People

The last piece of the climate puzzle is perhaps the most complicated and dynamic of all: people. The overwhelming majority of climate researchers have reached the understanding—based on decades of evidence, modeling, and debate—that it is extremely likely[1] that human activities are responsible for rising temperatures on Earth. Human behavior will continue to be a major factor in climate change research, and understanding the feedbacks between human behavior and climate variability is critical.[2] Humans can adopt social and commercial practices and implement government policies and laws that significantly affect greenhouse gas emissions. We can increase our energy efficiency and invent alternative fuel sources for our energy-intensive activities. And human ingenuity might even provide geoengineering technologies capable of reversing some of the effects of anthropogenic climate change.

NSF supports research in all non-health-related human sciences. Some academic fields, such as sociology, rely almost exclusively on NSF for government research funding in the United States. Overall, NSF provides approximately 61 percent of federal support for basic research in the social sciences at U.S. academic institutions.[3] NSF's tradition in the social, behavioral, and economic sciences has emerged as a key strength for climate change research. Not only must human systems be factored into climate projections, but an understanding of human science provides the entire research community with the opportunity to learn how to effectively communicate research findings to society. At NSF, we see the transformative research of the future emerging at the boundaries between the traditional scientific and engineering disciplines, and climate change is no exception. Some of the most compelling and paradigm-changing research results have come from multidisciplinary teams that include the human science aspect.

---

1 "From new estimates of the combined anthropogenic forcing due to greenhouse gases, aerosols and land surface changes, it is extremely likely that human activities have exerted a substantial net warming influence on climate since 1750." Solomon, S., et al., Technical Summary, in *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, 2007, p. 81.

2 Pfirman, S., and the AC-ERE, *Complex Environmental Systems: Synthesis for Earth, Life, and Society in the 21st Century*, 2003.

3 NSF FY2009 Budget Request to Congress, SBE-2.

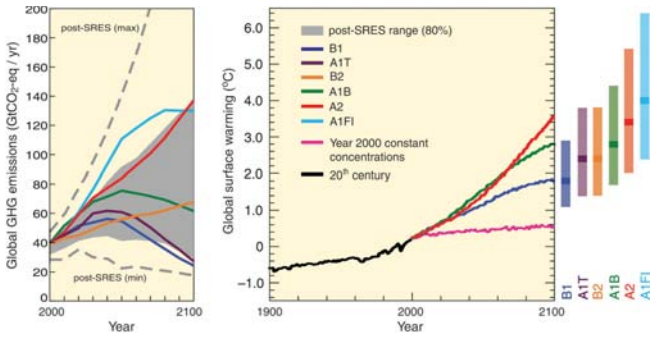
Top image credit: © 2009 JupiterImages Corporation

In addition to supporting the social, behavioral, and economic sciences, NSF addresses the human aspect of climate change through education. NSF research grants to academic institutions not only provide funds for research equipment, overhead costs, and infrastructure, they also enable principal investigators (PIs) to offer financial support to undergraduate and graduate students and postdoctoral researchers training to become the next generation of scientists and engineers dedicated to studying climate change and addressing its impacts. NSF PIs frequently share their time and resources through educational outreach activities involving undergraduate and K–12 students, and members of the community at large. These outreach activities, along with NSF-supported formal and informal education programs (including classroom materials, television programs, and Web sites), engage and educate students and members of the public about scientific and technological issues, including climate change.

Engineering and the physical sciences hold the potential to provide breakthrough technologies in energy, transportation, construction, and other human endeavors that affect the climate. Progress in these hard sciences influences human-factors research as we strive to understand the emergence, dissemination, and adoption of new knowledge and advanced technologies. These tools have the potential to help us adapt to climate change, as well as reduce—and perhaps one day reverse—anthropomorphic greenhouse gas accumulation in the atmosphere.

Modeling Human Behavior

Human behavior may be the most mercurial of all the variables confronting climate modelers. While other parameters follow the laws of physics, human behavior depends on social norms and values, economic forces, technological advances, government policies, and other factors that are all but impossible to account for in physical models. In the latest Intergovernmental Panel on Climate Change (IPCC) report, human behavior was factored into future projections by assuming different levels of greenhouse gas emissions. These scenarios depend on varying levels of economic growth, the adoption of various energy-efficient practices and technologies, and more or less stringent cultural and government influences on energy systems. The integrated climate models of the future will need to account for the critical human factor, including the behavior of groups of humans. Humans may represent the most complex and dynamic of systems to model. Computational models will allow us to begin to understand the phenomena of emergent behavior and tipping points in human interactions.



In this graphic from the Intergovernmental Panel on Climate Change (IPCC) Assessment Report 4 (Figure SPM.5), colored lines represent projections from six different emission scenarios developed in the IPCC's 2000 Special Report on Emission Scenarios (SRES). Each scenario represents emissions resulting from a set of assumptions about world economic and population growth rates, and the adoption of varying degrees of resource-efficient technologies. The panel on the left shows greenhouse gas emissions in the absence of climate policies: six SRES scenarios and the 80th percentile range of recent scenarios published since the SRES (gray shaded area). The panel on the right shows the surface warming projections for the SRES scenarios. The pink line is not a scenario, but represents simulations where atmospheric concentrations of greenhouse gases are held constant at year 2000 values. The bars at the right indicate the likely range of the SRES scenarios for 2090–2099. All temperatures are relative to the period 1980–1999. *Credit: Intergovernmental Panel on Climate Change (IPCC) Assessment Report 4 (Figure SPM.5), www.ipcc.ch/index.htm*

Collaboration and concurrent visualization of 20 simulation runs performed by the International Panel on Climate Change (IPCC). The Highly Interactive Parallelized Display Wall (HIPerWall) project provides unprecedented high-capacity visualization capabilities to experimental and theoretical researchers. *Credit: Falko Kuester, California Institute for Telecommunications and Information Technology, University of California-San Diego*

Computer science and engineering continue to have a profound impact on humanity's ability to track and predict climate change and to manage our response to it. Advances in computational tools must involve advances in the human interface. Computational methods provide visualization tools that help people process and handle complex information. One example of an advanced visualization tool is the Highly Interactive Parallelized Display Wall (HIPerWall) project, a facility aimed at advancing Earth science modeling and visualization. HIPerWall is being used to analyze IPCC data sets.[4] Other human interface advances will come in the form of intelligent software that makes results accessible and useful to policymakers, and networking tools to promote collaboration among research groups around the world.

4 NSF Highlight 12691: HIPerWall: Development of a High-Performance Visualization System for Collaborative Earth System Sciences.

As climate models improve, researchers will continue to provide more accurate and detailed predictions of climate on temporal and spatial scales of great significance to policymakers. Regional climate predictions that integrate the region's biological, social, and economic characteristics and trends will make the projections all the more useful.[5]

Decisionmaking

In the complex, multifaceted area of climate change, uncertainties abound. Climate modeling attempts to take into account every variable researchers can quantify, but there will always be unknowns. Given that the uncertainties in the projections of future temperature, precipitation patterns, species adaptation, and many other variables cannot be fully resolved; and given that government officials, business owners, and the public at large will have to make decisions on the basis of uncertain science, NSF funds three Decision Making Under Uncertainty (DMUU) Centers and two interdisciplinary research teams to tackle these issues.

