IOWA WATCH
THE CENTER FOR GLOBAL AND REGIONAL ENVIRONMENTAL RESEARCH
FALL 2004

Blowing in the Wind

From the time our progenitors swung down from trees and strode away across Africa's savannas, the human story has been inextricably linked to climate. While these links must always have been sensed, explanations of weather's frightful extremes and its graceful nurture of life remained shrouded in mystery, explained only through superstition, folklore, and myth. Individuals remained captive to their personal or cultural interpretations of weather systems.

Then suddenly in the 17th century the situation changed. The invention of three simple instruments – the thermometer, barometer, and hygrometer – opened the door for studying the physics of the atmosphere and deciphering its structure. Research networks were established to apply these instruments simultaneously in multiple locations. By the late 1700s, an international observational network stretched around the northern hemisphere, leading to the creation of the weather map in 1816.

This summer another international network executed the world's largest air quality experiment, the first coordinated international campaign to establish benchmark atmospheric readings.

In the U.S. and Canada, atmospheric scientists from several governmental agencies and a dozen universities joined forces to investigate gases and polluting aerosols that are pulled around the globe by weather systems. Major project goals included characterizing and quantifying air pollutants and identifying their sources, chemical transformation, intercontinental transport, radiative effects, and global impact on climate. European atmospheric scientists simultaneously carried out parallel investigations.

This experiment's sophisticated air-sampling instruments, which measured concentrations down to parts per trillion, were mounted in satellites, balloons, and research aircraft and ships. Real-time data were fed into numerical models that tracked the movement of specific air pollutants and guided additional data collection. CGRER contributed to the process by helping predict the course and speed of specific pollutants, and thus guiding flight patterns and data collection locations of research aircraft. Greg Carmichael and his research group applied their STEM – 2K3 numerical model to execute "chemical weather forecasting." This model predicted the placement of polluted air four days in advance

(continued next page)

This issue of IoWatch considers studies of our atmosphere's functions and character.

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and thus guided real-time data collection. Participating in the project meant that Carmichael, CGRER research scientist Youhua Tang, and their Iowa colleagues spent nearly two months in mission flight centers in St. Louis, MO, and Portsmouth, NH, there interacting with several dozen other scientists and flight crews and applying their model.

While scientists in Europe were focusing on identifying pollutants blown across the Atlantic from the U.S., North American scientists concentrated on gathering data along our East Coast, which catches air pollution from the western U.S. Special emphasis was placed on New England's air quality. However the tracking of massive eastward-moving pollutant plumes required the aircraft to collect data over much of the continent. Thus the CGRER researchers were able to apply their models for the first time to their home state.

These Iowa observations revealed several unexpected results. For example, smoke and particulate matter from Alaska's and Canada's distant forest fires were seen high above Iowa. And Asian-generated pollution plumes were seen hovering over the state. Asia's ozone had previously been known to affect the U.S. only during the spring, when ambient ozone levels are usually not problematic. Its arrival in summer, when U.S.-generated ozone is at its peak, may present major setbacks to efforts attempting to hold regional summertime ozone concentrations at safe levels. Additional arrivals from Asia included high carbon monoxide levels and possibly atmospheric chemicals now banned in the U.S. such as certain halogens.

Although most of Iowa's weather arrives from the west, occasional easterly winds were seen blowing Chicago's smog across Illinois and into our state. CGRER researchers observed that Iowa also contributes air pollutants to Illinois and beyond: high levels of ammonia from Iowa's agricultural operations play a key role in formation of problematic, but widely dispersed, atmospheric particulates.

These several observations exemplified Iowa's complex atmospheric interconnections with regions near and far. Air quality problems generated far away are indeed affecting us here in the Heartland – even when we have no idea that they may be doing so, and even as we are affecting others distant from us.

In centuries past, predicting weather into the future was impossible in part because data collected at multiple sites could not be readily transmitted. The creation of the first telegraph system in the mid-1800s changed all that. Suddenly a wealth of data could be rapidly compiled and statistically analyzed. Climate "laws" could be identified, and meteorologists could produce daily maps that permitted weather forecasts.

By early in the 20th century, researchers were attempting to meld data with theory to express the atmosphere's dynamics mathematically and thus calculate future weather more accurately. Following World War II, one of the world's first electronic computers was applied to meteorological problems, and in 1950, the first computerized simulation of weather was produced. Numerical forecasting immediately thrust meteorology into a new era.

