IOWA WATCH

THE CENTER FOR GLOBAL AND REGIONAL ENVIRONMENTAL RESEARCH

FALL 2007

Gazing into the Future

Dealing with nature's complexities has always pushed scientists and engineers to search for new paradigms and tools to advance their understanding. In recent years, researchers in multiple disciplines have been working to create computer-based models of large-scale natural processes that are predictive of future events. The creation of such models depends on understanding processes in small areas in great detail, so that data can be accurately extrapolated to large landscapes. Doing so is the vision of a major NSF (National Science Foundation) initiative to establish a series of national centers that focus on Earth's natural elements and ecosystems. These digital field observatories, if they materialize, could thrust science and education in new directions. CGRER's members have been especially active in efforts to establish a center that focuses on water-related processes in natural and disturbed landscapes.

To understand this concept in more detail, travel back to around 2000, when a nationwide group of research hydrologists – scientists and engineers who study the flow of water as it cycles above, over, and underneath Earth's surface – met to discuss mechanisms for pushing their research initiatives forward. Other areas of environmental research were reaching new limits through well-funded centers that promoted integration of research projects and provided the instruments and computerized information systems to complete them. What could be done to provide similar amenities for the study of water? Would a single well-funded research entity be better able to address the complex research questions the hydrologists were voicing?

The hydrology researchers were not alone in their search for answers. Around this time, a number of converging features were creating unprecedented challenges for studies of Earth's environment. New technologies – more capable instruments for recording data, and computers for processing and modeling data – were collecting growing amounts of information, but did not have the ability to create predictive analogues that could be applied across broad landscapes. Simultaneously, new environmental problems were emerging, and their acknowledgement revealed that even more data, as well as new types of data, were needed. Looking into the future, environmental problems were sure to intensify as continued growth of the human population, resource consumption, and pollution

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This issue of IoWatch focuses on efforts to establish National Environmental Observatory Networks.

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pushed Earth's systems and processes to new limits. The 21st century became labeled as "the water century" – a period when the availability of water (or lack thereof) would determine social and political stability. All of these physical parameters were converging, and societal pressures were demanding more accountability from the scientific community.

The passions of the hydrologists and other researchers reached the ear of the NSF, which agreed to consider funding a set of National Environmental Observatory Networks, centers that would investigate a stated portion of the natural environment. Several such observatories are now in the planning stages – for example NEON (the National Ecological Observatory Network), GEON (the Geosciences Network), and OOI (the Ocean Research Interactive Observatory Network). Each will involve a different set of research disciplines and research questions. In 2001, innovative hydrologists formed a group called CUAHSI (the Consortium of Universities for Advancement of Hydrologic Science) to focus on the study of water's flow. The following year, a group of environmental engineers concerned with water quality and the nation's drinking water and wastewater infrastructure formed CLEANER (the Collaborative Large-Scale Engineering Network and Environmental Research project) and also initiated discussions about creating a national observatory. In 2005, NSF encouraged the CUAHSI and CLEANER communities to join their efforts within a single entity, and in 2006 WATERS (the Water and Environmental Research Systems Network) was created from the merger. This entity is now working on developing a ten year, $300 million grant proposal, to be submitted in 2009 for funding in 2012, for the construction of a national environmental observatory network focusing on water quality and quantity.

The proposed NSF-funded observatory network will be an integrated, real-time, distributed observing system that will promote the understanding of human interactions with water and the natural and built environment. This will enable academic and government scientists, engineers, educators, and practitioners to advance effective management of our nation's water resources. A mission of this magnitude and breadth is not created overnight. Years of multi-institutional discussions and field tests are required to determine if such a broad-spanning observatory network is possible.

From the beginning, CGRER members have been involved in conceptualizing the observatory. Keri Hornbuckle, for example, has served on CLEANER's Engineering Science subcommittee. Witold Krajewski was one of the founding university representatives of CUAHSI and today remains the University of Iowa's representative to the consortium. In 2003, he was on a CUAHSI team to design a "paper observatory" on North Carolina's Neuse River, a planning project that provided the initial prototype of an integrated hydrologic observatory. And Jerry Schnoor was instrumental in CLEANER's formation and subsequent discussions. In 2003, he received an NSF planning grant for regional water quality planning on the Upper Mississippi River. In 2005 Schnoor and colleagues received an NSF planning grant to fund a CLEANER Project Office, followed by a 2007 planning grant for the WATERS Project Office. Schnoor also received an Iowa Water Center grant in 2005 to begin real-time sensing of water quality in the Iowa River Basin, an effort that he has folded into the Clear Creek observatory efforts described below.