The Phoenix, Arizona, skyline. The Decision Center for a Desert City at Arizona State University uses nearby Phoenix as a laboratory to study water management and other climate change adaptation strategies. The findings could have implications for other cities in the American West and beyond. *Credit: Tim Trumble/ASU-CAP LTER*

The Decision Center for a Desert City (DCDC) at Arizona State University uses nearby Phoenix as a laboratory for studying adaptation strategies, especially those related to water management in an arid climate. The city's past successes in managing its water supply are being challenged by current drought conditions. A multidisciplinary team of researchers and local water managers are confronting the question of whether this desert city has enough water to sustain growth, given that many climate models predict that the western United States will be warmer and drier in future decades.[6] DCDC has led to the development of practical computational models used by decisionmakers in the Phoenix area, and the center will serve as a model for other Western cities facing similar water problems as a result of the changing climate.

At Carnegie Mellon University's Climate Decision Making Center, researchers focus on how to deal with "irreducible uncertainties"—the limits of our understanding of climate change and its impacts. The center has developed methods for policymakers to rank ecological risks, incorporating the informed judgments of ordinary citizens along with input from experts. This combined approach to risk analysis can be used as a model for other risk-management decisions.[7]

At Columbia University, the Center for Research on Environmental Decisions (CRED) studies individual and group decisionmaking under climate uncertainty. CRED seeks to improve risk communication and increase the use of scientific information on climate variability and change.[8]

Two research teams were also funded under the first DMUU solicitation. The University of Colorado at Boulder's Science Policy Assessment and Research on Climate (SPARC) team examines many issues relating to policy informed by science, including the economic implications of more frequent and intense disaster events such as storms and floods.[9] A research team from the RAND Corporation focuses on water management issues in California and the design of observational systems to provide warning of abrupt climate change.[10]

---

5 Pfirman, S., and the AC-ERE, *Complex Environmental Systems: Synthesis for Earth, Life, and Society in the 21st Century*, 2003, p. 26.

6 NSF Highlight 16008: Water-Related Decision Making for a Desert City.

7 NSF Highlight 10357: Ecological Risk Ranking: A Method for Improving Public Participation.

8 Center for Research on Environmental Decisions Web site: www.cred.columbia.edu/about.

9 NSF Highlight 16006: Science Policy Assessment and Research on Climate (SPARC) for Decision Making Under Uncertainty.

10 NSF press release 04-132: Climate Change a Focus of New NSF-Supported Research on How Decisions Are Made in a World of Uncertainty: www.nsf.gov/news/news_summ.jsp?cntn_id=100447.

Communicating Risk

NSF has a long history of supporting research on disaster warning systems. Disaster warning systems can help protect human life during an extreme event such as a hurricane. Increasing sea surface temperatures mean a likely increase in the intensity of hurricanes, because warm water has more energy to contribute to storms. Climate change will also raise global sea level, which will also increase the potential danger of hurricanes, because low-lying areas will be more susceptible to inundation from storm surges. With these increased risks, clear disaster communication between government officials and the public is essential.

Hurricane Katrina on August 28, 2005. Sea surface temperatures have increased in regions where hurricanes like Katrina form. *Credit: NOAA*

In the aftermath of Hurricane Katrina, NSF sponsored several research teams to study not only the failure of the levee system, but also the human and social aspects of the storm, including the vulnerability of the poor, the public health impacts, and how socioeconomic factors correlated with evacuation planning and decisions.[11] These studies provided vital information about how disaster planning and response can be more effective during future natural disasters, including wildfires. Wildfires are expected to increase in frequency as changing weather patterns lead to drier conditions throughout much of the American West.[12]

Dynamics of Coupled Human and Natural Systems

Anthropogenic climate change is one of the most significant and large-scale examples of the coupling of human and natural systems. We know that human behavior is a powerful force of change at the local, regional, and global scale. At all scales, human behavior both causes environmental change and responds to it. The interactions between humans and ecosystems—especially the dynamics of these interactions—are expected to change as the effects of global climate change are increasingly seen in local ecosystems. For example, changes in precipitation patterns will lead to changes in the availability of freshwater for municipal drinking supplies, which will have an influence on patterns of urban growth. To gain a greater understanding of these issues, NSF created a formal, cross-directorate multidisciplinary program to support teams of researchers focused on the social, natural, and physical science behind the coupling of human and natural systems.[13] Examples of research topics funded through the Dynamics of Coupled Human and Natural Systems program include the future of developed coastal barrier islands with respect to sea-level rise; the interaction between land management and the carbon cycle; the influence of climate change on fire hazards and ecosystems in the interface between wildlands and urban areas; the interactions between changing climate and technological innovations in agricultural decisionmaking; and numerous other projects dealing with climate change issues.[14]

NSF researchers are working in places like rural China to help decisionmakers implement sound environmental policy. *Credit: Jack Liu, MSU*

11 NSF Hurricane Katrina Small Grants for Exploratory Research (award search keyword SGER; reference code 7582).

12 NSF News From the Field: New Study Shows Climate Change Leads to Extreme Drought in U.S. Southwest: www.nsf.gov/news/news_summ.jsp?cntn_id=110017.

13 www.nsf.gov/funding/pgm_summ.jsp?pims_id=13681

14 NSF press release 07-144: www.nsf.gov/news/news_summ.jsp?cntn_id=110437; NSF Press Release 08-173: www.nsf.gov/news/news_summ.jsp?cntn_id=112346.

Arctic Social Sciences

Earth's Arctic region has experienced more significant climate change than perhaps any other area on Earth. The intact native cultures spread around the Arctic Circle present a unique opportunity for social scientists to study and document cultures in flux. Many indigenous people depend on hunting the native species of the Arctic, not only for food, but also as the basis for cultural identity. More unpredictable weather and diminishing sea ice are reducing access to cultural hunting grounds.[15]

With their cultural sensitivity to changing environmental conditions, native people may see patterns and changes that researchers might miss. To capture native knowledge and involve native people in the study of their own environment, NSF-funded researchers have enlisted the input of native people in environmental observation, while at the same time helping the people document and preserve their cultural heritage for future generations. The knowledge and observations passed on to indigenous people from their ancestors provide researchers with an invaluable source of information about climate change.

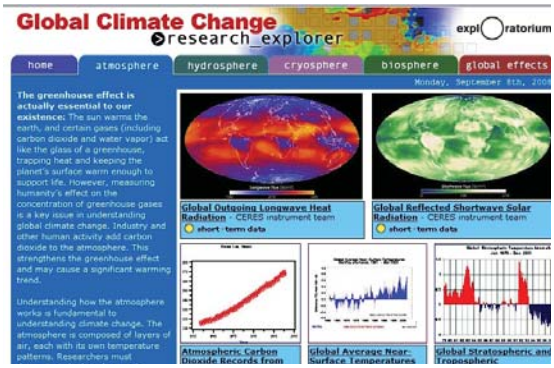
A new study of living conditions in the Arctic indicates that traditional ways of life are important to indigenous people and that wages earned in the cash economy often are used to support traditional folkways. *Credit: Glenn Williams and Narwhal Tusk Research*

The Exchange for Local Observations and Knowledge of the Arctic Project

The Exchange for Local Observations and Knowledge of the Arctic (ELOKA) project is an International Polar Year–related activity supported by NSF. The data management and networking project helps collect, preserve, exchange, and use the knowledge of local Arctic residents and indigenous people. Through local and traditional knowledge, research, and community-based monitoring, Arctic communities are making significant contributions to understanding their changing environment.