Greg Carmichael has been tracking atmospheric chemicals around the globe and developing numerical models of their journeys since he was a graduate student in the 1970s. At that time he created one of the first regional-scale numerical models for acid

Weather Through the Years

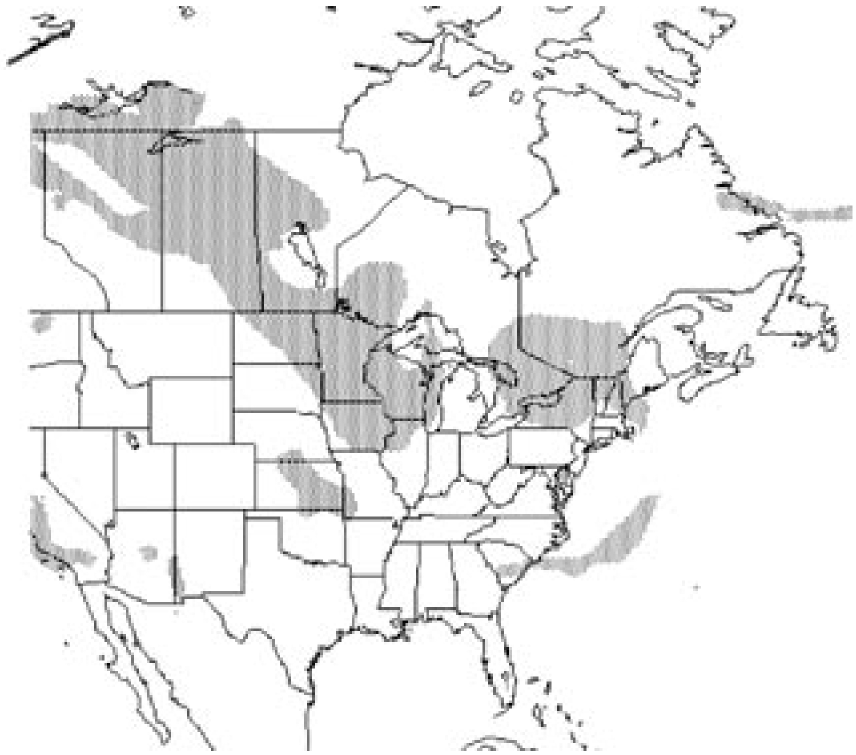
1641
Sealed-tube thermometer invented

1643
Mercury barometer invented

rain. This work expanded to include regional perspectives on ozone and fine particulates. For example in the mid-1980s he helped establish that high ozone values in Japan's Alps resulted from long-range transport of precursors emitted in Tokyo.

By 1990, when CGRER was formed, Carmichael had established studies of Asia's greenhouse gases and air pollutants, which were rising rapidly with the region's soaring economic development. That decade was dedicated to deciphering the characteristics and sources of Asia's trace gases and aerosols with increasing detail. Experimental work and increasingly complex models drew him into large multinational projects that linked environmental pollutants and industrial growth to regional questions about health, agricultural production, economic development, and governmental policy. Pollution problems

A satellite photo of the plume of smoke blowing to Iowa from Alaskan and Canadian wildfires (above) is successfully defined by Carmichael's numerical model (below).



1687
Hygrometer invented

1714
Mercury thermometer and Fahrenheit temperature scale developed

1752
Ben Franklin demonstrates electric charges in storm clouds

1827
Jean-Baptiste Fourier writes first account of greenhouse effect

from Asia's expanding "megacities" became increasingly obvious, as did the global transport of pollutants by weather systems: in 1999, Carmichael coauthored the first scientific paper establishing that Asian air pollutants demonstrably decreased air quality in the western U.S.

This finding precipitated Carmichael's current attempts in the emerging field of chemical weather forecasting. By 2000, his models were successfully predicting the long-range transport of dust and pollutants eastward from Asia. By 2002, his forecasting techniques were utilized in field studies identifying Asian pollutants blowing into the western U.S. These studies were preamble to this summer's efforts tracing pollutants across North America and toward Europe.

Before the 17th-century advent of weather measurements, people had understood weather as a here-and-now phenomenon: weather events in one village had no relationship to events over the hill. Soon thereafter, the definition of global trade winds started producing a major shift in viewpoint. The motion of the atmosphere came to be seen as continuous and global. Benjamin Franklin in 1743 was the first to trace the movement of a storm across the earth's surface in a predictable manner.