The results of efforts such as these, carried out by dozens of researchers across the nation, have produced the following conceptual plan: WATERS will be a digitally interconnected network of well-instrumented observing stations, collectively representing all of the nation's major watersheds. Each observatory in the network will record data on all features affecting a given site's water-flow and quality within a given region. For example, these stations might measure and record information on landuse features, sediment runoff, and details of precipitation. The data collected will be sufficient and high enough in resolution to validate models and, in future years, to predict events such as flood frequency, stream turbidity, and the arrival of nitrate plumes. Data and modeling results will be distributed freely on a continuous basis – that is, information will be fed from unmanned field instruments into computer systems that could be accessed remotely by others. Model results will be available at various levels of expertise to scientists, the general public, managers, public officials, educators, and any other interested party. Information thus can be used for multiple purposes that improve the understanding of water's processes and uses, as well as water's governance and public education. One hopeful result will be ensuring the adequacy of water for human use without forfeiting the integrity of aquatic ecosystems. Eventually the establishment of observatory networks around the globe would safeguard natural resources and nature's support systems worldwide.

Needless to say, this grand vision has not been executed anywhere on Earth at this time. One of the first steps to bring it to reality will be to design, construct, and test small prototype observatories, a process that commenced even before WATERS was formed. Here again CGRER members have been in the forefront. In 2003, several University of Iowa researchers started to meet regularly to discuss the creation and operation of a prototype "digital observatory," a watershed-based field site with abundant embedded digital sensing technologies. In 2006, the same year that WATERS came into being, a University of Iowa team – Craig Just, Marian Muste, and Anton Kruger – was awarded an NSF grant to build a "test bed" observatory and began to do so in the Clear Creek watershed just northwest of Iowa City.

This prototype test bed has become the focus of several CGRER members, all of whom are research engineers at the UI's IIHR-Hydroscience & Engineering which, from the start, also has participated in the water-focused observatory planning process and has provided seed funds for establishing the test bed. Each Clear Creek researcher is looking at one aspect of the larger whole. Thanos Papanicolaou, for example, will do detailed studies involving erosion processes, water infiltration, carbon cycling, corn production for biofuels, and watershed models. Jerry Schnoor and Craig Just will establish a sensor network for real-time instream measurements of turbidity, phos-

Graduate student JV Loperfido, sampling in the WATERS Clear Creek test bed, inspects an in-stream water quality monitor that operates unattended for weeks at a time.

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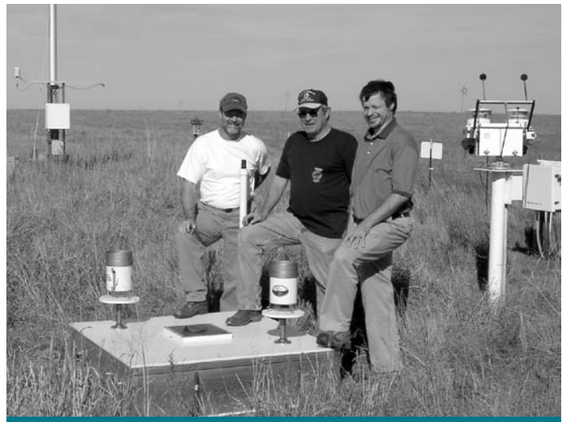
phorus, and nitrates. Witold Krajewski will use remote sensors to collect rainfall measurements. Marian Muste will be working on creating a computer-based information system ("platform") to integrate the multiple types of data that are collected. Anton Kruger will explore new, low-energy-consuming wireless communications for real-time data transmittal and sensor programming. And Larry Weber will help by facilitating the planning of the Clear Creek studies and educational activities.

The WATERS network's ultimate goal is to embed small observatories such as Clear Creek within regional observatories, the combination forming a network of field facilities that will enable modeling of the entire nation. In anticipation of this effort, Marian Muste in collaboration with IIHR and the UI's Obermann Center organized and held the UMBRO (Upper Mississippi River Basin Observatory) International Planning and Design Workshop in Iowa City in July, 2007. This workshop aimed at catalyzing the collaborative network necessary for formation of UMBRO.