Education

One of NSF's strategic goals is a public that is engaged and well informed about science and technology. To achieve this goal, NSF funds science and engineering programs and activities in both formal and informal settings. Formal settings include classrooms, while informal education can take place through informative television programs, Web sites, museum exhibits, and other settings where people of all ages and backgrounds can be reached. By communicating the science behind climate change, NSF is committed to ensuring that the public will be prepared to make choices about how to handle the effects of climate change. An informed citizenry will be able to make sound decisions about local issues such as coastal development, municipal water supplies, and agricultural land use.



NSF funds educational organizations, including San Francisco's Exploratorium science museum, to produce materials that engage and educate the public, such as the Exploratorium's award-winning Global Climate Change Research Explorer Web site. *Credit: © 2002 The Exploratorium*

The International Polar Year created worldwide interest in polar science and provided researchers with the opportunity to share their stories through videos on the Web, television reports and documentaries, and interviews with journalists.[16] On Web sites hosted by scientific programs such as

15 ACIA, *Impacts of a Warming Arctic: Arctic Climate Impact Assessment*, Cambridge University Press, 2004, p. 11.

16 For example, http://www.ipy.org/; www.waisdivide.unh.edu/multimedia; http://neptune.gsfc.nasa.gov/wais/waisFlash/index.htm; www.polenet.org/polenet_schools.htm; www.andrill.org/flexhibit/index.html.

the West Antarctic Ice Sheet Initiative, POLENET (Polar Earth Observatory Network), ANDRILL (Antarctic Geological Drilling), and others, teachers and students can find a wealth of age-appropriate information, animations, videos, and other interactive and educational materials. One polar science–related Web site, www.penguinscience.com, draws on the public's love for penguins to educate people about the effects of climate change on penguin habitats.

Another NSF-funded, Web-based climate change research education tool is the Exploratorium's award-winning Global Climate Change Web site, a colorful, fact-filled site where people of all ages can explore the various aspects of climate change research and even submit questions on particular topics.[17]

Eighth-grade students from Anvil City Science Academy (ACSA) in Nome, Alaska, drill a hole in the ice on the ACSA Pond before measuring the ice thickness. The site is part of the ALISON (Alaska Lake Ice and Snow Observatory Network) program, a science education and scientific research partnership between the University of Alaska, Fairbanks, and the K–12 education community in Alaska. *Credit: Martin Jeffries, Geophysical Institute, University of Alaska, Fairbanks*

Alaska Lake Ice and Snow Observatory Network

The NSF-supported Alaska Lake Ice and Snow Observatory Network (ALISON) program is a science education and scientific research partnership between the University of Alaska, Fairbanks, and the K–12 education community in Alaska. The project blends science and science education in rural and urban classrooms throughout Alaska.[18] ALISON participants monitor Alaska lake ice thickness and duration, which are sensitive indicators of climate variability and change. ALISON involves the Alaskan community in this research, supporting teacher professional development and student learning in the local context. ALISON serves the dual purpose of collecting valuable environmental observational data and alleviating some of the physical and professional isolation that causes high teacher turnover rates in Alaska at the expense of student performance in science and mathematics.[19]

Developing Ocean Literacy

The often-devastating consequences of global climate change, ocean acidification, and the collapse of commercial fisheries illustrate the powerful role that ocean processes play in shaping the human condition. Preventing or mitigating these consequences requires that ocean scientists, educators, and policymakers work together so that informed choices are made for the common good.

Geologist Tracy Jones gives high school students a hands-on opportunity to learn about their local marine environment. NSF's Centers for Ocean Science Education Excellence integrates ocean science research into high-quality education programs, promoting a deeper public understanding of the oceans and their influence on our quality of life and national prosperity. *Credit: John Dindo, Dauphin Island Sea Lab*

NSF's Centers for Ocean Sciences Education Excellence have been instrumental in promoting the development of ocean literacy concepts on a national scale. In June 2006, NSF co-sponsored the Conference on Ocean Literacy, which brought together representatives from federal agencies, experts in formal and informal education, nongovernmental organizations, and industry representatives to lay the groundwork for developing a national strategy for an ocean-literate society. The recommendations from the conference include revamping curricular standards; improving links among research communities, educators, and government agencies; and fostering regional and national networks. The collective recommendations represent a major advance in meeting the challenge of increasing public understanding of ocean processes.[20]

17 Global Climate Change: Research Explorer: www.exploratorium.edu/climate/index.html.

18 NSF Highlight 8705: The Alaska Lake Ice and Snow Observatory Network (ALISON): A Statewide K–12 and University Science Education and Research Partnership.

19 ALISON Web site: www.gi.alaska.edu/alison.

20 NSF FY 2009 Budget Request to Congress: www.nsf.gov/about/budget/fy2009/pdf/20_fy2009.pdf.

Technologies

NSF-funded researchers are working on innovative technologies that can reduce the effects of humans on Earth's climate. NSF-funded basic research is the feedstock that engineers and entrepreneurs will use to create these technologies.

Wind farms like this one near Lamar, Colorado, provide electricity without producing carbon dioxide emissions. NSF researchers are exploring new ways to incorporate alternative energy sources, such as wind farms, into the national power grid. *Credit: Bob Henson*

NSF-funded engineers are rethinking everything from how computer chips are powered[21] to how new buildings are constructed to find new ways to make human activities more energy-efficient, thus reducing carbon emissions. For example, researchers are developing a thin-film technology that adheres both solar cells and heat pumps onto surfaces, ultimately turning a building's walls and windows into a climate-control system that harvests the Sun's energy to heat and cool.

Innovative energy solutions will not only lead to reductions in greenhouse gas emissions, they also have the potential to fuel the American economy. NSF funds alternative energy research focused on next-generation solar cell materials,[22,23,24,25] biofuel production,[26],[27] strategies for matching alternative energy production to consumer demand,[28] new fuel cell designs and materials,[29],[30] and novel methods of converting mechanical energy into electrical energy,[31] among others. NSF's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs fund small companies that are seeking new ways to power the planet.

Konarka Technologies, Inc., a recipient of several NSF Small Business Innovation Research grants, is working to bring flexible solar cells based on specialized plastic materials to the marketplace. *Credit: Konarka Technologies, Inc.*

In addition, numerous NSF-funded centers and research projects focus in whole or in part on alternative energy, environmental, and other forward-thinking green technologies. For example, NSF-funded researchers are pursuing catalytic methods for producing high-octane fuels from biomass.[32] With alternative energy sources such as wind turbines already joining the electric grid, and with emerging alternative energies on the horizon, NSF-funded engineers have turned their attention to the nation's aging electric grid. The grid in its current configuration was not designed for distributed generation sources such as wind and solar farms, and cannot accommodate large numbers of these systems. NSF-supported researchers are redesigning the methods used to control

21 NSF Highlight 14470: Saving Power and Energy in Computer Systems.

22 NSF 07-43, Benchmarks of NSF Innovation: www.nsf.gov/news/reports/nsf0743/7plastic.jsp.

23 ANTEOS, Inc.: www.nsf.gov/awardsearch/showAward.do?AwardNumber=0822652.

24 NetCrystal, Inc.: www.nsf.gov/awardsearch/showAward.do?AwardNumber=0810717.

25 NanoGreen Solutions Corporation: www.nsf.gov/awardsearch/showAward.do?AwardNumber=0810026.

26 Cortright, Randy, Virent Technologies, Inc, briefing to U.S. Congress, September 2008.

27 Edenspace Systems Corp.: www.nsf.gov/awardsearch/showAward.do?AwardNumber=0810640.

28 Dixon Ladd LLC: www.nsf.gov/awardsearch/showAward.do?AwardNumber=0740001.

29 Faraday Technologies, Inc.: www.nsf.gov/awardsearch/showAward.do?AwardNumber=0740077.

30 Energetics Incorporated: www.nsf.gov/awardsearch/showAward.do?AwardNumber=0750325.

31 Tetramer Technologies LLC: www.nsf.gov/awardsearch/showAward.do?AwardNumber=0739814.

32 NSF press release 08-056: www.nsf.gov/news/news_summ.jsp?cntn_id=111392.

distributed generation sources to enable more alternative energy installations to be incorporated into the power grid.[33] NSF's Energy for Sustainability program has made dozens of awards to researchers studying topics including improving the storage capacity of batteries, new types of fuel cells, harnessing microbes to produce electricity, and new materials for hydrogen storage, to name a few.[34]

