomic energy facilities. With this funding, Aldrich will jump start a project which tackles issues of global warming, energy and the environment through research on the past and future siting of nuclear power plants in the United States. In the language of political science, Aldrich seeks to understand the ways in which political mobilization and social capital affect decision making about controversial facilities. Important questions to be addressed include, What determines a "good" site for nuclear power plants? Can social scientists understand which communities will be most amenable to atomic energy? Using quantitative and qualitative data, this project seeks to map out the demographic, socioeconomic, political, and social capital characteristics of past host communities and to predict where plants will be placed in the future.

Hydrological sensitivity of the Upper Indus River to glacier changes in the Western Karakoram Himalaya region - Bibi Naz and Laura Bowling, *Agronomy*
In recent years, most of the world's mountain glaciers have shown negative mass balance and rapid decrease in glacier area and volume. Accelerated glacier recession trends have also been reported for the Greater Himalayan region due to global atmospheric warming. The trends in glacier changes, however, are not well documented in the Western Karkoram region. Given the difficulties involved in field surveys and the absence of long-term historical data, we propose to build on our on-going remotely-sensed data analysis in this region, to use a combination of remotely sensed data and surface hydrological modeling to determine the potential impact of glacier changes on downstream river systems in the Western Karakoram Himalaya. The proposed work will provide an accurate estimate of glacier changes in the past and enhance our knowledge of their potential impact on streamflow in the future climate system. The overall goal of this project will infer the effect of glacier and snow cover fluctuations on the downstream freshwater regime of the Indus River over the last 40 years of historic climate variability using the Variable Infiltration Capacity (VIC) hydrologic model developed by Liang et al. In order to accomplish this goal, the VIC model will need to be modified to better represent ice accumulation, ablation and transport in alpine glacier systems.

Leveraging USDA and Purdue Mission-Oriented Grant Funds as a Catalyst for Socio-Economic Research on the Supply of Climate Regulating Ecosystem Services from Agriculture - Benjamin Gramig, *Agricultural Economics*
Indiana is an integral part of the nation's agricultural economy, ranking fourth in total soybean production and fifth in total corn (for grain) production in 2008. As world population continues to grow, so too does the demand for grains, and agricultural producers are called upon to be more productive while also supplying additional non-commodity services to society from managed agro-ecosystems. These services have come to be called "ecosystem services" (ES), and are closely linked to domestic and international policies to address concerns about climate change and ongoing policies that address soil and water conservation. Agriculture has long been on the front lines of soil and water conservation, but concerns about climate change are a relatively new development that creates both challenges and opportunities for Indiana farmers. This project will identify characteristics, beliefs, information needs and economic incentives that influence Indiana farmers to adopt conservation practices capable of supplying climate regulating ecosystem services from working lands; provide farmers with scientific and economic information needed to overcome obstacles to adoption when favorable economic and environmental circumstances exist; and supply socio-economic research and extension activities to meet the needs of Indiana farmers by leveraging an externally funded multi-disciplinary grant that will establish a multi-departmental team at Purdue to address crop productivity and environmental sustainability in maize-based cropping systems.

The Public Revolution in Emissions Trading Policy – Leigh Raymond, *Political Science*
In this project, Raymond proposes to study a startling and important shift in emissions trading policies. Such policies, which rely on creating a limited number of tradable rights or "allowances" to emit a given pollutant, are an important but controversial part of society's approach to serious public challenges like climate change. These policies have traditionally used so-called "squatter's rights" principles to grant emissions allowances to existing polluters for free. Although economists have long supported allowance auctions as a more efficient allocation option, their arguments have fallen on deaf ears. Starting in 2005, however, several new emissions trading programs have proposed auctioning large numbers of allowances, treating the atmosphere as a public resource rather than giving allowances to existing polluters. This is a remarkable policy change that merits detailed explanation and analysis: How did such a dramatic shift, affecting potentially billions of dollars of revenue, happen in such a short period of time (2005-present)? How did such a dramatic shift occur when experts dismissed auctioning as political "unthinkable" as recently as a decade ago? How likely is this shift in principles to endure in the future? Yet there has been little scholarly analysis of these questions. This purpose of this project is to explain the sudden emergence of this new paradigm of public resource ownership and allocation, and to consider its future policy implications.

Climate Change and Africa - Richard Grant and Cliff Johnston, *Agronomy*
A seminar is under development on 'Climate change and Africa' with the objectives of broadening student perspective on both the science and realities of climate change, and the people affected by the changes. The seminar course would be 2 credit course offered in the fall with the overseas experience in Nouakchott and Rosso, Mauritania during winter break. Rich Grant and Cliff Johnston traveled to Mauritania in April to prepare the course. The students will spend a number of days on a Saharan desert oasis and a number of days at an Agricultural Research Institute on the Senegal River. The owner of the oasis, Sidi el Moctar Waled, has received the UNEP Sasakawa Prize (2006) for efforts in to fight desertification and has developed a inter-planted cropping system within his oasis for fruits and vegetables among palm and other native trees. The focus of the course experience in Mauritania will be combining the changes in climate in the Sahel and desert and the impacts on the people through challenges they face with soils and water quality and availability.

Numerical modeling of precipitation changes resulting from regional climate change across the US - Sonia Lasher-Trapp, Cecille Villanueva-Birriel and Dan Arthur, *Earth & Atmospheric Sciences*

Globally, clouds precipitate one meter of rainfall annually, based on observations over the last half-century. Different regions will receive more or less than this amount, as determined by large-scale and regional weather patterns, and local aerosol, dynamic, and thermodynamic characteristics of the environment. The storms providing the bulk of this rainfall can be examined in terms of their *precipitation efficiency (PE)*, that is, the ratio of some measure of the amount of water mass reaching the ground (precipitation) to some measure of the amount of water mass ingested by the storm (vapor) or condensed within the storm (condensate). Hypotheses regarding the behavior of the future climate system must assume a precipitation efficiency for storms occurring in those climates, such as an increased PE as in the "adaptive iris hypothesis," a constant (unchanged) PE as in the "thermostat hypothesis," or a decreased PE (resulting from increases in aerosol) broadly classified as the "cloud lifetime effect." Establishing changes in the PE of storms occurring in various regions across the globe is important not only for predicting future climate, but also for addressing the impacts of climate change to society, especially with respect to water resources. The overarching objective of the proposed work is thus to improve understanding of this interplay between the liquid and ice processes occurring inside a convective storm in modulating its PE, and how changes of the thermodynamic and dynamic environment resulting from regional climate change might affect this interplay. The goal is to *discover fundamental relationships* between a regional atmospheric environment (induced by climate change) and its aerosol characteristics, and the production of precipitation in storms occurring in such conditions.

Prof. Richard Grant checking out a raingauge at an oasis in the Sahara desert. Rain events in the desert are remembered.