Today it's well accepted that our wastes have become part of this atmospheric global circulation pattern – that all atmospheric components mix to form a churning, evolving, and predictably moving unit. Weather systems transport trace gases and aerosols vertically throughout the atmosphere and horizontally around the globe, even as the pollutants are being transformed and intermixed with other compounds. Weather's effects on pollutants are now integrated into climate models. Less well understood is air pollution's influence on weather – the influence of aerosols, for example, on shaping cloud systems. Carmichael's predictive tracing of varied pollutants is helping to establish this interaction. "That's where our research and modeling are pushing the envelope," he says when talking about air chemistry's reshaping of the weather. Eventually, he believes that our understanding of pollution's effects on climate will not only improve our weather predictions, but also will provide forewarnings of severe pollution.

Carmichael has remained at the forefront of emerging research in part because of his emphasis on regional explorations. While modelers of urban problems traditionally emphasize practical management concerns, global modelers live primarily in a theoretical world. Carmichael, with his intermediate regional models, has remained poised to merge theory with practical application. In addition, he has maintained competence both in experimental measurements and in developing numerical models – his participation in this summer's field experiments being a case in point. Just as early weather discoveries flowed from the interplay of observation and theoretical study, so today's measurements are fed into numerical models with consequent improvement in both. The result falls within the umbrella of "cyberinfrastructure," a term referring to the integrated use of large multidisciplinary data sets, computer networks, and programs to guide decision-making.

These diverse skills have led to the identification of Carmichael's CGRER researchers as one of the premier chemical modeling groups in the world, awarding

1871
First 3-day weather forecasts issued in US

1875
First weather map appears in *London Times*

1891
US Weather Bureau founded

1896
Svante Arrhenius links climatic changes to atmospheric carbon dioxide

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eminence that has led them toward numerous interesting applications. Their work has been pulled out of the laboratory, away from academia, and into real-world applications that link governmental policy and energy use to environmental issues. For example they helped develop an easily used software package that allows Asian planners to enter varied energy options into a computer and then read, in map format, decades of financial, environmental, and health costs of each option. This integrated tool helped China's leaders select optimal sites for enforcing sulfur reduction strategies. Carmichael has initiated efforts to enlighten policymakers and to train the international community in applications of modeling techniques, and he works with the World Meteorological Organization to help governmental agencies manage their air quality problems. CGRER will be a major participant in yet another significant new initiative, the United Nations-led "Atmospheric Brown Cloud Initiative" which will integrate the science of pollution and climate change with aspects of human health and governmental policy in Africa and the Americas.

Carmichael claims that his ability to apply his expertise to significant ongoing problems has been one of the joys of his work. Another has been its truly international nature: not only does he work around the globe on problems that span national borders, he also works routinely with scientists of diverse cultural and national allegiances. His current working group, for example, includes a dozen graduate students, post-doctoral researchers, research scientists, and visiting scholars from eight countries. Scientists who gained skills while visiting CGRER, as well as Carmichael's former graduate students, are now applying their knowledge around the world.

Today we know more than ever about the workings of the atmosphere. This knowledge has not, however, freed us from our bondage to climate's whims. If anything, with effects of global warming starting to be recognized, we have more to worry about than ever before. We are all for example likely to suffer from increases in the extreme weather events that will accompany climate change. Smoke plumes from the northwest, stemming from fires induced by unusually hot, dry summers, may shade Iowa in ever-increasing numbers.

At the same time, greater knowledge provides hope. Even as this summer's unprecedented atmospheric studies expanded scientific understanding, they set the stage for international cooperation in combating pollution and establishing a universal perspective on emissions standards. Until now, our nation has lagged behind in incorporating the knowledge produced by CGRER and others into policy changes or international accords. The results of this summer's massive experiments invite us to do better – to unite knowledge with wisdom and a compassionate gaze into the future, coupling all in policies that will recognize the single continuous blanket of air embracing all humans and nations on this globe. ✣

The history of meteorology was taken from William Stevens' book *The Change in the Weather: People, Weather, and the Science of Climate* (Delacorte Press, New York, 1999).