NSF-funded researchers are exploring catalytic methods for converting corn stover (the plant material left over after the grain is harvested) into biofuels, including biogasoline and biodiesel. *Credit: National Renewable Energy Laboratory*

Strategies for the Future

Science and engineering not only have the potential to reduce the amount of greenhouse gases humans put into the atmosphere, they also have the potential to one day help reduce the impact of anthropogenic climate change. A recent NSF-sponsored workshop focused on the use of carbon dioxide (CO_2) as a feedstock for the manufacture of transportation fuels and other products. Using CO_2 in this manner has the potential to "recycle" carbon that would otherwise end up in the atmosphere.[35] Other NSF-funded researchers are exploring ways to stimulate the growth of foraminifera and other carbon-fixing plankton in the ocean to allow more of these organisms to live, die, and sink to the bottom of the sea, removing carbon from the atmosphere in the process. Still other NSF-supported researchers are exploring methods for removing CO_2 from the exhaust of industrial processes[36] and underground containment strategies for sequestering carbon.[37]

Conclusion

The human contribution to global climate change is nearly indisputable. But so, too, is the human ability to innovate and to change course. NSF funds research in the many aspects of "people science," from social, behavioral, and economic science to high-tech physical science and engineering. The common link is research relating in one way or another to people and their behavior. None of the climate change research funded by NSF, or by any organization, would be meaningful without human beings to learn from it and apply the knowledge to some endeavor, such as building a better climate model, planning a strategy to save a species or ecosystem, creating a law to cap carbon emissions, or designing a new set of experiments to address the next unanswered question. The research highlights that follow describe a variety of research projects aimed at the human aspect of climate change. Social, behavioral, and economic science; education; and green technologies are some of the featured research areas. These research projects have not only contributed to our understanding of the role of people in climate change, they have also provided learning opportunities for the students who will become the next generation of scientists and engineers.

33 NSF Highlight 15233: Improving Grid Reliability with Distributed Energy and Storage.

34 www.nsf.gov/awardsearch/tab.do?dispatch=4 (search element code 7644).

35 Reversing Global Warming: Chemical Recycling and Utilization of CO_2. NSF-sponsored workshop, July 2008.

36 NSF Highlight 12867: Carbon Dioxide Removal—Microscopic Chemical Membrane Versus Cumbersome Gas Plant.

37 NSF Highlight 15796: International Workshop Explores Bio-Geo Engineering Research Opportunities.

People Research Highlights

Water-Related Decisionmaking for a Desert City

Lake Mead National Recreation Area, Nevada. *Credit: National Park Service*

The Decision Center for a Desert City (DCDC) at Arizona State University focuses on water-related decisionmaking in the arid Phoenix metropolitan area. A transdisciplinary team of scientists led by Patricia Gober and local water managers is confronting the pertinent question of whether this desert city has enough water to sustain growth, given that the western United States is expected to be warmer and drier in future decades. Center researchers have built a new model of science and policy engagement that allows water managers and scientists to collaborate on important research questions and experiment with new methods, visualizations, and decision tools so that policymakers can make better decisions for their cities, states, and regions.

DCDC's signature product, WaterSim, integrates a number of quantitative models that represent water consumption and availability in central Arizona under varying scenarios of population growth, climate change, individual behavior, and policy choices. WaterSim links the results of the center's research projects into an interactive tool that allows users to explore the landscape of plausible futures and consider the strategies for avoiding unacceptable scenarios. DCDC's knowledge, tools, and visualizations are jointly produced, as scientists mine new insights for model development and water managers ensure that the model itself is consistent with the decision context in which it will be used. Model results support scenario planning at the municipal level, highlight the need for water conservation, and demand management at the regional level to avoid the deleterious consequences of worst-case climate change conditions.

WaterSim currently characterizes only the metro Phoenix water situation. Once refined, the model's methods will be transferable to cities around the globe. Beyond the obvious application to regional water supplies in other cities challenged by the uncertainties of climate change and growth, this approach also can be used to support decisions about entire river basins or watersheds. Center researchers plan to integrate regional data to properly assess the vulnerabilities in the water supply from the Lower Colorado River Basin, with Las Vegas, Los Angeles, and Tucson as the potential partners. WaterSim is available to the general public on the Web (http://watersim.asu.edu). Local high schools are testing WaterSim with an eye toward linking new scientific knowledge and student learning, with societal needs and policy choices. **Highlight ID: 16008 SBE/SES**

Ecological Risk Ranking: A Method for Improving Public Participation

To improve public participation in environmental decisionmaking, regulators and risk managers report that they need judgments from average citizens who have taken the time to develop thoughtful, informed views about a set of risks. Granger Morgan, Michael DeKay, Paul Fischbeck, and others at Carnegie Mellon University extended their risk-ranking method to incorporate ecological risks and their attributes. The method combines input from experts with judgments from ordinary citizens in a deliberative process. The experts identify relevant risks, categorize them, and organize the discussions, and the citizens provide judgments and ratings. Results were consistent with those from previous studies involving only health and safety hazards, providing additional evidence for the validity of the method. Participants reported that they were satisfied with the procedures and results, and indicated their support for using the method to advise real-world risk-

management decisions. Although groups placed more weight on health and safety attributes than on environmental attributes, they considered attributes reflecting significant environmental impacts to be important. **Highlight ID: 10357 SBE/SES**

Science Policy Assessment and Research on Climate for Decisionmaking Under Uncertainty

Scientists have warned that the costs of future disasters likely will increase because of more frequent and intense extreme events, such as storms and floods. Disaster losses also are expected to increase over time because more people, property and wealth will occupy locations exposed to extreme events. The destructive potential for hurricanes in Miami Beach, for example, is much greater because of dramatic increases in development over recent decades.

Working together on the Science Policy Assessment and Research on Climate (SPARC) project, Roger Pielke, Jr. of the University of Colorado-Boulder and Daniel Sarewitz of Arizona State University have sought to quantify the sensitivity of future losses to possible changes in climate and possible patterns of future development. They have identified the factors that are likely to be most responsible for future costs of disasters across a wide range of climate change scenarios so decisionmakers can identify policy actions robust to uncertainties.

Pielke and Sarewitz found that the most important factors contributing to the growing costs of disasters through 2050 are patterns of development under any climate change scenario. In one scenario examining possible hurricane damage, they concluded that for every dollar in damages in 2000, $4.60 in damages would be expected in 2050. Half of this $3.60 increase would be due to development, while only one-sixth would be directly related to changes in climate. The overwhelming importance of societal change in driving future losses is robust across all scenarios of climate change, development, and damage projections. In other scenarios, the role of development is much greater.