At this time, NSF has funded eleven test bed sites such as the Clear Creek observatory. At each test bed site, researchers are designing and testing the WATERS national observatory concept. The central tenet behind these test beds is *integration* – a concept that is crucial to the success of WATERS and the other proposed national observatory networks. Integration must occur at all levels: integration of people and disciplines as well as observational tools, information technologies, and analytical processes. Experimentalists and theorists from multiple disciplines and institutions will need to commit to working together toward a stated end within a given watershed basin, there carrying out comprehensive and complementary long-term observations that would draw on their varied skills. Only through thus integrating the skills of many can such a massive, complex, and difficult effort be successful. Only through integration can WATERS hope to fulfill its expressed grand vision statement:

"The WATERS Network will transform our scientific understanding of Earth's water and related biogeochemical cycles and human water use. Networked sensors, assimilation of high-frequency data and interdisciplinary experimentation will enable forecasting and management of critical water processes affecting and affected by human activities across multiple spatial and temporal scales. The WATERS Network will revolutionize the way we perform research and how we educate future scientists across disciplines, and it will improve the public's understanding and concern for the dynamic water cycle. (http://www.watersnet.org/index.html)"



Anton Kruger, Dan Nelson, and Craig Webb installing hydrological observatory field equipment in Kansas.

Considerable effort, expertise, and financial investment will be required to execute this grand vision. The final product, whatever that may be, will result from the synthesis of thousands of smaller efforts. The many research activities of Witold Krajewski and his IIHR colleagues are observatory-directed. Already before the formation of CUAHSI, Krajewski had proposed a well instrumented, networked hydrology field observatory, the Iowa Hydrologic and Environmental Validation Site. While this was never created, in 2005, Krajewski helped implement a multi-institutional hydrological observatory in Kansas ("Hydro-Kansas") to test the scaling of flood and riparian evapotranspiration data from small watersheds to large. Another current NSF grant is funding the creation of software that will increase the use of NEXRAD weather data. This software is already being tested in certain of the

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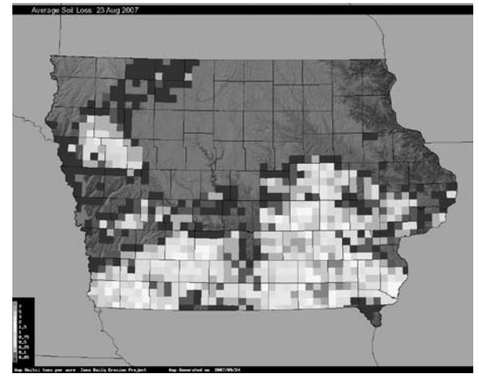
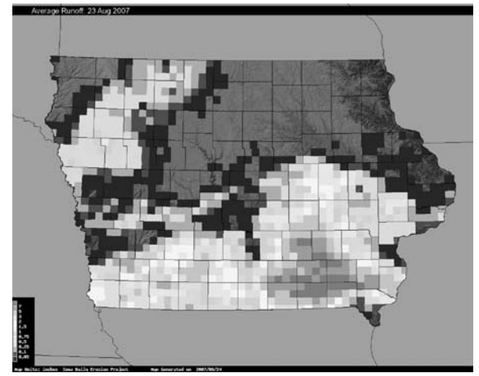
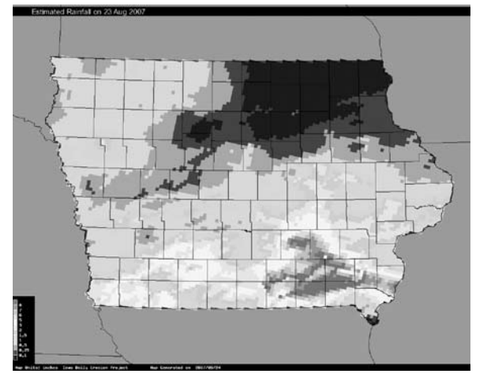
National observatories could eventually provide real-time readouts about multiple aspects of the natural world, thus allowing a new way of viewing and understanding environmental processes. An elementary version of one such readout is the Iowa Daily Erosion Project, which enables a web user to pull up maps of Iowa's rainfall, runoff, soil moisture, and soil loss for a given 24-hour period. Information for the rainfall aspect of the project's numerical model was provided by CGRER's Witold Krajewski. Check out these maps at <wepp.mesonet.agron.iastate.edu/>.



