IOWA WATCH

THE CENTER FOR GLOBAL AND REGIONAL ENVIRONMENTAL RESEARCH

FALL 2006

The Mega-Challenges of Mega-Cities

In 2007, for the first time in Earth's history, more people will live in cities than in the countryside. Our planet's rural-urban balance is shifting as large numbers of immigrants flow into metropolitan areas in search of opportunities and better lives. Inflows are magnified by Earth's burgeoning human population (which grew from 2.6 billion in 1950, to 6.1 billion in 2000, to a predicted 9 to 10 billion by 2050), and by our planet's continuing globalization and industrialization.

The global urbanization of humanity has been paralleled by a steady rise in the number of very large cities. Settlements of 10-million-plus have multiplied from one (New York City) in 1950, to 19 in 2000, to a predicted 59 by mid-century. Tokyo with its 35 million residents currently tops the list, followed by Mexico City, New York-Newark, São Paulo Brazil, and Mumbai (Bombay) India.

The sheer size of these "megacities" transforms them into profoundly new entities. Provision of food, water, shelter, energy, and other basic resources to densely packed knots of humanity raises immense problems. Consider also the disproportionately large quantity of wastes produced, and resulting pollution of air, water, and soil. These complex problems are magnified by the simultaneity of megacity processes: by industrial pollution, traffic volume, ecological overload, and social unrest feeding upon one another and magnifying the difficulties of urban management. In addition, the vast majority of megacities are

(continued next page)

This CGRER newsletter examines the concerns and opportunities of Earth's growing number of extremely large cities.

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sprouting in developing nations with limited capital and other resources, where explosive growth rates exceed the development of support services: in such locations, the concept of functional infrastructures providing adequate basic human services becomes even less imaginable.

The tragic results too often are megacities where pockets of wealth intermingle with festering shanties, sites where humanity's extremely poor and most vulnerable exist without water, sewage systems, employment, or hope, on geologically fragile lands prone to flooding, mudslides, or earthquakes. These slums tend to become disease-prone, virtually lawless areas characterized by high death rates, crime, and loss of social cohesion. It is no wonder that the names of many current megacities are coupled with images of social or environmental collapse: Mumbai with flooding, São Paulo with crime and violence, Seoul with overcrowding, Lagos with faulty sanitation and abundant waste, Mexico City with air pollution.

Gazing across Iowa's expanses of green, even the concept of a megacity seems distant in the extreme. But our planet is shrinking. The widespread effects of distant events and decisions are becoming increasingly obvious. Mushrooming megacities are, by definition, sites of intense anthropogenic activities whose "ecological footprint" is observed well beyond city limits. These human concentrations are destined to reshape global economics, as well as the quality and use of natural resources, in Iowa and around the globe. They are increasingly the focus of interest and concern to policymakers and researchers who are determined to minimize present as well as future megacity turmoils.

Solutions to megacities' new breed of mega-problems are not simple. CGRER researchers are taking a first stab at minimizing harms associated with air quality. In March, 2006, three CGRER members and their research groups converged on Mexico City along with 300-plus additional researchers from more than 60 institutions and many nations, each bringing unique skill sets, modeling programs, and instrumentation to the table. That megacity, with some of the worst air quality in the world, emanates an immense pollution plume that can exceed 13 km in thickness and 60 km in width. The many researchers were part of an unprecedented international effort to observe and quantify, for the first time, the fate of anthropogenic pollutants emitted in the plume.

Each of CGRER's members considered the plume on a different scale. Charlie Stanier, working from a rooftop in central Mexico City, took his ground-level measurements at the source of pollution generation. His goal was to measure aerosol size, distribution, and water content. These traits are important in determining sources of pollutants and their atmospheric chemical reactions, and also identify how inhaled aerosols behave in human lungs. Charlie reports being amazed at how dynamic the ultrafine aerosols were at ground level: the rich mixture of sources, complicated airflow patterns, and intense photochemical reactions resulted in large and rapid variations in aerosol concentrations.

Bill Eichinger, funded by NSF, used lidar and other instruments to regionally characterize the plume within Mexico City, define chemical changes within its first few days, and trace its movement more than 200 kilometers to the north and east to the Gulf of Mexico. By moving his lidar along Mexican highways and collecting information about reflected laser light shot into the plume and from scattered sunlight, he was able to map not only the plume's direction, height, and particle size distribution, but also to identify chemical constituents and their evolution as moving pollutant particles interacted with atmospheric chemicals and moisture. This research was particularly thrilling for Bill because it represented the first time he had used mobile lidar to track large-scale particulate movement.