Because any changes to energy policies resulting in lower emissions of greenhouse gases will take many decades to have a discernible effect on the climate system, and because the exact relationship of greenhouse gases and patterns of extreme events remains uncertain and contested, these findings mean that decisionmakers have considerable ability to influence the nature of future economic losses from disasters by influencing development patterns in regions exposed to extreme events. Thus, efforts to reduce the growing rate of disaster losses around the world can proceed while scientific research continues to reduce uncertainty about the pace and magnitude of climate change. **Highlight ID: 16006 SBE/SES**

The Alaska Lake Ice and Snow Observatory Network: A Statewide K–12 and University Science Education and Research Partnership

Eighth-grade students from Anvil City Science Academy (ACSA) in Nome, Alaska, drill a hole in the ice on the ACSA Pond before measuring the ice thickness. The site is part of the ALISON (Alaska Lake Ice and Snow Observatory Network) program, a science education and scientific research partnership between the University of Alaska, Fairbanks, and the K–12 education community in Alaska. *Credit: Martin Jeffries, Geophysical Institute, University of Alaska, Fairbanks*

The Alaska Lake Ice and Snow Observatory Network (ALISON) is a science education and scientific research partnership between the University of Alaska, Fairbanks, and the K–12 education community in Alaska. The project is a blending of science and science education in rural and urban classrooms throughout Alaska. Using a planning grant from NSF, Martin Jeffries has created a network of classroom observatories in seven Alaskan communities, four in rural regions serving primarily Alaskan native students. The results of the pilot network can be reviewed at the ALISON Web site (www.gi.alaska.edu/alison). This project continues and expands the innovative concept of research scientists partnering with science and math teachers and

their students by facilitating the students in collecting, analyzing, and interpreting data that are used in the principal investigator's (PI's) research project on ice, snow, and water. The PI's research is to determine variability and change of ice, snow, and water over the course of one winter and multiple winters. In this way, students and their teachers learn about the nature of scientific inquiry involving questions, simple investigation, data gathering, data analysis, explanation, and communication of investigations and explanations. **Highlight ID: 8705 OD/OPP**

Saving Power and Energy in Computer Systems

Laptop computer. *Credit: © 2009 JupiterImages Corporation*

An NSF-funded researcher has investigated the potential of computer compiler optimizations for power and energy savings. Several optimizations were identified that resulted in significant power and energy savings over existing state-of-the-art technologies. These optimizations are dynamic voltage and frequency scaling, resource hibernation, and remote program execution.

Dynamic voltage scaling (DVS) is recognized as one of the most effective power reduction techniques. It exploits the fact that a major portion of power of CMOS (complementary metal–oxide–semiconductor) circuitry scales quadratically with the supply voltage. As a result, lowering the supply voltage can significantly reduce the power dissipation.

As part of this research project, the principal investigator developed a compiler-supported DVS optimization strategy, implemented the compiler, and evaluated its performance. The evaluations were based on physical power and energy measurements. On a high-performance AMD laptop (Compaq Presario), total system energy savings of up to 28 percent were achieved with a performance degradation of less than 5 percent. On average, the system energy and energy-delay product were reduced by 11 percent and 9 percent, respectively, with an average performance slowdown of 2 percent. **Highlight ID: 14470 CSE/CCF**

HIPerWall: Development of a High-Performance Visualization System for Collaborative Earth System Sciences

The Highly Interactive Parallelized Display Wall (HIPerWall) project provides unprecedented high-capacity visualization capabilities to experimental and theoretical researchers. The primary focus is on Earth science visualization, but collaborating researchers in fields including biomedical science and engineering also benefit from HIPerWall's capabilities. Earth science data sets often cover large areas of the planet at high resolution and depth, with many values at each grid point that vary over time, resulting in many gigabytes or terabytes of data. Visualizing these multidimensional, time-varying data sets is a challenge to computational/storage infrastructure and current display technologies. With HIPerWall, researchers can see the broad view of the data and details concurrently, enabling collaboration and shared viewing of complex results. A visualization cluster of high-performance commodity computers transfers and manipulates data displayed on HIPerWall's 50 display tiles, which operate at a combined resolution of more than 200 megapixels. The visualization cluster receives simulation data from the University of California-Irvine's (UCI's) Earth System Modeling Facility, an IBM supercomputer (funded by NSF in 2003); connects to UCI's digital workspace of the future project, VizClass (funded by NSF in 2001); and communicates over the Calit2 OptIPuter network (funded by NSF in 2003). HIPerWall's ability to display extremely high-resolution data sets drives and provides focus for ongoing research into management, transfer, and visualization of terabyte-scale data, establishing a cyberinfrastructure test bed.

Visual Analytics' HIPerWall supports simultaneous display of raw, processed, and fused data. For example, 20 simulation runs performed by the International Panel on Climate Change (IPCC) are currently being analyzed on HIPerWall, allowing climate predictions, which differ in resolution, to be

visually correlated by teams of Earth System Science researchers. By discovering climate effects that are evident across most or all of the models, scientists can reach consensus. Without the massive resolution of HIPerWall, correlating such changes would have to be accomplished by converting all the results into a common-size data format and attempting machine correlation. Because the human eye is so efficient at pattern recognition, humans can do such discovery more easily when presented with the data in a clear manner. By enabling scientists to see predicted changes in multiple models with their own eyes, and drawing from their specific domain expertise, it is more likely that consensus can be reached.

The software tool to display the IPCC data on HIPerWall is a direct result of the availability of the massive display and computation resources provided by HIPerWall. The tool reads NetCDF result files generated by the participating institutions and displays the parameter, such as 2-D temperature and rainfall variables, geo-referenced on an Earth map image. For example, time-varying temperature and rainfall data can be displayed simultaneously for each model with 50-year separation between them and correlated with the difference in the temperature and rainfall maps from the corresponding month of the start year, 2000. The tool can step forward or backward through time, month-by-month, from 2000 to 2099, with simultaneous updates to the eight results displays for all 20 data sets. This enormous amount of data is presented in a clear and concise manner that makes visual correlation of features possible and easy. Data are provided in the context of a virtual desktop and can be moved freely to any of HIPerWall's display tiles, allowing researchers to organize (cluster) relevant information.

Even though HIPerWall is still being developed, it already allows researchers from different disciplines to come together to work on information visualization problems that were previously elusive. The core research team now consists of 15 faculty, postdoctoral researchers, and graduate and undergraduate students who collaborate with groups in six departments and four schools at the University of California-Irvine and the University of California-San Diego on problems in Earth system science, remote observation, sensor networks and sensor fusion, emergency assessment and response, bioinformatics, and distributed computing and visualization. **Highlight ID: 12691 CISE/CNS**

Improving Grid Reliability With Distributed Energy and Storage

A solar panel installation is one example of an alternative energy source entering the grid as a distributed energy resource. *Credit: © 2009 JupiterImages Corporation*

Current control and protection of wind farms and other forms of distributed energy resources (DERs) render them useless at the times they are most needed. This is because wind farms, fuel cells, and other DERs are automatically switched off by internal controllers to protect them from damage during a disturbance. NSF-supported researchers at the University of Missouri-Rolla, led by Badrul Chowdhury, are developing new technologies and control strategies to improve the power electronics interface required to integrate DERs, including renewables, into the power grid. Use of energy storage devices such as superconducting magnetic energy storage (SMES) or fuel cells can provide higher flexibility to allow DERs to remain online during a disturbance.