Average Soil Loss*



Average Runoff*



Estimated Rainfall*

* From 8/23/07

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WATERS test bed observatory sites. And with ISU CGRER member Brian Hornbuckle, Krajewski and UI colleagues Bill Eichinger and Anton Kruger have established a small field observatory for the remote microwave sensing of soil moisture. This year Krajewski's research group received a major NSF grant to acquire a set of four unique networked radar units that will operate essentially as a single unit to yield especially high resolution precipitation data. These mobile units will be stationed at the Clear Creek test bed, but can be easily transported to other research sites.

Today, national environmental observatories constitute a vision and a goal. CGRER members and other researchers across the country, fed by promises of commitment and funding from the federal government, are taking concrete steps toward establishing such observatories. What will become of this movement in the next few decades? Will national environmental observatories transition from concept to reality? One thing is certain: new and growing environmental stresses are sure to provide fodder for limitless research. Nearly as certain will be the continued development of instrumentation, information technologies, and other tools that could feed into environmental observatories.

The WATERS Network will transform our scientific understanding of Earth's water and related biogeochemical cycles and human water use. Networked sensors, assimilation of high-frequency data and interdisciplinary experimentation will enable forecasting and management of critical water processes affecting and affected by human activities across multiple spatial and temporal scales.

But will knowledgeable scientists and engineers work together to form the integrative teamwork required to develop the necessary large-scale predictive models? Will long-term funding for such efforts continue? And will nature's complexities submit to being defined and deciphered as researchers now hope? These questions remain unanswered. Some scientists state that national observatories remain the indisputable wave of the future – that only with such large-scale collaboration can the complex web of life-supporting processes and species be understood and supported through human actions. Others who remain reluctant to commit are standing back, watching, and waiting.

At this time, WATERS (and other proposed national observatories) offer an invitation as well as a grand vision. They offer a pathway into a murky future. Will the pathway be followed? And if not, what alternatives will open themselves to a planet in stress, littered with challenged societies and growing populations, all seeking the water and other amenities they need to survive? CGRER remains committed to helping answer these difficult questions.

This article was based in part on the following websites, each of which can be consulted for more information on its respective program:
http://cleaner.ncsa.uiuc.edu
www.cuashi.org
http://www.watersnet.org/index.html

SEEDS

In 2007, CGRER funded five new seed grants for the coming fiscal year, for a total of $148,230. Each seed grant is preliminary to submission of a larger proposal to outside funding sources.

Optimization of Environmental and Economic Benefits of Corn Harvesting for Biofuel Production

Amy Kaleita (ISU, Agricultural and Biosystems Engineering) with **James K. Newman** (ISU, Environmental Sciences), $30,000.

Biofuels are seen as economic windfalls for Iowa. While corn-based biofuels currently are made from the corn kernels, methods for converting lignin-containing plant materials (such as corn stalks and leaves) into ethanol are being developed. However, the removal of corn residues from cropland significantly increases the risk of soil erosion – one of several potential environmental costs related to biofuel production. How do biofuel's immediate economic benefits balance with such long-term environmental costs and the land's sustainability? This grant proposes to create a numerical model that will produce a county-by-county "erosion risk map" that would estimate soil loss at different rates of corn residue harvest. This model also would be available to individual farmers, who could use it to calculate biofuel-related erosion losses on a more detailed level. The model should help inform the state's biofuel dialogue about how, and how much, ethanol production can be carried out without significantly compromising environmental safeguards.

The Effect of Harvesting Trees, Shrubs, and Native Grasses on Soil Carbon Sequestration and Greenhouse Gas Flux in Riparian Buffers Designed to Provide Biomass for Biofuel Production

Richard Schultz and **Thomas Isenhart** (ISU, Natural Resource Ecology and Management), $29,280.

In addition to multiple other benefits, riparian buffer strip plantings concentrate nitrogen fertilizers and carbon in their living and dead plant parts. Because they sequester more carbon and nitrogen than they release, buffers help control the greenhouse gases carbon dioxide, nitrous oxide, and methane. By supplying carbon to the microbes in the soil ecosystem, riparian buffers stimulate the denitrification process which converts excess nitrogen fertilizer to harmless nitrogen gas. Buffer strip plants are now being considered as a cellulosic biofuel feedstock. This use would increase the frequency of harvesting and accelerate decomposition in the buffers. Such changes may shift the release of harmless nitrogen gasses to higher proportions of potent nitrous oxide. This project will compare the release of the various forms of nitrogen gas (as well as carbon dioxide and methane) from undisturbed riparian buffer strips with that of harvested sites, and thus will assess the ramifications of biofuel production before such harvests commence.