1913
Charles Fabry discovers ozone layer

1949
Radar first used to obtain meteorological data

1960
First weather satellite launched

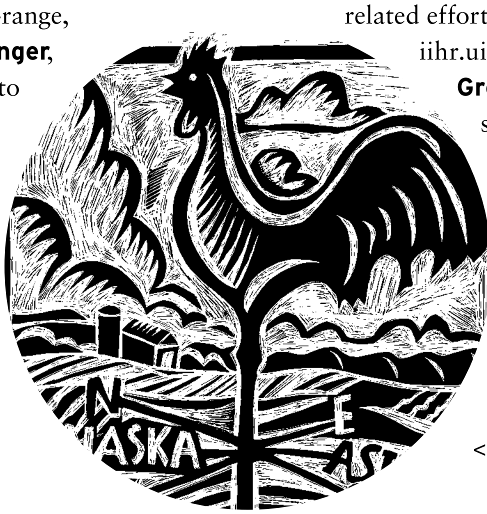
1985
Depletion of ozone layer over Antarctica discovered

Looking Up

Numerous CGRER members are working on deciphering characteristics of our current and future atmosphere. In addition to the atmospheric chemistry efforts of Carmichael's research group, **Keri Hornbuckle** has been studying atmospheric concentrations of synthetic fragrances and pesticides. **Vicki Grassian**'s research on the chemical interplay between atmospheric mineral dusts and trace gases has initiated major new program funding in heterogeneous atmospheric chemistry from NSF and the DOE. Grassian often collaborates with **Paul Kleiber** and **Mark Young**, whose expertise with laser techniques and spectroscopy of gas phase molecules complements her skills in surface analysis.

Several CGRER members are involved specifically with climate studies. **Witold Krajewski** evaluates satellite remote sensing data of global precipitation and studies their statistical properties for improved understanding of climate variability. **Allen Bradley** is newly involved with a National Weather Service grant to assess the accuracy of long-range, probabilistic river forecasts. And **Bill Eichinger**, an expert in utilizing laser beams and lidar to detect extremely small atmospheric components with high resolution, has recently coauthored a new handbook on the subject: *Elastic Lidar: Theory, Practice, and Analysis Method* (Wiley-Interscience, 2004). **Kosta Georgakakos** and colleagues at the Hydrologic Research Center are leading a multi-year research and development effort ("INFORM") intended to demonstrate how climate information can improve the management of water resources, specifically those of northern California's five largest reservoirs. And ISU's **Gene Takle** and **Bill Gutowski** have a central role in preparing regional climate information for climate change assessments for the 2006 IPCC report.

Several additional CGRER members are working with cyberinfrastructure development more generally. **Marc Armstrong** and colleagues are investigating ways to use a nationwide distributed computing network (the "TeraGrid," see <http://www.teragrid.org/>) to perform computationally intensive statistical analyses of very large spatial data sets. **Jacob Odgaard** has for years been promoting the concept of "hydroinformatics," which applies cyberinfrastructure concepts to hydraulic engineering. In 2000, he brought the first hydroinformatics conference held in the U.S. to the UI. CGRER is a major player in "CyberEnviroNet," a developing network aimed at coordinating the cyberinfrastructure-related efforts of UI researchers (see <http://www.iihr.uiowa.edu/ CyberEnviroNet/About.html>). **Greg Carmichael** participated in an NSF steering committee for cyberinfrastructure research and development in the atmospheric sciences (see <http://www.cyrdas.org/>). And **Jerry Schnoor** is a primary coordinator of the CLEANER project, a new effort to use cyberinfrastructures to perform and apply research that promotes sustainability of human-impacted environments (see <http://www.cgrer.uiowa.edu/cleaner/>). ✣



1990
The UN's IPCC published first report on climate change

1996
IPCC reports global warming has been detected; 5-day forecasts become as accurate as 1980's 3-day forecasts

SOURCE: Allaby, M. 2002. *Weather and Climate Handbook*. Facts On File Inc, New York, pp 254-261.

SEEDS

In 2004, CGRER funded five new $20,000 seed grants for the coming fiscal year. Each is preliminary to submission of a larger proposal to outside funding agencies.

❇ **John Nason** (Ecology, Evolution, and Organismal Biology, ISU) will consider the long-term effects of changing climate on genetic variability. His project *Historical Controls on the Evolution of Continental Plant and Insect Herbivore Biotas* will examine the amount of genetic divergence in four Sonoran Desert plants and their dependent herbivorous insects.