As part of the effort, the researchers have developed a control strategy for switching signals of a three-phase inverter using a decoupled active/reactive power control scheme. In studying the response time of a solid oxide fuel cell (SOFC) system to disturbances, simulation results have shown that the response time is improved by 50 percent with the DC/DC converter connected to an SOFC. The response time is further improved by an additional 45–48 percent (i.e., 95–98 percent overall) with the three-phase inverter connected to the SOFC-DC/DC system. The faster response time will help provide faster stabilizing signals to damp the oscillations

caused by system disturbances. Such an operating paradigm can be vital in preventing cascading outages that lead to wide-area blackouts, such as the one in the northeastern United States on August 14, 2003. **Highlight ID: 15233 ENG/ECCS**

Carbon Dioxide Removal: Microscopic Chemical Membrane Versus Cumbersome Gas Plant

Carbon dioxide (CO_2) removal from gases that require refinement prior to use can be an expensive enterprise. After CO_2 removal, certain gases have many commercial uses. For example, CO_2 is removed during hydrogen and ammonia production and in natural gas purification. The current commercial process for the removal of CO_2 from gases involves cumbersome, large-size manufacturing gas plant operations using aqueous amine solutions. This expensive, capital- and energy-intensive process includes the pumping of vast amounts of both loaded and regenerated amine solutions, the consumption of great amounts of energy in heating the loaded amine solution via steam for solution regeneration, and the use of expensive equipment to process the solutions. Furthermore, the thermodynamic equilibrium limits the solubility of CO_2 in the amine solution, which increases the size of the absorber, regenerator, and associated equipment (i.e., a bigger gas plant).

In view of the deficiencies of current gas plants, the Ho Group at Ohio State University is researching and developing an effective process with both capital and energy savings. The Ho Group uses a novel approach through a CO_2-selective membrane. This new approach combines the absorption and stripping of CO_2—which is carried out in two separate steps in the commercial technology—into a one-step membrane process. This one-step process not only simplifies the separation process, but eliminates the expensive equipment used in the commercial technology and results in a smaller environmental footprint. The one-step process also overcomes the thermodynamic solubility limit of aqueous amine solution.

The Ho Group's research uses a novel CO_2-selective membrane approach to overcome many of the deficiencies of the commercial gas-treating technology. This membrane approach will have both significant capital and energy savings. The membranes have many potential applications, including the purification of synthesis gas to produce high-purity hydrogen for fuel cells, CO_2 capture from flue gas for its sequestration, and CO_2 removal from biogas, natural gas, confined space air, and ambient air. **Highlight ID: 12867 ENG/CBET**

International Workshop Explores Bio-Geo Engineering Research Opportunities

The convergence of advances in molecular biology, nanoscience, microbiology, imaging and visualization techniques, and engineering simulation offers an enormous opportunity for geotechnical engineers, together with bio-geo scientists, to provide society with solutions to problems created by rapid global and regional change. These solutions include sustainable approaches to the regeneration of cities, carbon sequestration, rehabilitation of infrastructure, cleanup of brownfields, disposal of hazardous waste, protection of water resources, and maintenance of ecosystems for food. Solutions to these challenges require interdisciplinary research at the interfaces between traditional science and engineering disciplines, including geotechnical engineering, geosciences, microbiology, geochemistry, molecular biology, soil science, and geoenvironmental engineering.

Exploration of this emerging interdisciplinary field occurred in April 2007 at an international workshop jointly funded by NSF and the Engineering and Physical Sciences Research Council of the United Kingdom. Interdisciplinary teams identified applications by considering Earth's subsurface as a living open reactor system whose mechanical, biological, and chemical processes are dynamic and changing. The applications were broadly categorized into the areas of mechanical control of the subsurface, hydraulic control of the subsurface, remediation and waste treatment, energy production and carbon sequestration, and soil-plant interactions. Among the applications identified were microbes cementing loose sand to prevent building collapse during earthquakes; biological and chemical processes to increase soil water retention capacity and plant growth in drought-prone areas; creation

of subsurface containment facilities for clean water, sequestered carbon, and fuel; and national and international initiatives such as Kyoto Targets, Water Framework Directive, and Soil Framework Directive. Fundamental science and engineering research priorities were identified for all application areas, with several priorities having universal relevance. **Highlight ID: 15796 ENG/CMMI**

Climate Changes in a Tribal College

Climate change takes on a whole new meaning at Haskell Indian Nations University, where departmental changes for the better are occurring. The Tribal Colleges and Universities Program (TCUP)-supported program, in an effort to extend beyond mathematics and science, has collaborated with the faculty of Haskell's American Indian Studies program to address educational and societal needs. Last summer, Haskell hosted a symposium on the Impact of Climate Change on Indigenous Peoples. Native environmental professionals from agencies and tribal colleges met to discuss how science and technology might help in planning for the future as the environment changes. Oscar Kawagley, an Alaskan native and professor at the University of Alaska, Fairbanks, described how his village had to move because of sea-level rise. Haskell students assisted at the meetings. Josh Meisel, Jr. made a presentation on sea-level rise. **Highlight ID: 14463 EHR/DGE**

Cultivating the Next Generation of Computer Scientists

Summer Internships in Parallel Computational Science (SIParCS) interns, from left to right: Ryan O'Kuinghttons (Colorado School of Mines, or CSM), Victor Snyder (CSM), Kenny Gruchalla (University of Colorado at Boulder, or CU), Michael Levy (CU), Arunasalam Rahuynanthan (University of Wyoming), Matthew Norman (North Carolina State University), and Robert House (CU). The 2007 inaugural SIParCS program generated publication-quality research, improvements in grid coupling and visualization applications, and collaborative relationships with other research institutions. *Credit: Courtesy Computational and Information Systems Laboratory (CISL), NCAR*

To tackle complex, real-life problems like climate change, we need sophisticated computing and data systems and the people who can run them. Currently, the United States faces a shortage of scientists and engineers trained to use and maintain high-performance computer and data systems. The National Center for Atmospheric Research and its Computing and Information Systems Laboratory are striving to make inroads into this issue. In 2007, the laboratory launched its Summer Internships in Parallel Computational Science program. The program allows students to gain practical experience with a wide variety of parallel computational science problems. The students work with the high-performance computing systems on applications relevant to the center's Earth science mission, while being mentored by computational experts. Seven interns from Colorado, Wyoming, and North Carolina universities participated in the program. **Highlight ID: 15881 GEO/ATM**

Experiencing Climate Change: Assessing Knowledge, Resilience, and Adaptation Among the Viliui Sakha

George Mason University researchers are investigating the resilience of Arctic peoples to changes in their local environments due to global climate change. In particular, they want to see what information the Viliui Sakha—native people in northeastern Siberia—need to gain a more holistic understanding of global climate change to bolster their ability to adapt. Viliui Sakha are native horse and cattle breeders inhabiting the Viliui River regions of northwestern Sakha Republic in Russia. The 3-year, four-village study is a collaborative effort involving the active participation of the targeted communities, field assistants, native specialists, an in-country research team, and an international collaborator. In a 2004 survey of inhabitants of four villages, the principal investigator found that 90 percent of them expressed concern about local climate change, that it was causing unprecedented change in local areas, and that it threatened to undermine subsistence. **Highlight ID: 16486 OPP/ARC**

Synthetic Photosynthesis? Inventing Alternative Sources of Energy

Researchers at the University of Akron are studying the chemistry and physics of photosynthesis via synthetic energy models. This research, funded through the Chemistry Division at the National Science Foundation, will give scientists insight into effective manipulation of light absorption technologies and may lead to more advanced tools for energy conversion from light.

Photosynthesis is an elegant and complex series of efficient, photo-initiated events that involve energy and electron transport over long distances. The net result of these processes is the conversion of light into chemical energy. Investigators use macromolecular systems to manipulate electrons and study mechanisms of energy transfer through light absorption, effectively mimicking photosynthesis.