Transport realization of Hestia Pilot fossil fuel CO2 emissions and presentation to AGU Western Pacific Geophysics Meeting: towards collaboration on a US-China collaborative - Yuyu Zhou and Kevin Robert Gurney, *Earth & Atmospheric Sciences* and *Agronomy*

In late 2006 China overtook the United States as the world's number one emitter of carbon dioxide. Interestingly, the lack of a systematic, independent, and reliable monitoring, reporting, and verification (MRV) system for greenhouse gas emissions in China and the U.S. was a significant barrier to progress on international agreement in Copenhagen. In order to increment the Hestia pilot effort in the city of Indianapolis towards a prototype MRV system, we propose to build an atmospheric realization of the Indianapolis emissions. Though the high resolution emission inventory built for Indianapolis is a significant advance, understanding how the emissions are transported in space and time is an essential component of a complete MRV system which must include atmospheric sampling as a verification of the Hestia estimate emission sources at the surface. The proposed work will complete the transport realization using the Hybrid Single Particle Lagrangian Integrated Trajectory Model model. These simulations will provide a complete 4D concentration matrix for the urban domain which can be analyzed in order to isolate individual sources or test sampling strategies for verification. The transport realization was a gap in the currently funded work with Shepson and colleagues and hence, now offers dual benefits by strengthening the analysis in that research effort and simultaneously building a strong foundation for new collaborative research funding aimed at a larger China-US effort.

Water security under a changing climate
Rabi Mohtar, *Agricultural & Biological Engineering* and *Global Engineering Program*

It is evident that changes across nearly all sectors of the economy are expected as a result of water shortages, which are compounded by climate changes and ecological zone shifts. However, to a large extent, integrated multi-scale tools for water decisions and water footprints are lacking, and even more so in a changing climate. We need to better understand the water system under changing climate conditions and to establish measures for linkages between water and other systems that affect water security such climate, trade, food, and energy to name a few. This project will develop a framework that involves many of the scientists at the interface of water and climate. Open discussions and meetings between the Purdue water community and the PCCRC will synergize the two communities and help catalyze curricular changes and the introduction of courses at the interface between climate change and water security and adaptation.

Journal Articles

This year's peer-reviewed publications and highlights from selected papers are listed. Students' names are underlined, and Purdue authors appear in bold.

- **Ahmed, S. A., N. S. Diffenbaugh and T. W. Hertel,** (2009) Climate Volatility Deepens Poverty Vulnerability in Developing Countries, Environ. Res. Lett. 4 No 3.

- Ali, J. R. and **M. Huber**, Mammalian biodiversity on Madagascar controlled by ocean currents, Nature, 20 January 2010 | doi:10.1038/nature08706.

- Anderson, R. G., J. G. Canadell, J. T. Randerson, R. B. Jackson, B. A. Hungate, D. D. Baldocchi, G. A. Ban-Weiss, G. B. Bonan, K. Caldeira, L. Cao, **N. S. Diffenbaugh**, **K. R. Gurney**, L. M. Kueppers, B. E. Law, Sebastiaan Luyssaert, and Thomas L O'Halloran Biophysical considerations in forestry for climate protection, Frontiers in Ecology and the Environment.

- Arantes, V., Y. Qian, S. S. Kelley, A. M. F. Milagres, **T. R. Filley**, J. Jellison, B. Goodell (2009) Biomimetic oxidative treatment of spruce wood studied by pyrolysis–molecular beam mass spectrometry coupled with multivariate analysis and 13C-labeled tetramethylammonium hydroxide thermochemolysis: implications for fungal degradation of wood, J. Biol. Inorg. Chem. doi: 10.1007/s00775-009-0569-6.

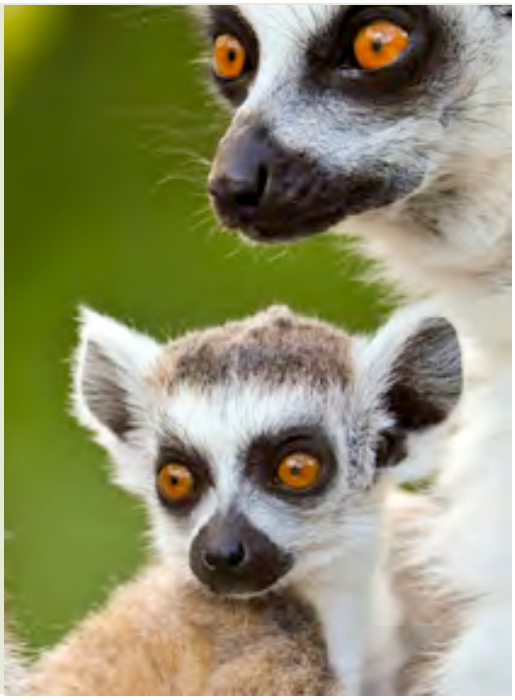
- **Bowen, G**., Isoscapes: Spatial Pattern in Isotopic Biogeochemistry, Annual Review of Earth and Planetary Sciences.

- **Bowen, G.J**., J.B. West, and J. Hoogewerff, Isoscapes: Isotope mapping and its applications, Journal of Geochemical Exploration, doi: 10.1016/j.gexplo.2009.05.001.

- Caballero, R. and **M. Huber,** Spontaneous transition to superrotation in warm climates simulated by CAM3, Geophysical Research Letters.

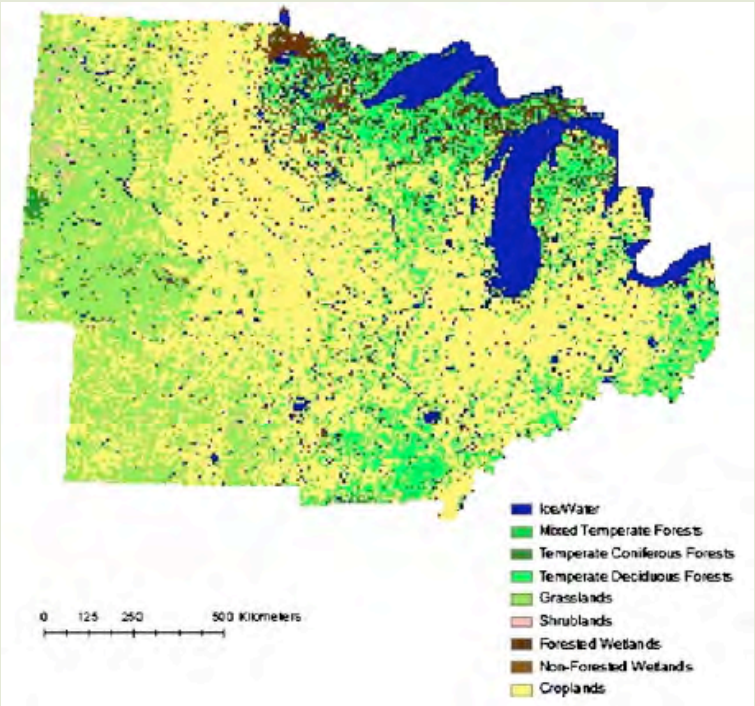
Madagascar hosts one of the world's most unusual, endemic, diverse and threatened concentrations of fauna (lemurs, pictured to the right, are among Madagascar's unique mammals). To explain its unique, imbalanced biological diversity, G. G. Simpson proposed the 'sweepstakes hypothesis', according to which the ancestors of Madagascar's present-day mammal stock rafted there from Africa. This is an important hypothesis in biogeography and evolutionary theory for how animals colonize new frontiers, but its validity is questioned. Studies suggest that currents were inconsistent with rafting to Madagascar and that land bridges provided the migrants' passage. In this paper, the authors show that currents could have transported the animals to the island and highlight evidence inconsistent with the land-bridge hypothesis. Using palaeogeographic reconstructions and palaeo-oceanographic modelling, they find that strong surface currents flowed from northeast Mozambique and Tanzania eastward towards Madagascar during the Palaeogene period, exactly as required by the 'sweepstakes process'. Subsequently, Madagascar advanced north towards the equatorial gyre and the regional current system evolved into its modern configuration with flows westward from Madagascar to Africa. This may explain why no fully non-aquatic land mammals have colonized Madagascar since the arrival of the rodents and carnivorans during the early-Miocene epoch. One implication is that rafting may be the dominant means of overseas dispersal in the Cenozoic era when palaeocurrent directions are properly considered.