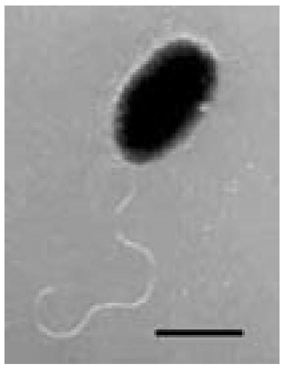
These organisms are thought to have migrated into their current Sonoran locations during the past 10,000 years, following the close of the Pleistocene. By using molecular genetics to compare the standing genetic variability of multiple plant-insect populations, this project will determine whether genetic adaptability was lost during the northward migrations, or whether physical barriers induced more significant changes in the species' genetics. The identification of migration-induced genetic changes could bode poorly for native communities that are likely to be forced to migrate by global warming: loss of genetic variability could reduce the environmental adaptability of native populations, making them more susceptible to possible extinction.

❇ *Capturing Iowa's Industrial Age Record of Global Change* will be Iowa's first attempt to use the isotopic composition of rainfall as a tool to fingerprint climatic trends of the past few hundred years.

Grant recipients **Jeff Dorale**, **Greg Ludvigson**, and **Dick Baker** (all UI Geoscience) will be attempting to procure intact layered sediments from the depths of northwest Iowa's Lake Okoboji. These annual sediment deposits, which are visibly layered and thus can be counted and aged, contain isotopes of oxygen that identify the geographic origin and airmass history of precipitation falling on the lake. They thus can be used to track the global air circulation patterns that cause precipitation in Iowa. Identifying the changes in isotopic composition, and thus in global circulation patterns, will hopefully allow the investigators to identify evolving weather trends from before the Industrial Revolution to the present, an accomplishment that in turn may be predictive of Iowa's future weather and precipitation patterns.

❇ **Jiasong Fang** (Geological and Atmospheric Sciences, ISU) will be investigating whether biomarkers now used to decipher ancient oceanic environments are valid, using his grant, *Stable Carbon Isotope Fractionation in Fatty Acid Biosynthesis of Piezophilic Bacteria and Implications to Paleoenvironmental Reconstruction*.

The deep sea floor serves as the final repository for all oceanic activities. Sediments there contain bacterial by-products (fatty acids) which are used to interpret the ocean's paleoenvironments. However interpretation of oceanic deposits is now based on our understanding of fatty acid synthesis and carbon isotope fractionation in surface-water bacteria. Fang will use his grant to grow deep-water oceanic bacteria and compare their fatty acid synthesis and carbon isotope fractionation to that of surface-water bacteria. Differences or similarities found in this comparison can then be used to ensure that we are correctly reading the ocean's ancient geochemistry and distant past.



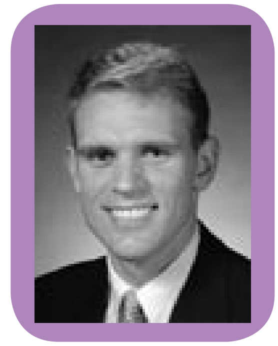
❇ *Development and Implementation of an Aerosol Flow System for Laboratory Studies of the Impact of Atmospheric Aging on the Optical Properties of Mineral Dust Aerosol,* awarded to **Paul Kleiber** (UI Physics & Astronomy) and **Vicki Grassian** (UI Chemistry), concentrates on the climatically significant interplay between light and dust. The absorption and scattering of solar radiation by mineral dust aerosol is crucial to the Earth's temperature balance and climate. In simple terms, dust scattering of incoming solar radiation tends to cool the atmosphere, while dust absorption of outgoing terrestrial radiation has a warming effect. However, dust's optical properties are so poorly understood that we don't know at present whether mineral dust aerosol causes net global warming or cooling. Physical and chemical aging of atmospheric dust can further complicate the radiative forcing problem. This grant will fund the construction and initial laboratory use of an aerosol flow-absorption cell designed to investigate these questions.

❇ *How Accurately Can I Remotely Sense Surface Temperature? Practical Options for Investigators* focuses on improving the accuracy of remote sensing equipment used to measure surface temperatures.

This grant, received by **Brian Hornbuckle** (ISU, Agronomy and Electrical and Computer Engineering), **Thomas Sauer** (USDA, National Soil Tilth Laboratory and ISU, Agronomy), and **Elwynn Taylor** (ISU, Agronomy), will attack inaccuracies inherent in the use of an infrared thermometer (IRT). Although the research instrument of choice when remotely obtaining detailed radiometric temperatures of land surfaces (vegetation, soils, etc.), an IRT actually compounds measurements of Earth surface emissions with those of infrared emissions from the sky. This grant will concentrate on quantifying the resulting error and its variation, in preparation for submission of a major grant to determine standard, easily applied correction methods for this error. ✣

Newcomers

CGRER has welcomed six new members in the past year:



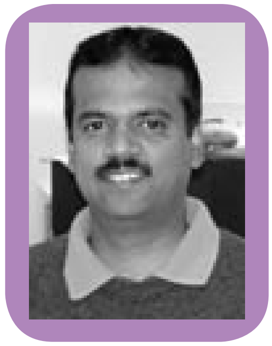
Dennis Dahms has taught in UNI's geography department since 1990, but finds equal allegiance to geologists, in particular those working to unravel secrets of the Ice Ages. Commencing with his doctoral work in physical geography at the University of Kansas, he has focused on the Pleistocene history of the greater Yellowstone region, particularly that of Wyoming's Wind River Range. There he is attempting to define the region's paleoclimate history and glacial stratigraphy. Recent use of soil geomorphology, cosmogenic isotopes, lake sediments, and speleothems as paleoclimate proxies has involved him in joint research efforts with CGRER members Dick Baker and Jeff Dorale (both UI Geoscience). Dennis looks forward to similarly stimulating cooperative efforts and interdisciplinary communications with other CGRER members.

Bill Field completed his doctorate work, studying natural radionuclides in groundwater, in the UI's Department of Occupational and Environmental Health in 1994. He followed this with a decade of research in the UI's Department of Epidemiology performing seminal research linking radon to lung cancer. In 2003 he joined the faculty with joint appointments in both departments. While his radon-related research continues both nationally and internationally, he also carries out environmental epidemiologic studies developing better techniques for estimating human exposure to various toxicants and studying the occupational health of workers at Burlington's Iowa Army Ammunition Plant. His concerns about the complex links between human health and evolving environmental contaminants drew him into joining CGRER's interdisciplinary community.

Brian Hornbuckle left his native Iowa to complete graduate work at the University of Michigan in electrical engineering and atmospheric science. He returned in 2003, when he joined ISU's faculty with joint appointments in agronomy and electrical and computer engineering. This combination reflects his use of remote sensing instruments to measure microwave emissions and to model their dependence on soil moisture content. More specifically, field measurements are used to improve numerical models of moisture exchanged between the soil, vegetation, and the atmosphere, factors important to agriculture that also influence weather predictions. Brian joined CGRER to participate in joint efforts with others concerned about interdisciplinary environmental modeling. His own work is being advanced by a CGRER seed grant (see page 8.)

Newcomers *(continued)*

Laura L. Jackson's recent book, *The Farm as Natural Habitat: Reconnecting Food Systems with Ecosystems* (Jackson and Jackson Eds, Island Press, 2002), tells of her abiding interest in melding human use of the land with healthy native ecosystems. This interest has defined her career. Her doctoral work in ecology and evolutionary biology at Cornell University included an agronomy minor. Her three-year post-doc at the Desert Botanical Garden in Phoenix directed her toward studies of abandoned desert farmland. Since 1993, when she joined UNI's biology faculty, she has investigated incorporating native grasses into pasturelands, evaluated nutrient loading in concentrated livestock regions, and sought methods to increase diversity in prairie reconstructions. She trusts that CGRER will help keep her abreast of climate change and other issues that tie broadly to environmental integrity.



Ramanathan Sugumaran (Sugu) taught in agricultural, engineering, business, and liberal arts colleges, and received doctorates both in India and Great Britain, before becoming a member of UNI's geography faculty in 2002. His many activities are linked through his expertise in GIS, GPS, Spatial Decision Support Systems (SDSS), and remote sensing, all of which he is utilizing in his diverse environmental and natural resource studies. Currently, for example, he is examining hyperspectral images from satellites and aircraft to determine water quality in Iowa's lakes. Sugu also is using GIS and SDSS to model urban growth trends in Iowa and Montana. He was attracted to CGRER's fold by its use of diverse environmental studies for planning and management purposes.

Mark Young, a member of UI's chemistry faculty since 1990, completed his doctorate at the University of California - Berkeley. He frequently collaborates with CGRER member Vicki Grassian and others on projects characterizing the chemistry of heterogeneous atmospheric particulates and their transformation in the troposphere. Other research concerns the photochemistry of particulates in water, and development of techniques for measuring and characterizing particulates suspended in both air and water. His innovative laboratory methods and measurements create data sets that identify complex interactions between light, pollutants, and particulates, which in turn can influence numerical models of our changing climate. Mark's new CGRER membership will formalize and strengthen his longstanding collaborations with many CGRER members and ongoing projects. ✣

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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.

IOWA WATCH

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