If successful, this research could lead to new methods of converting solar energy to chemical energy, which can be used to generate electricity. This technology has the potential of providing alternative sources of energy to combat global warming. **Highlight ID: 911 MPS/CHE**

Fighting Pollution, One Molecule at a Time

Chemists at Spellman College, a predominately African-American women's college, have developed and are testing a multidimensional spectrometer to study the structure and behavior of harmful atmospheric molecules. Techniques developed using this tool may increase the accuracy in dynamic models of atmospheric pollution movement.

Atmospheric pollution in the form of nitrogen oxides and halogens has been shown to deplete the ozone and cause respiratory damage to plants and animals. Mainly released from vehicles and industrial production, these pollutants have spread over large parts of Earth and affect the ozone content of the atmosphere worldwide. The structure and behavior of damaging molecules such as bromine (Br_2) and nitrogen dioxide (NO_2) have been difficult to study using conventional forms of spectroscopy. The new technology developed through this NSF-funded project has been shown to effectively image these atmospheric pollutants. **Highlight ID: 14498 MPS/DMS**

South American Climate Change Linked to Fall of Mayan Civilization

Mayan Temple of Inscriptions, Palenque, Mexico. *Credit: © 2009 JupiterImages Corporation*

A project currently under way in the Cariaco Basin of the tropical North Atlantic has produced some interesting results regarding past climate change and its implications. Sediment cores from the Cariaco Basin provide an excellent record of climate change, down to the annual scale, through the use of proxies. These records have been compared with records from Greenland ice cores to determine whether climate change is consistent throughout the low and high latitudes. The Cariaco records show climate shifts analogous to those indicated by the ice core records, including the Younger Dryas cooling event of the North Atlantic. Overall, there is an excellent correlation between the Cariaco and Greenland records, indicating that abrupt climate shifts first identified in Greenland were experienced in the tropics as well. However, there are also differences that may provide clues to the nature of climate forcing. For example, iron and titanium concentrations in the sediment samples are being used as a proxy for changes in regional precipitation and hydrology over northern South America. The results to date suggest that these changes are not clearly linked to high-latitude temperature but are instead responses to the forcing caused by Earth's rotational precession that dominates solar radiation at low latitudes.

The investigators have been able to link their results with the collapse of the Mayan civilization. They were able to achieve multiple measurements from each annual sediment layer and to distinguish annual

wet and dry seasons. Previous studies have suggested that a mega-drought lasting a century caused the end of the Mayan empire, but the detailed records from this study show a series of shorter droughts of 4–9 years, superimposed on the prolonged dry period. The timing of these droughts seems to correlate with recorded abandonments of Mayan settlements. The relationship between the droughts and larger climate change in the region and the termination of a major human civilization is a reminder of how important it is to understand climate change on a regional and global scale. **Highlight ID: 11973 GEO/OCE**

Acquisition of Shipboard Instrumentation by the EAGLE Consortium for Interdisciplinary Geosciences Research and Research Training Aboard *Explorer of the Seas*

Explorer of the Seas represents a unique partnership among academia (University of Miami), the Federal Government (NSF, NOAA, NASA), and private industry (Royal Caribbean Cruise Lines). *Explorer of the Seas*, a passenger cruise ship, was equipped with scientific instrumentation to take oceanic and atmospheric measurements for climate, pollution, and societal research during routine cruises. In addition to collecting data for researchers during cruises, passengers can participate and learn about the ongoing scientific activities through interactive displays in laboratories set up on board the vessel and through lectures given by visiting scientists. Public tours of the atmospheric and oceanographic laboratories draw 200–300 passengers of diverse ages and cultural backgrounds each week. During 2002, visiting scientists made 52 original science presentations on topics such as coral reef fish and health, global warming, El Niño, hurricane research, hydrothermal vents, whales, atmospheric aerosols, and marine archaeology.

The exchange of waters between the tropical Atlantic and the Caribbean influences such things as the formation of the Gulf Stream and the circulation and distribution of planktonic organisms throughout the Caribbean. Using data collected from the instrumentation on board the *Explorer of the Seas*, scientists have learned much about topics such as the impact of atmospheric aerosol mass loads on Earth's solar energy budget and the influence of non-sea-salt sulfate, mineral dust, and sea salt on aerosol properties. At least 27 researchers have used the data collected by the *Explorer of the Seas* for their research.

In 2003, the University of Miami led a pilot undergraduate course focused on data analysis techniques using the *Explorer of the Seas* data set. The course included a weeklong intensive laboratory internship on board the vessel, during which students experimented with salinity calibrations, alkalinity titrations, and plankton sizing using the flowing seawater system. The students presented a summary lecture of their results to passengers. **Highlight ID: 8096 GEO/OCE**

Agricultural Decisionmaking in Indonesia: Integrating Climate Science, Risk Assessment, and Policy Analysis

Indonesia is the world's fourth most populous country, and roughly half of its population is directly involved in agriculture. Changing rainfall patterns resulting from global climate change could have a profound effect on Indonesian farming, particularly rice cultivation. *Credit: © 2009 JupiterImages Corporation*

Rosamond Naylor and a team of colleagues in economics and climate science from Stanford, the University of Washington, and the University of Wisconsin have made significant progress in understanding the effects of climate variability and climate change on Indonesian agriculture. Indonesia is the world's fourth most populous country, and roughly half of its population is directly involved in agricultural production. Such production is very sensitive to short- and long-term changes in rainfall, changes that directly affect the welfare of tens of millions of poor Indonesians.

Through NSF-funded work, Naylor and her colleagues have developed forecasting models that anticipate both year-to-year changes in

Indonesian rainfall (related to El Niño events in the Pacific) and longer term changes in rainfall under conditions of global warming. The team then links these changes to agricultural decisionmaking in Indonesia. The findings suggest that changes in the timing of the monsoon rains explain much of the observed variation in agricultural productivity, and that these rains will come later and later as the planet warms—with negative implications for poor farmers in Indonesia's main rice-growing regions, Java and Bali.

The team's models are now being used by policymakers in the Indonesian Ministry of Agriculture to anticipate immediate and potential future needs with respect to the agricultural sector. Under a new NSF grant, this work is being replicated and extended in China, with the hope of aiding hundreds of millions of Chinese farmers who are facing similar climate fluctuations. The scientific research in China will be incorporated into the policymaking process via colleagues at the Chinese Center for Agricultural Policy and the Center for Global Forecasting at the Chinese Academy of Sciences. **Highlight ID: 13579 SBE/SES**

Teaching Teachers About Climate Change

The development of the Global Climate Change Teacher Institute by Kurt Pregitzer of the Michigan Technological University has resulted in the training of dozens of middle and high school teachers from around the country in physical, chemical, and biological research on global change. Pregitzer's NSF-funded research is showing how continual, long-term atmospheric nitrogen deposition affects nitrogen and carbon cycling in northern hardwood forests. Throughout his project, Pregitzer has made efforts to increase the involvement of teachers and students in science. Every summer, the weeklong Teacher Institute brings teachers to the field sites and laboratories connected to Pregitzer's project. There, teachers learn about the impact of elevated carbon dioxide and ozone levels, nitrogen saturation, acid rain, and invasive species on forest ecosystems while earning graduate course credit. By the end of this intensive week, each teacher develops a "citizen science" project that he or she can use in the classroom. The Teacher Institute multiplies the impact of the instruction by providing teachers with educational tools they can use in the classroom and equips the teachers with the knowledge and confidence to seek out further research opportunities between their classes and professional scientists. For instance, one teacher used her experience at the course to develop a collaborative project with a government agency to test acid deposition around a local power plant. Pregitzer's course has received national attention—both the U.S. Forest Service and the National Park Service are looking at ways to develop programs similar to the Global Climate Change Teacher Institute around the country. **Highlight ID: 13518 BIO/DEB**