- Ali, J. R. and **M. Huber**, Mammalian biodiversity on Madagascar controlled by ocean currents, Nature 463, 653-656 (4 February 2010).



The Midwest of the United States includes 12 states and accounts for about a quarter of the total United State land area. In recent years, there is an increasing interest in knowing the biomass potential and carbon balance over this region for the past and the future. In this study, Lu and Zhuang use the Terrestrial Ecosystem Model (TEM) to evaluate these quantities in the region from 1948 to 2099. The model is parameterized with field data of major crops, including corn, soybean, and wheat; then the model is applied to the region for the historical period (1948–2000). Next, the authors evaluate the simulated forestry biomass with forest inventory data, the agricultural net primary production (NPP) with agricultural statistics data, and the regional NPP with a satellite-based product at the regional scale. The results show that the simulated annual NPP for the Midwest increased by 1.75% per year and the whole Midwest terrestrial ecosystem acted as a carbon sink during 1948–2005. During the 21st century, vegetation and soil carbon fluxes and pools show an increase trend with a great inter-annual variability. The ecosystems serve as a carbon sink under future climate scenarios. NPP in the Midwest will increase and net ecosystem production (NEP) will also increase and show an even larger interannual variability. This study provides state-level information for the Midwest, which will help the region's stakeholders better manage their land for the dual purposes of increasing carbon sequestration and meeting the increasing demand for biomass.

- **Lu, Z.**, and **Q. Zhuang**, Evaluating climate impacts on carbon balance of the terrestrial ecosystems in the Midwest of the United States with a process-based ecosystem model, Mitig Adapt Strateg Glob Change (2010) 15:467–487.



Land cover in the Midwest was derived from the National Land Cover Dataset database which is the first land-cover mapping project with a national (conterminous) scope.

- **Cherkauer, K.A**. and **T. Sinha** (2010). Hydrologic Impacts of Projected Future Climate Change in the Lake Michigan Region; Journal of Great Lakes Research, doi:10.1016/j.jglr.2009.11.012.

- **Crow, S. E**., K. Lajtha, **T. R. Filley**, C. W. Swanston, R. D. Bowden, and B. A. Caldwell, Sources of plant-derived carbon and stability of organic matter in soil: implications for global change, Global Change Biology (2009), doi: 10.1111/j.1365-2486.2009.01850.x

- **Delshad**, **A.**, **L. Raymond**, **V. Sawicki**, and **D. Wegener**, Public attitudes toward political and technological options for biofuels, Energy Policy

- **Fall, S.**, **N. S. Diffenbaugh**, **D. Niyogi**, R. Pielke, Sr, and **G. Rochon** Temperature and equivalent temperature over the United States (1979-2005), International Journal of Climatology. DOI: 10.1002/joc.2094.

- **Fall, S**., **D. Niyogi**, **A. Gluhovsky**, R. A. Pielke Sr, E. Kalnay and **G. Rochon**, Impacts of land use land cover on temperature trends over the continental United States: assessment using the North American Regional Reanalysis, International Journal of Climatology.

- **Francisco, J**., P. Bera and T. Lee, Identifying the Molecular Origin of Global Warming, The Journal of Physical Chemistry A.

- **Gasner, M**., **J. Jankowski**, A. Ciecka, **K. Kyle** and **K. Rabenold**, Projecting the local impacts of climate change on a Central American montane avian community, Biological Conservation.

- **Hertel, T. H**., A. A. Golub, A. D. Jones, M. O'Hare, R. J. Plevin, and D. M. Kammen (2010) Effects of US Maize Ethanol on Global Land Use and Greenhouse Gas Emissions: Estimating Market-mediated Responses. BioScience 60: 223–231.

- **Hertel, T. W**. , **W. E. Tyner**, and **D. K. Birur** (2010) The Global Impacts of Biofuel Mandates. The Energy Journal, Vol. 31, No. 1.

- **Jiang, Y.**, **Q. Zhuang**, M.D. Flannigan, and J.M. Little, Characterization of wildfire regimes in Canadian boreal terrestrial ecosystems, International Journal of Wildland Fire. 18, 992–1002. doi:10.1071/WF08096.

- **Jurgens, J.A.**, R. A. Blanchette, **T. R. Filley** (2009) Fungal diversity and deterioration in mummified woods from the ad Astra Ice Cap region in the Canadian High Arctic, Polar Biology doi:10.1007/s00300-008-0578-x.

- **Knepp, T**., **T. Renkens**, and **P. B. Shepson,** (2009) Gas phase acetic acid and its qualitative effects on snow crystal morphology and the quasi-liquid layer, Atmos. Chem. Phys., 9, 7679–7690.

- Le Quéré, C., M. R. Raupach, J. G. Canadell, G. Marland, L. Bopp, P. Ciais, T. J. Conway, S. C. Doney, R. A. Feely, P. Foster, P. Friedlingstein, **K. Gurney**, R. A. Houghton, J. I. House, C. Huntingford, P. E. Levy, M. R. Lomas, J. Majkut, N. Metzl, J. P. Ometto, G. P. Peters, I. C. Prentice, J. T. Randerson, S. W. Running, J. L. Sarmiento, U. Schuster, S. Sitch, T. Takahashi, N. Viovy, G. R. van der Werf and F. I. Woodward, Trends in the sources and sinks of carbon dioxide.Nature Geoscience, November 17, 2009; DOI: 10.1038/NGEO689.

- **Lu, X.** and **Q. Zhuang,** Evaluating evapotranspiration and water-use efficiency of terrestrial ecosystems in the conterminous United States using MODIS and AmeriFlux data, Remote Sensing of Environment.

- **Lu, Y**., **Q. Zhuang**, **G. Zhou**, A. Sirin, J. Melillo and D. Kicklighter, Possible decline of the carbon sink in the Mongolian Plateau during the 21st century, Environmental Research Letters. **4 045023 (8pp)**

- **Lu, Z.**, and **Q. Zhuang**, Evaluating climate impacts on carbon balance of the terrestrial ecosystems in the Midwest of the United States with a process-based ecosystem model, Mitig Adapt Strateg Glob Change (2010) 15:467–487.