Inter-Calibration of Global Remotely Sensed Vegetation Measures

Marc Linderman (UI, Geography), **Kate Cowles** and **Dale Zimmerman** (UI, Statistics and Actuarial Science), $29,950.

Numerical models of vegetation, hydrology, climate and other environmental features and processes rely in part on data collected remotely by satellites. Data sets of nearly 30 years duration are available, but recent design advances have improved sensors that collect information on the spectral and thermal characteristics of Earth's surface. Although previous data sets continue to provide valuable long-term records, improving the compatibility of earlier data sets and more recent data collected with the improved sensors would provide more robust analysis of the Earth's surface features. This project will attempt to provide such improved compatibility by using current, high-quality satellite data to correct earlier, less reliable data sets. If successful, the improved long-term data set will better assess trends in our planet's vegetational activity, and will provide better baseline information for today's more precise studies of changes in agriculture, land cover, climate, and other Earth systems.

Heterogeneous Photochemistry of Atmospheric Aerosol

Vicki H. Grassian and **Mark A. Young** (UI, Chemistry), $29,000.

For nearly a decade, Vicki Grassian and collaborators have been working with heterogeneous atmospheric chemistry – that is, the chemical interplay between atmospheric particles and trace atmospheric gases. She has investigated how these interactions are significant in altering the troposphere's chemical balances, a feature important to the modeling of changing climate. Now she and Mark Young will extend that research into a new area, incorporating the effects of sunlight and asking the question, "What influence does heterogeneous *photo*chemistry play in atmospheric chemistry?" They will look at organic material of biological origin (e.g. from soil) as well as organic- and nitrate-coated particles, and measure light-induced changes in the particles and key trace gas species, changes that also could be important to climate and climate models. This seed grant will initiate that research by funding the renovation of the atmospheric reaction chamber so it can provide and characterize the "sunlight" necessary to the experiments.

Observational and Modeling Studies of Rainfall Interception by Corn Plants

Witold F. Krajewski (UI, IIHR-Hydroscience & Engineering and Department of Civil and Environmental Engineering), $30,000.

Numerical models are continuing to increase our scientific understanding of the hydrological cycle. However, variations in the earth's surface cover and roughness and other variables continue to confound measurements and models. This project addresses one such variable: Interception of rainfall by corn, a process that is not well understood and is thought to be underestimated in importance. Corn provides significant storage for water when integrated over Iowa's vast fields of rowcrops. This storage modifies rainfall-runoff processes and the exchange of water mass and energy between land surface processes and the atmosphere through evaporation. The project will study the interception of rainfall by corn plants using in-house developed sensor systems. The CGRER seed grant will fund the development of the observational system and demonstrate its usefulness in the field – efforts that are necessary prerequisites to subsequent field-sampling experiments and the development of mathematical models of the rainfall interception process.

Newcomers

CGRER has welcomed five new members in the past year:

Craig Just received undergraduate and masters degrees in chemistry from the University of Northern Iowa and a doctorate from the UI's Dept. of Civil and Environmental Engineering - Environmental Science track. He now is an associate research engineer at IIHR-Hydroscience & Engineering. His joint expertise in chemistry and engineering allows him to fill many roles. With Keri Hornbuckle, he oversees chemical analyses for a large study of PCBs in the environment and living tissues. He is setting up water-pollution sensor clusters and simple water-quality models for the Clear Creek watershed (see "Gazing Into the Future"). He also enjoys "taking students to underdeveloped countries and opening their eyes" – something he does regularly as faculty advisor for the UI's student chapter of Engineers for a Sustainable World. Craig explains his CGRER membership as a response to students who have challenged him to expand his knowledge of climate change and other large-scale environmental issues. He trusts that CGRER will help educate him about these issues so that he can better educate students.