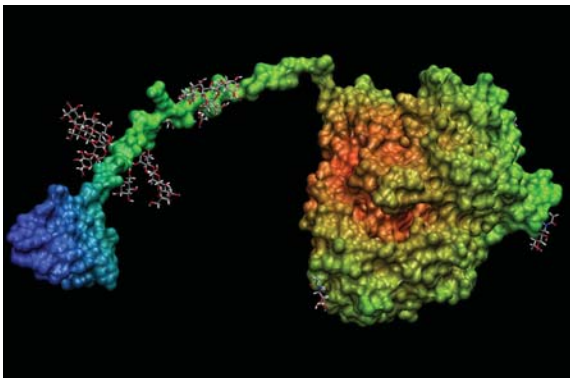
Workshop to Spur U.S.-China Cooperation in Bioenergy Development

As the top two countries in carbon dioxide emissions, China and the United States have a unique opportunity to develop solutions to pressing energy and environmental problems. Researchers at the Institute for a Secure and Sustainable Environment (ISSE) at the University of Tennessee-Knoxville (UTK), together with Chinese partners at the Institute of Geographical Sciences and Natural Resources Research (IGSNRR), Chinese Academy of Sciences convened a fall 2008 workshop focused on the multidisciplinary themes of sustainable production of bioenergy crops, land-use change, carbon sequestration, water resources, and ecological restoration. The joint workshop is expected to catalyze new research on critical U.S.-China topics important for meeting global energy demand and protecting the environment. Participants discussed ecosystem processes and management, environmental sustainability of bioenergy production, and ecological foundations of water resources. An important outcome expected from this meeting is planning for testing and development of new technologies that mitigate the negative impact on eco-environmental systems. The meeting allowed five U.S. graduate students to explore the issues and develop research relationships that may help drive future U.S.-China research priorities. In addition to research, the workshop is expected to spur the establishment of a mechanism to bring students and junior researchers into cross-cultural, international research addressing bioenergy and environmental change. **Highlight ID: 14956 OD/OISE**

Computational Sustainability: Computational Methods for a Sustainable Environment, Economy, and Society

Balancing environmental, economic, and societal needs for a sustainable future encompasses problems of unprecedented size and complexity. With naturally occurring settings, global scale, dynamic and uncertain behavior, a mixture of discrete and continuous effects, and highly interactive components, problems associated with sustaining Earth's resources can greatly benefit from computational methods and thinking. There is a key role to be played by computing and information sciences in increasing the efficiency and effectiveness of the way humanity manages and allocates natural resources. This project aims to establish and nurture a new field of study—computational sustainability—driven by a wide range of hard computational problems and critical challenges in the area of sustainability. The applied theoretical expedition will pursue interdisciplinary research across three computational sustainability themes: conservation and biodiversity; balancing socioeconomic demands and the environment; and renewable energy. With the view that natural problems may have a special structure discoverable by machine learning techniques that allow them to be solved, this research attempts to stimulate synergies that cross boundaries and merge ideas from combinatorial optimization, dynamical systems, machine learning, and constraint reasoning. An Institute for Computational Sustainability, based at Cornell University, will be the nexus of foundational science advancements and practical applications in sustainability. Part of its mission is to establish a vibrant and diverse research community in the area of computational sustainability, drawing new students into the field from all backgrounds, including students from underrepresented groups, via summer research experiences and other proactive activities. **Press Release 08-141 CISE**

Improving Biomass Conversion to Ethanol for Renewable Energy



To improve the conversion of biomass into ethanol, NREL researchers simulated the action of the enzyme cellulase on cellulose using the CHARMM community code. The binding domain is on the left in blue, the glycosylated linker in green, and the catalyst domain on the left in orange and yellow. *Credit: James Matthews, Linghao Zhong and John Brady, Cornell University; Mike Himmel and Mark Nimlos, NREL; Tauna Rignall, Colorado School of Mines; Mike Crowley, The Scripps Research Institute*

The National Renewable Energy Laboratory (NREL) is striving to develop the efficient large-scale conversion of biomass into ethanol to provide a clean-burning and renewable fuel source. This will reduce dependence on fossil fuels and imported oil, and protect the climate. A key bottleneck in making this process economically viable is the slow breakdown of cellulose by the enzyme cellulase; scientists want to understand this process at the molecular level so they can target further research to speed up the reaction.

To explore the intricate molecular dynamics of this process, the researchers have used the CHARMM (Chemistry at Harvard Molecular Mechanics) code, a versatile community code for simulating biological reactions. However, the size of the simulations needed is so large (more than a million atoms) and the simulation times so long (more than 5,000 time steps for a 10 or more nanosecond simulation) that they exceed the current capabilities of CHARMM.

Researchers at the San Diego Supercomputer Center (SDSC) are working with colleagues at NREL, Cornell, the Scripps Research Institute, and the Colorado School of Mines to enhance CHARMM so that the simulations can scale up to millions of atoms and run on hundreds of processors on the largest supercomputers, including SDSC's DataStar and the TeraGrid. This will make it feasible to simulate this key reaction. The research is enabling the largest simulations ever of an important scientific problem that will yield economic and environmental benefits. In addition, the improvements to the CHARMM code will be available for the scientific community to apply to a wide range of other problems. **Highlight ID: 10859, Version: AC/GPA**

Antarctic Penguins: Teaching the Science of Climate Change

Adélie penguins resting on an iceflow in front of the Mt. Bird Ice Cap. Mt. Bird is one of four volcanoes that together have formed Ross Island. The retreating Ice Cap left Cape Bird bare and covered with moraines beginning about 7,000 years ago, the oldest age of penguin remains found there. The penguins make nests of the pebbles left by the glacier. *Credit: Melanie Massaro, School of Biological Sciences, University of Canterbury*

An NSF-funded effort to translate the Adélie penguin "Bellwether of Climate Change" research to the K–12 community has produced tangible results. More than 9,000 individual, kid-designed postcards showing children's love and concern for penguins have been received from 450 K–8 classrooms in 30 states. Many postcards contained questions and indicated classroom connections to the project. Each was answered and sent back, stamped from Antarctica.

The interactive Web site (www.penguinscience.com) was expected to reach a million hits by January 2008. It offers a daily look into the process by which penguins raise their chicks. Six nests are showcased to offer students a chance to collect data and keep their own field journals. Banded adults allow children to record which parent is on the nest, how long it takes the egg(s) to hatch, and how much each mate has contributed to the effort, as well as weather conditions and their effects. The children can follow the transformation of chicks from fluff balls to strapping fledglings ready to take on the sea. The Web site also contains information geared toward teachers about global climate change and how penguins are coping with the changes in their environment.

The message is reaching a broad audience. This classroom-ready material, which complements a DVD, provides teachers with quality lesson plans, pictures, graphics, and activities about penguins, the polar regions, and global climate change, as well as a feature showing how scientists work. An educational DVD targeting grades 4–8 was produced and distributed through the Web site and at teachers' workshops in major cities around the country. An embellished version of the DVD aired on national television (Animal Planet) in March 2008. **Highlight ID: 14971**