- Mahmood, R., R.A. Pielke Sr., K.G. Hubbard, **D. Niyogi**, G. Bonan, P. Lawrence, B. Baker, R. McNider, C. McAlpine, A. Etter, S. Gameda, B. Qian, A. Carleton, A. Beltran-Przekurat, T. Chase, A.I. Quintanar, J.O. Adegoke, S. Vezhapparambu, G. Conner, S. Asefi, E. Sertel, D.R. Legates, Y. Wu, R. Hale, O.W. Frauenfeld, A. Watts, M. Shepherd, C. Mitra, V.G. Anantharaj, S. Fall,R. Lund, A. Nordfelt, P. Blanken, J. Du, H.-I. Chang, R. Leeper, U.S. Nair, S. Dobler, R. Deo, and J. Syktus, 2010: Impacts of land use land cover change on climate and future research priorities. Bull. Amer. Meteor. Soc., 91, 37.46, DOI: 10.1175/2009BAMS2769.1

- **Martins,D.**, Colm Sweeney, **Brian Stirm**, and **Paul Shepson**, (2009) Regional surface flux of CO2 inferred from changes in the advected CO2 column density, Agricultural and Forest Meteorology 149 (10), 1674–168.

- Medina, S., R. Houze, Jr., A. Kumar, and **D. Niyogi,** Summer Monsoon Convection in the Himalayan Region: Terrain and Land Cover Effects, has just been published in Quarterly Journal of the Royal Meteorological Society.

- **Mishra, V.**, **K.A. Cherkauer**, and **L. Bowling**, Parameterization of Lakes and Wetlands for Energy and Water Balance Studies in the Great Lakes Region, Journal of Hydrometeorology.

- **Mishra, V.**, **K. A. Cherkauer**, **D. Niyogi**, **M. Lei**, **B. Pijanowski**, **D. Ray**, **L. Bowling**, and **G. Yang**, A regional scale assessment of land use/land cover and climatic changes on water and energy cycle in the upper Midwest United States, International Journal of Climatology.

- **Mishra, V**., **K. Cherkauer**, and S. Shukla, Assessment of Drought due to Historic Climate Variability and Projected Future Climate Change in the Midwestern United States, Journal of Hydrometeorology.

- **Nielson, K**., and **G. Bowen**, Hydrogen and oxygen in brine shrimp chitin reflect environmental water and dietary isotopic composition, Geochimica et Cosmochimica Acta. 74, 1812-1822.

- **Niyogi, D**., C. Kishtawal, S. Tripathi, and R. S. Govindaraju, Observational evidence that agricultural intensification and land use change may be reducing the Indian summer monsoon rainfall, has just been published in Water Resources Research.

- **Patchen, M.** (2010) What Shapes Public Reactions to Climate Change? Overview of Research and Policy Implications. Analyses of Social Issues and Public Policy, DOI: 10.1111/j.1530-2415.2009.01201.x.

- **Rochon, G. L**., **D. Niyogi**, **S. Fall**, **J. E. Quansah, L. Biehl**, B. Araya, C. Maringanti, A. Torres Valcarcel, L. Rakotomalala, H. S. Rochon, B. Hilaire Mbongo, and T. Thiam (2010) Best management practices for corporate, academic and governmental transfer of sustainable technologies to developing countries. Clean Technologies and Environmental Policy, Vol 12:1. DOI: 10.1007/s10098-009-0218-3.

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People

As a faculty-led center, we know that our strength derives from the scholarship, creativity, and energy of our members. The PCCRC was founded by a group of 12 faculty members representing 8 academic units across campus and has since grown to include 54 active members from 16 departments.

Faculty Awards and Appointments

Ernie Agee was presented with the **Cleveland Abbe Award for Distinguished Service to the Atmospheric Sciences** at the 90th Annual Meeting of the American Meteorological Society on January 20, 2010. The award committee has awarded this honor to Prof. Agee for nearly 40 years of contributions and service to atmospheric science at the local, national, and international levels.

Kevin Gurney was recipient of the national **Sigma Xi Young Investigator Award**. His work focuses on the global carbon cycle, understanding sinks for atmospheric CO_2, how CO_2 changes connect to climate change and how to connect good climate science to development of sound public policy. Kevin is the first Purdue faculty member to receive this award. On March 9, 2010 Kevin presented a Sigma Xi seminar in the Pfendler Auditorium entitled, "*Chasing carbon through the Earth System … or how I came to care about trains, planes, trees and dirt*."

Sigma Xi President Joseph Whittaker presenting 2010 Young Investigator Award to Kevin Gurney.

Thomas Hertel was elected **President of the Agricultural & Applied Economics Association** (AAEA), and will serve a 3-year term. Tom's 2010 AAEA Presidential Address, *The Global Supply and Demand for Agricultural Land in 2050: A Perfect Storm in the Making?* may be downloaded here:

http://www.agecon.purdue.edu/pdf/Hertel_AAEA_Presidential_Address_LongVersion.pdf

PCCRC Membership

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

Agricultural & Biological Engineering: Indrajeet Chaubey [2], Keith Cherkauer, and Rabi Mohtar

Agricultural Economics: Otto Doering, Ben Gramig, Thomas Hertel, Edna Tusak Loehman, Gerald (Jerry) Shively, and Wally Tyner

Biological Sciences: Kerry Rabenold

Botany & Plant Pathology: Nancy Emery

Building & Construction Management: Kirk Alter

Chemistry: Paul Shepson

Civil Engineering: Larry Nies, Suresh Rao [4]

Earth & Atmospheric Sciences: Ernest Agee , Michael Baldwin, Gabriel Bowen, Noah Diffenbaugh, Timothy Filley, Alexander Gluhovsky[3], Kevin Gurney [4], Jennifer Haase, Harshvardhan, Matthew Huber, Sonia Lasher-Trapp, Greg Michalski, R. Jeffrey Trapp, Wen-wen Tung, Qianlai Zhuang[4]

Economics: Timothy Cason

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

IT Discovery Resources: Gilbert Rochon[2]

Mechanical Engineering: Jay Gore, Greg Shaver

Political Science **:** Daniel Aldrich, Elizabeth McNie [2], Leigh Raymond, and Mark Tilton

Sociology: Martin Patchen

Statistics: Hao Zhang [6]

Executive Committee

Laura Bowling, Timothy Filley, Richard Grant, Matthew Huber, Larry Nies, Kerry Rabenold, Leigh Raymond, Gerald Shively, Jeff Trapp, and Ronald Turco

Administrative Staff

Otto C. Doering, III, Director
Leigh Raymond, Associate Director
Rose Filley, Managing Director

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

Jennifer Haase and her research team are deploying a new airborne GPS radio occultation remote sensing system this hurricane season in the NSF sponsored project, Pre-Depression Investigation of Cloud-systems in the Tropics (PREDICT). Approximately 80% of intense hurricanes in the Atlantic originate as African easterly waves, however, of the many tropical waves that emerge each year, it is not known which of these will become tropical storms or hurricanes. Haase, along with a team of scientists from JPL, UC Davis, NCAR, Naval Research Laboratory, NASA and NOAA will be flying over these regions of potential development in order to further our understanding of the conditions that promote or hinder the formation of a tropical cyclone vortex. The new remote sensing system will provide information on moisture profiles and their evolution in these regions of strong convection. The field campaign will take place from August 15 through September 30 out of St. Croix, US Virgin Islands. Haase will be assisted by graduate students Brian Murphy, Alexandria Johnson, and Paytsar Muradyan.