After completing medical school and a residency, **Joel Kline** came to Iowa in 1990 for training in pulmonary medicine. He later joined the faculty, and he is currently a Professor of Medicine and Environmental and Occupational Health. He investigates the causes and treatment of airway inflammation, especially those related to environmental contaminants. He leads the UI Asthma Center and is Deputy Director of the Environmental Health Sciences Research Center, there supporting translational research regarding the impact of environmental exposures on human disease. Joel notes that the lung is the body's largest surface area exposed to the environment, and that asthma (which is now rising in prevalence and severity) is linked to environmental exposures. Thus, he has been increasingly drawn into the interaction between environmental factors and health. Joel hopes that his membership will help increase CGRER's focus on the human health aspects of climate and environmental changes, and also that he will enhance his understanding of the impact of these changes on asthma and other disorders.

Marian Muste received a civil engineering degree in Romania, his homeland, and then taught there for a decade. In 1991, he came to the UI for masters and doctoral degrees in Civil and Environmental Engineering. He performed his research at IIHR-Hydroscience & Engineering, where he has been employed as a research engineer since 1997. His research focuses on developing instrumentation and data acquisition systems for better understanding river hydraulics and watershed processes. He also evaluates the capabilities and uncertainty of acoustic and image-based field instruments. Most recently, he has worked on developing computer-based geo-temporal data bases for storing and handling data from multiple sources and disciplines. These data bases will be the centerpiece of the information systems for WATERS and other eco-hydrologic observatories (see "Gazing into the Future"). Marian trusts that his CGRER membership will nurture the collaboration that is crucial for developing multidisciplinary field observatories, which he feels will certainly dominate future research.

Newcomers *(continued)*

Geb Thomas received graduate degrees in industrial engineering from Penn State. He joined the UI's Mechanical and Industrial Engineering faculty in 1997, bringing with him an uncommon interest: development of robotic systems for planetary exploration. His NASA-funded projects allow him to consider the interactions between humans and robots. More specifically, Geb develops interfaces and information systems that translate what research scientists want, and how they think, into robotic responses that collect the best possible scientific data. The pleasures of his research include testing robots in remote locations that resemble extra-planetary terrain, such as Chilean deserts and Icelandic rubble fields. Geb joined CGRER in part because of discussions with Keri Hornbuckle about developing information systems and robots to aid in studies of PCB-contaminated sites. Future interactions with other CGRER members could involve using robots for carrying out remote scientific explorations of other hazardous and dangerous environments.

In 1984, **Larry Weber** left the family farm near Dyersville to attend the UI. He did not realize then that he had come to stay. He earned undergraduate and graduate degrees in Civil and Environmental Engineering and now is a member of the CEE faculty. He also serves as director of IIHR-Hydroscience & Engineering. Larry's research focuses on coupling models of hydrodynamic and ecological systems and applying these models to river restoration and fish passage past structures such as dams. Most of his projects have addressed migrating salmon in the Pacific Northwest, where he and his colleagues have developed predictive models for determining the salmons' behavioral response to their local fluid environment. He also studies fish passage and ecological restoration in the backwaters of the Upper Mississippi River basin. Larry says that joining CGRER has formalized the close relationship he has held with CGRER members for several years. He hopes that his membership will allow him to expand the IIHR's role at the state level.

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IOWA WATCH

THE CENTER FOR GLOBAL AND REGIONAL ENVIRONMENTAL RESEARCH

The University of Iowa's Center for Global and Regional Environmental Research (CGRER) promotes interdisciplinary efforts that focus on the multiple aspects of global environmental change, including its regional effects on natural ecosystems, environments, and resources, and on human health, culture, and social systems. Center membership is composed of interested faculty members at any of Iowa's colleges and universities.

Center goals are promoted by encouraging interdisciplinary research and dialogue among individuals whose disciplines touch upon any of the multifaceted aspects of global change. More specifically, the Center awards seed grants, fosters interdisciplinary courses, provides state-of-the-art research facilities and equipment, and holds seminars and symposia. The Center encourages students to broaden their studies and research through considering the multidisciplinary aspects of global and regional environmental problems. Through such activities, the Center attempts to assist Iowa's agencies, industries, and citizens as they prepare for accelerated environmental change that may accompany modern technologies.

Housed in the Iowa Advanced Technology Laboratory at the University of Iowa, the Center was established by the State Board of Regents in 1990 and received funding from a public utility trust fund, as mandated by the State of Iowa's Energy Efficiency Act.

IoWatch is published each fall. Comments, questions, and requests for additional copies should be directed to:

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