TOMORROW'S LEADERS

As we work to ready our students for the challenges of the 21st century, the PCCRC strives to create a learning environment that introduces students to interdisciplinary thinking and fosters the development of cross-disciplinary interactions and collaborations.

Enriching Experiences

The success of our students is a top priority. The Center supports and enhances the activities of our faculty, and has created new resources to help develop our students into future junior colleagues.

PCCRC students travel to COP15

Students Hannah Bergeman, Maya Zawadsky-Weist, Christine Chung, and faculty members Karen Marais, *Aeronautics and Astronautics* and Kevin Gurney, *EAS and Agronomy,* attended the 2-weeks long Conference of the Parties to the UN Framework Convention on Climate Change in Copenhagen December 7-18. The three students and Kevin posted daily blogs and tweets of their journey to Copenhagen and back again.

To help sort through all of the Twitter talk at COP15 (over 15,000 are expected to attend the meetings) Purdue released an online tool to show which comments are the most popular, as well as provide other information about the global conversation. The Need4Feed Web site showed all of the tweets related to the meeting, and it also sorted through the tweets to display which were the most popular, who was posting the most tweets, which links were the most popular and other helpful information. Anyone with an internet connection was able to follow the conversation by going to http://www.need4feed.com/Copenhagen

This year, for the first time ever, the US Department of State, in coordination with the White House and multiple federal departments and agencies, hosted a US Center at the Conference of the Parties.

COP15
COPENHAGEN
UN CLIMATE CHANGE CONFERENCE 2009

Karen spoke at the conference as co-lead investigator for PARTNER Project 32, Near-term Operational Changes. The Partnership for Air Transportation Noise & Emissions Reduction (PARTNER) is a leading aviation cooperative research organization, and a FAA/NAS/Transport Canada-sponsored Center of Excellence. Karen reviewed how improved operations enable environmental impact reductions and discussed upcoming research in that area. Karen's talk was one of 70 events sponsored by the US Center.

Research Experiences for Undergraduates

There is an urgent need in Native American communities to develop "on-reservation" expertise and leadership in the Earth sciences, yet studies continue to report on the challenges and the near stagnant growth of Native American students in graduate school. Experiential learning associated with culturally relevant environmental problems is often highlighted as an important avenue for increasing interest of Native American students in the STEM disciplines. With this in mind, Timothy Filley and collaborators have created a summer research opportunity to encourage Native American undergraduate students to pursue higher education in terrestrial biogeosciences, a field that offers a broad Earth sciences perspective and a particularly relevant skill set for future land managers and environmental decision makers.

With funding from the NSF through EAR 0748746, 3 students will participate in an intensive summer research experience developing skills that are directly applicable to addressing environmental issues on their native lands and preparing them to pursue graduate study in the earth sciences. In addition to laboratory and field experimentation the students will be formally engaged in a program questioning the ethics and limits of conducting modern science on Tribal Lands. A number of extracurricular opportunities will be highlighted during their stay including a regional geology trip, forest ecology hikes, a GRE prep course, a trip to Chicago, and summer programs at the Purdue Native American Educational and Cultural Center.

Field Work

EAS graduate students Alexandria Johnson, Brian Murphy, and Paytsar Muradyan are part of an NSF project, *Pre-Depression Investigation of Cloud Systems in the Tropics,* to better understand the conditions that promote or hinder hurricane formation and provide earlier warnings to those in harm's way. The students are working with Jennifer Haase, EAS, who leads the Purdue experiment, and James Garrison, *Aeronautics and Astronautics*.

"Often hurricanes originate in storm systems that develop off the west coast of Africa, but it is very difficult to predict which storm systems will develop into a hurricane and which will produce thunderstorms and then dissipate," Haase said. "We are flying into these areas to make measurements and try to figure out what conditions lead to the development of a hurricane."

The team is studying the moisture-uptake process to find early characteristics that drive a storm to eventually form a hurricane. They have developed the GPS Instrument System for Multistatic and Occultation Sensing (GISMOS) to measure satellite signals as they travel through the atmosphere. The signals' speed varies depending on atmospheric conditions, and, through small signal delays, the team can determine the amount of water vapor in the atmosphere.

Graduate student Brian Murphy works at a bank of measurement equipment onboard a Gulf Stream V research aircraft.

"If the moistening process is understood, then we may be able to identify which storm systems are the most critical to track and improve forecasting," Haase said. "We hope to make it possible to forecast hurricanes further in advance, for example five days rather than the current two or three."

The instrument has been installed on a Gulfstream V research aircraft owned by the NSF and run by the National Center for Atmospheric Research. The jet can reach an altitude of about 43,000 feet, enabling scientists to take observations near the tops of storms that form thousands of miles off the coast.

If the Purdue experiment is a success, the instrument could be installed on hurricane research planes to feed information to forecasters or eventually on commercial airlines to collect data during routine flights. The team hopes that results from the project will eventually be able to give people more time to prepare or evacuate to save lives and reduce the destruction when a hurricane makes landfall.

The results also could be applied to future use of satellites that gather similar information, however, there are not currently enough satellites to be able to provide data in good locations for hurricane forecasts.

New Courses

Ecological Footprints: Designing a Community Tool for Sustainable Living
(AGRY598/FNR598)

Instructors: Laura Bowling and Linda Prokopy

This course was offered for the first time in Spring 2010. The class assessed the feasibility of developing an interactive web-site for Tippecanoe County for quantifying stormwater runoff, carbon footprints and backyard habitat value.

Comparative Environmental Politics: NIMBYism at Home and Abroad
(POL 42900-002)

Instructor: Daniel Aldrich

During the semester, students explored the phenomenon known colloquially as NIMBY ("Not In My Back Yard")ism. Through cross-national case studies, the class will look at how decisions concerning controversial facilities are effected by local resistance and concern. Specific topics include environmental racism, issues of equity and fairness, risk perception, governmental strategies for handling NIMBY conflicts, and possible solutions. To enhance our knowledge and to participate in local politics, students will carry out field studies of local NIMBY phenomena in the area. Successful completion of this class will provide students not only with theoretical knowledge of this important topic, but experience working with it directly as well.

Fellow updates

Each year PCCRC awards up to two fellowships to recruit outstanding doctoral students to Purdue. In this section, meet our Fellows and read about their progress.

Congratulations to our first graduates

Joseph Alfieri (2005 Fellow; *Agronomy*, Prof. Dev Niyogi, advisor) successfully defended his PhD dissertation, "Impacts of spatial heterogeneity on the measurement and modeling of land-atmosphere interactions." Dr. Alfieri accepted a position with the USDA-ARS Hydrology and Remote Sensing Laboratory in Beltsville, MD where he is a Research Physical Scientist.

In March, 2010, Vimal Mishra (2006 Fellow; *Agricultural and Biological Engineering*, Prof. Keith Cherkauer, advisor) successfully defended his PhD dissertation, "Understanding the impacts of historic climate variability and climate change on lakes in the Great Lakes Region." Dr. Mishra is now a postdoctoral researcher at the University of Washington working with Prof. Dennis Lettenmaier.

Jinyun Tang, 2006 Fellow

Jinyun Tang is a 5th year PhD student in EAS (Qianlai Zhuang, advisor). Starting with a background in meteorology, Jinyun is now focusing his efforts on improving the quantification of greenhouse gas fluxes, particularly CO_2 and CH_4, with respect to the atmosphere. This is achieved by developing and applying various mathematical tools, including process based models (TEM), atmospheric transport models (GEOS-Chem), and data assimilation techniques (Monte Carlo based approaches and 4-D Var technique). The goal is to integrate our knowledge from both the small scale measurements, e.g. plot-scale eddy flux data, and large scale information, e.g. satellite remote sensing data from the space, to give a comprehensively constrained budget of these trace gases. In this past year, Jinyun has published two papers:

Kendra Castillo is working with NCAR's Sam Levis and Gordon Bonan on tests of the newest Community Land Model.

Jinyun Tang and Q. Zhuang (2010), Modeling soil thermal and hydrological dynamics and changes of growing season in Alaskan terrestrial ecosystems, *Climate Change*, DOI 10.1007/s10584-010-9988-1.

Jinyun Tang, Zhuang, Q., R. D. Shannon, and J. R. White (2010), Quantifying wetland methane emissions with process-based models of different complexities *Biogeosciences*, 7, 3817-3837, doi:10.5194/bg-7-3817-2010, 2010.

Charlotte Kendra G. Castillo, 2007 Fellow

Kendra Castillo's (EAS; Kevin Gurney, advisor) current research focuses on the biophysical-biogeochemical-climate interactions of time-dependent tropical deforestation. She is investigating impacts different deforestation pathways through the use of the Community Climate System Model. Kendra is currently testing the sensitivity of the earth system to different deforestation rates with a view to aiding policy-making, but ultimately aiming to include preservation targets, spatial patterns and socio-economic factors into these scenarios. She has also been cultivating possible partnerships with in-country

experts at the Philippine office of the World Agroforestry Centre/International Council of Research in Agroforestry, and the Manila Observatory. Kendra presented her research prospectus and passed her comprehensive exams in October, 2009.

Kendra was renewed as a Fulbright scholar as well as a Schlumberger Faculty for the Future Fellow for 2010, and hopes to graduate in 2011. Last spring 2010, she was selected as a Graduate Student Visitor to the National Center of Atmospheric Research (NCAR) under the Advanced Study Program (ASP). Under this program, she was sponsored by Gordon Bonan and worked closely with Sam Levis of the Terrestrial Sciences section of the Climate and Global Dynamics Division. This visit was highly beneficial to Kendra's research goals as she was able to gain early access to the latest version of CCSM4, as well as invaluable interactions with key scientists and modelers. Kendra is preparing a joint paper with Levis and Bonan evaluating the new prognostic carbon-nitrogen model with dynamic vegetation in the works.

Kendra presented the following talks this year:

"Climate Change and Deforestation: Thinking Outside the Carbon Box" - The Philippine-American Academy of Science and Engineering (PAASE) 29th Annual Meeting and Symposium entitled "Linking Science and Development". This was held at the Ateneo de Manila University, Quezon City, Philippines.

"Thinking Outside the Carbon Box: Science and Policy Issues of Tropical Deforestation-Climate Feedbacks" at the Ateneo Innovation Center, Quezon City, Philippines, on January 11, 2010.

"Advancing quantitative understanding of the feedbacks between climate change, deforestation, and land-use decisions: 'Putting people into CCSM4'" at the Mesa Lab Main Seminar Room on April 8, 2010, as part of the Climate and Global Dynamics Division (CGD) Research Reports, National Center of Atmospheric Research (NCAR).

Yini Ma, 2008 Fellow

In the 2009-2010 academic year, Yini Ma (EAS; Timothy Filley, advisor) has continued making progress on her research project investigating how the soil-earthworm-litter system influences the stabilization of soil organic carbon in Eastern deciduous forests. This year she completed two field trips to collect soil and amendment residue samples at the Smithsonian Environmental Research Center (SERC) site. In order to investigate the different mechanisms of soil organic matter (SOM) stabilization, she spent time working on size and density separations of soil aggregates and running carbon and nitrogen elemental analyses as well as stable isotope analyses. Yini's research results from the past year show a clear land use legacy effect as well as impacts from earthworm activity across different soil fractions, including the most stable soil fractions.

Yini attended the 2009 American Geophysical Union annual fall meeting with a poster presentation entitled, "Earthworm - Land Use History Controls on Soil 15N and 13C Natural Abundance in Eastern Deciduous Forests." In May 2010, she presented a second poster at the European Geophysical Union annual meeting with her progress on soil physical separation and earthworm impact on SOM dynamics in different aggregated fractions.

Fan Wang, 2009 Fellow

Fan Wang (EAS; Greg Michalski, advisor) joined the department of Earth & Atmospheric Sciences in the fall of 2009. In her first year at Purdue, she took courses on Stable Isotope Forensics, Atmospheric Chemistry and Statistics. She is currently working on the the origin and evolution of nitrate deposits in the hyper-arid regions. She has conducted field work in the Atacama Desert, Chile (Dec. 27-Jan 18) and Kumtag Desert, China (Mar 12-Apri 9). During the 2010 Goldschmidt Conference, she gave a poster presentation entitled, "Role of water availability in source partitioning for desert nitrate: New evidence from mass-independent oxygen isotopic compositions".

Clay Davis, 2009 Fellow

Clay Davis joined the Department of Agricultural Economics as a graduate student interested in the electricity sector (Paul Preckel, advisor). He is working on models of electricity generation from wind and the economic consequence of integrating wind into the electricity supply system. He has produced a prototype model of the integration of wind turbine electricity generation into the Indiana electric supply chain. The model is of interest to the Indiana Utility Regulatory Commission as they make decisions regarding how much to expand the use of wind as an energy resource in Indiana. Clay has produced a draft publication that is currently under review by the Commission titled "Determining the Capacity Value of Wind via the Temporal Patterns of Load and Wind Generation."

Arctic Stories *is a library of videos (digital stories) about the Arctic environment, how it is changing, how it is being studied, and what life in this beautiful part of the planet is all about. This project is a collaboration between Paul Shepson, Peter Lourie (adventure writer and photographer), Matt Huber, and many international partners and was sponsored by the National Science Foundation, with a grant to Paul for his work studying halogen chemistry and ocean-atmosphere-sea ice-snowpack (OASIS) chemical exchange.*

The stories can be accessed from the PCCRC home page, www.purdue.edu or by going to www.arcticstories.net.

DISCOVERY with DELIVERY

In this section, we provide a snapshot of our collaborative partnerships that put our knowledge and expertise regarding the complex, multidimensional issue of climate change to work.

Reports

Science is a shared knowledge. The PCCRC works to bring objective, science-based information to the policy making process.

Variable subsidy for ethanol better for producers and government

A variable subsidy for ethanol producers could cost the government less and provide more security for producers than current fixed rates, according to a study by Professor Wally Tyner, *the James and Lois Ackerman Professor of Agricultural Economics*.

A variable subsidy rate would insulate producers from risk because as oil and ethanol prices drop, the subsidy for producers would increase. The government would save money because it would not have to pay any subsidy when oil prices are high.

The current government subsidy for ethanol producers - a fixed rate of 45 cents per gallon of ethanol - will expire at the end of the year. Congress will have to decide whether to create a new fixed rate, implement a variable rate or go with no subsidy at all.

The study shows that a variable rate would be the most beneficial. A subsidy that lowers risk for producers could entice new cellulosic ethanol production, he said.

Tyner said producers would be profitable when ethanol prices and oil prices are high. When they dip, the subsidy would kick in to ensure that those producers continue that profitability. That assurance could attract new cellulosic producers who would see less risk to invest in the capital required to make ethanol.

Wally Tyner

In the analysis, the government would save money using a variable subsidy compared with the current fixed rate except when oil is at the highest prices. Based on Tyner's calculations, the government would pay $316 million under the current fixed subsidy over the life of a typical ethanol plant.

Under a variable rate, there would be no subsidy at $90 per barrel of oil. The subsidy would kick in at 17.5 cents per gallon when oil is at $80 and increase 17.5 cents for every $10 decrease in oil prices.

Using that scenario, the government would pay between $58 million and $360 million over the life of the plant, depending on the subsidy rate.

The study's findings would be moot if the Environmental Protection Agency does not increase the amount of ethanol that can be blended with gasoline from 10 percent to 15 percent. Tyner notes without that increase, the United States is at the blending wall, the point at which growth in ethanol production has to stop because the maximum amount possible is being purchased and used by consumers. The EPA is expected to make a decision on the blending limit this fall.

Tyner calculated the costs of the fixed and variable subsidies using data from the U.S. Department of Energy and the Dry Milling Model, a Purdue-developed model designed to make projections about ethanol production.

Brian Wallheimer, Ag Communications

Emissions Trading Workshop: Summary Report

On April 30, 2010, more than 70 people gathered for an all-day workshop on emissions trading at Purdue University's Discovery Park. The PCCRC organized the event to provide public stakeholders from academia, government, environmental groups, and industry with the opportunity to interact in a non-partisan manner with academic and private-sector experts regarding the strengths and weaknesses of different emission trading proposals.

The need for such discussion is great. Pollution trading is a high-visibility policy option that raises many complex policy design issues, and the idea has recently gained attention for application to "greenhouse gas" (GHG) emissions that contribute to climate change. A majority of U.S. states have already created or are in the process of creating regional GHG emissions trading programs, including a consortium of Midwestern states. The federal government is grappling with cap-and-trade proposals to address climate change as of this writing, with debates over such bills expected to continue well beyond 2010.

Meanwhile, the world continues to contemplate GHG emissions trading: Mandatory and voluntary markets are already up and running around the world, including the EU Emissions Trading System (ETS) and the Chicago Climate Exchange (CCX).

Despite the intense interest, considerable misinformation and confusion persist regarding emissions trading policies. Compared to earlier cap-andtrade programs, recent proposals for GHG emissions trading are far more complex, which raises a number of new policy design issues. For these reasons, PCCRC was pleased to sponsor an in-depth discussion of the many issues related to emissions trading policy design and to synthesize some of the main lessons learned in this summary report. economically viable, and environmentally acceptable energy resources.

Three Core Ideas

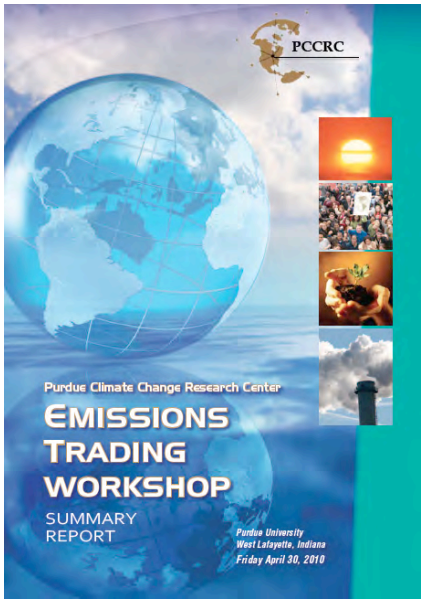
Three core ideas emerged from the day's discussions. The first is that emissions trading policies for air pollutants have a long line of important precedents. Governments have been in the business of privatizing natural resources subject to overexploitation for decades, and these previous experiences from fisheries and water pollution programs, as well as recent state and regional GHG policies, offer important lessons for new GHG emissions trading programs going forward.

The second is that emissions trading is not the answer to all environmental problems and brings its own distinctive set of advantages and disadvantages, like any other policy design. Indeed, the rapidly proliferating lexicon used to identify emissions trading programs makes clarifying the precise details of any such policy vital to a fair evaluation. Consideration of the likely consequences and tradeoffs associated with these precise details formed the core of the day's discussion.

Finally, a third core idea was the perception that additional GHG regulation is inevitable and that emissions trading or other market-based approaches are preferable to alternative policy designs using more traditional command and control techniques.

A copy of the report is available on our website:

www.purdue.edu/climate/emissions trading



Informing Policy

Our faculty engages in multidisciplinary analysis to provide science-based information tools for researchers, students, elected officials, and the public.

Building Resilience: Post-Disaster Recovery in International Perspective

With a grant from the Center for Global Partnerships, Japan Foundation, the PCCRC, Department of Political Science, and Purdue's Global Sustainability Initiative convened a conference on post-disaster recovery on Thursday March 25, 2010.

Chaired by Prof. Daniel Aldrich, this conference focused on the advances and discoveries made in the social and physical sciences in the field of resilience, post-crisis rehabilitation, and rebuilding. Through individual presentations made by scholars from around the world (US, India and Japan), combined with moderated panels and question and answer sessions, this event served to diffuse new discoveries on the topic and bring together experts to network and build research synergies.

The conference began with a lunch reception for conference participants and invited guests. Three speakers, including Eric Dietz, *Director of the Purdue Homeland Security Institute and Associate Professor, Computer and Information Technology*, Matthew Huber, *Associate Professor, Earth & Atmospheric Sciences*, and Ayhan Irfanoglu, *Assistant Professor, Civil Engineering*, gave short presentations on associated topics including limits to adaptation to climate change, homeland security and disaster recovery, and an update on the 2010 Haiti earthquake recovery efforts.

The afternoon session began with presentationas from Shigeo Tatsuki, *Doshisha University, Kyoto, Japan* Sudarshan Rodriguez, *Dakshin Foundation, Bangalore, Karnataka, India* and Rieko Kage, *University of Tokyo, Tokyo, Japan* who provided insights into the role of social capital in post-disaster recovery based on their ongoing research projects. The speakers were then joined by Prof. Mark Hastak, *Civil Engineering* and Prof. Irfanoglu for a panel discussion. Their interests in very different disasters and backgrounds in very different nations provided an excellent comparative view of the field.

Following a brief coffee break, Yasuyuki Sawada, *University of Tokyo*, Daniel Aldrich, *Purdue*, and Rick Weil, *Louisiana State University* presented their work on disaster recovery. A moderated question-and-answer session followed, which brought out important points about the role of the local community in the recovery process and the need to involve citizens in planning and mitigation strategies.

The conference drew an audience of 72 people with representation Purdue University faculty, staff and students from across campus, local elected officials, city, county, and state staff, including first responders (e.g., West Lafayette, Lafayette, Delphi, Carmel, Indianapolis), industry representatives (e.g., WellPoint, Lighthouse Readiness) and members of local neighborhood groups. The presentations and video of the afternoon sessions are maintained as a permanent page on the PCCRC Web site.

Usable Science: A Handbook for Science Policy Decision Makers

Elizabeth McNie, *Assistant Professor, Department of Political Science and Earth & Atmospheric Sciences* and colleagues at SPARC (Science Policy Assessment and Research on Climate) produced a guide for anyone involved in the process of designing, directing, or implementing research -- those who decide what research gets done and whose needs the research is intended to serve. The guide is about the challenge of producing usable science, which the team defines as science that meets the changing needs of decision makers. The handbook is available for download at: http://cstpr.colorado.edu/sparc/outreach/sparc_handbook/brochure.pdf.

US-Canada Collaboration on Agri-environmental Issues

Otto Doering was a participant and rapporteur for the Collaboration on Agri-Environmental Issues Dialogue between the USDA NRCS and Agriculture and Agri-Food Canada held in Washington, D.C., October 21-22, 2009. Meeting objectives included:

- Enhancing mutual understanding of the respective private agricultural lands conservation priorities and programs of each organization.
- Developing a common understanding of climate change issues related to mitigation and adaptation as well as the measurement of conservation practice and program outcomes.
- Identifying specific initiatives for new or strengthened collaboration between Agriculture and Agri-Food Canada (AAFC) and USDA.

Stop Listening to Scientists?

After this year's UNFCCC COP15 meetings, Kevin Gurney wrote a letter to *Science* in which he declares an "all or nothing" approach to developing policy around science is counterproductive. The article:

As a climate scientist and a contributing author to the Intergovernmental Panel on Climate Change, my heart always warms when I hear policy-makers refer to doing what "the science dictates," as President Obama did in his remarks toward the end of the U.N. Climate Change Treaty negotiations in Copenhagen, Denmark. However, after the first-hand experience of the rapid crash of the Copenhagen meeting, I have changed my thinking: World leaders, please stop listening to us! I don't say this because I have lost faith in the verity of scientific results or the projected warming and subsequent global damages. I say this because international policy-makers are adhering too rigidly and too literally to recommended concentration thresholds and emissions targets, and it is crippling the international policy process. By demanding nothing less than rigid recipes, we have lost valuable momentum. To combat this trend, I offer the following recommendations.

Leave aside the near-obsessive need to benchmark everything against the 2°C target. Science has done a commendable job outlining the boundaries of the climate change problem, and those boundaries are well-considered, rigorous guideposts, but don't use science recommendations as a litmus test for policy success or failure. Don't let the perfect be the enemy of the good. Accept any binding commitment as long as it demonstrates effort beyond Kyoto or "business as usual" (whichever requires the greater effort). This can be tightened in the future— you can't amend something you don't have.

Lower the rhetoric. Climate politics has evolved to a point where if one side thinks the other side isn't listening, they shout louder and invoke phrases like "genocide" and "murder." Overblown rhetoric inevitably leads to the well known "donor fatigue." Other than commitments to slow deforestation and forest degradation, leave forestry complications out of a current agreement. It has generated confusion, raced ahead of science, opened mitigation loopholes, and consumed far too much negotiating oxygen.

To the developing world: Approach funding offers as a starting point to get a funding system flowing. You can't attract new revenue, or extend or add funds, to financing that doesn't exist. Agree to even loose commitments on monitoring, reporting, and verification (MRV), a key sticking point in the Copenhagen talks. Science can solve this problem, but can't get started without a clear signal and research commitment from all large emitting countries. Prioritize country commitments to mobilize domestic and international energy research support.

In addition to technology transfer opportunities, effort can be directed toward MRV. In short, we need agreement, even an imperfect agreement, to show a consistent and committed forward momentum. What were general scientific guideposts have become ossified deal-breakers. Instead, we need a sufficient signal to unleash the private and public resources to begin decarbonization. With that, we will start walking in the direction of our goal but leave ourselves open to shortcuts we can't see at the outset.

--Kevin Gurney

Part of the community

PCCRC researchers participate in a variety of activities aimed at advancing scholarship, contributing to public education, and facilitating technology transfer.

ARCTIC STORIES

The Arctic, the bellwether for climate change, appears to be warming at a rate twice that of the planet as a whole. One of the main reasons is that as the sea ice melts, it impacts the reflectivity ("albedo") of the surface and accelerates the warming. The impact of this warming is likely to be profound, including a loss of habitat for a wide range of species reliant on the nature of the ocean/sea ice interface, and changes to ocean circulation and climate.

The Arctic environment increasingly captures the interests and imagination of the scientific community. It is also a rapidly changing environment that is home to native peoples in North America, Asia, Greenland, and Scandinavia. While the scientific community is adept at communication within its ranks, and the same may be said of native people in the Arctic, there is a need for better communication with the global population to the south.

The beauty of the Arctic, its precious and fragile nature, its critical role in maintaining a stable climate for the planet, and the rapid rate of change that is occurring there must all be conveyed to the general public. With "Arctic Stories," a team lead by Paul Shepson uses digital story telling, to put a human face on science, life, societies, and the natural world in the Arctic. On this Web site http://www.purdue.edu/climate/arcticstories/index.html the team presents a range of videos about the Arctic environment, how it is changing, how it is being studied, what the impacts might be, and most importantly, what life in this beautiful part of the planet is all about.

The project, a collaboration between Peter Lourie (adventure writer and photographer), Paul Shepson, Matt Huber, and many international partners, was sponsored by the National Science Foundation, with a grant to Paul for his work studying halogen chemistry and ocean-atmosphere-sea ice-snowpack (OASIS) chemical exchange. Some photos from the OASIS field campaign are shown below.