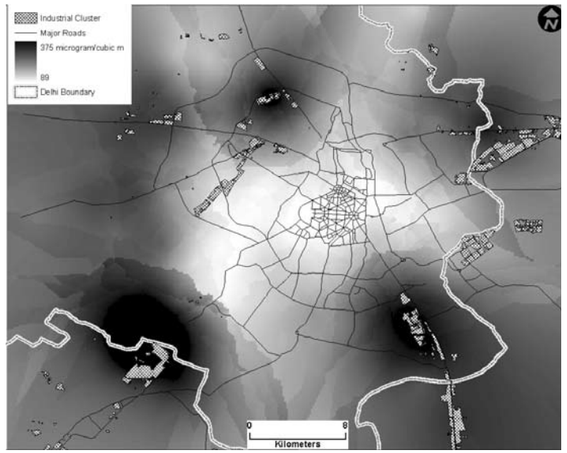
Greg Carmichael's NASA-funded research group worked on the largest scale, helping to trace international implications of moving air pollutants. As in previous large field experiments, Greg's group used its STEM numerical model to forecast movement of the pollution plume, and thus directed the flight patterns and sampling locations of several research aircraft, as well as those of mobile ground-based sampling units. The data obtained are proving invaluable to the evaluation and further improvement of their air quality forecast models, which are key tools for better managing the air quality of Mexico City and other megacities around the world.

Pollution over Mexico City, the subject of a large and unprecedented international research project. (Courtesy Cam McNaughton, University of Hawaii.

On the other side of the globe, Naresh Kumar's current research focuses on time-space dynamics of air pollution and its respiratory health effects in Delhi Metropolitan. This Indian megacity has severe air pollution problems, but has recently enacted environmental laws to improve air quality. Naresh and his multidisciplinary colleagues, funded by NIH, are working to devise new methods for detailing the

distribution and character of air pollution before and after enactment of these regulations. They are computing present and past air quality using MODIS satellite data collected between 2000 and 2006, and checking current satellite data with ground-based field measurements. This research will allow the research group to study changes in Delhi's air quality and the efficacy of air-quality regulations. It also will compute exposure of a cohort of Delhi residents to air pollution before and after control regulations, and thus address long-term health effects of air pollution. Preliminary findings indicate that satellite-based estimates of aerosol optical depth show a significant positive association with particulate measurements recorded on the ground, although particulate measurements are greatly influenced by atmospheric conditions.

Both of these major research projects are fundamental to the cities involved, providing descriptions not previously available of Mexico City's and Delhi's atmospheres.



Map of Delhi Metropolitan (in center), showing correlation between outlying industrial clusters and elevated levels of atmospheric particulate pollutants.

The projects hopefully will add import to these cities' need to regulate particulate emissions and focus pollution-related health and climate mitigation efforts. But with the number of megacities increasing rapidly, results of these massive research projects must also reach beyond the specific cities addressed – and both promise to do so. Naresh trusts that his research will pave the way to a general understanding of spatial and temporal trends of air pollution in megacities in developing countries. The Mexico City experiments were intended to identify the effect of megacities on regional and global climate. They also exemplified, once again, that pollutants produced in one location evolve as they travel long distances and affect distant sites, a fact applicable to multiple situations (such as movement of smoke from western forest fires across the U.S.). Data from both projects will ultimately help refine numerical models of changing air quality and climate. Also, both provide baseline data that may be impossible to collect in coming years: since plumes of air pollutants are likely to blur as megacities increase in number and density, now – while each city's "atmospheric footprint" remains distinctive – is the time to characterize it. In addition, both projects provide graduate students with rich international and intercultural experiences. Involved students, whose work is destined to thrust them into a higher global consciousness, receive lifelong lessons about the complexities of environmental challenges and our common global connections.

Perhaps most importantly, developing greater understanding of megacities' air pollution problems now may proactively feed into better city design and environmental regulations and policies. These in turn may minimize future air pollution problems, and help control morbidity and mortality, in newly developing megacities around the world. This final goal reaches beyond the seemingly immense problems of megacities and considers this possibility: megacities present global opportunities as well as risks. They may be the sites where future environmental challenges are best addressed. How? By capitalizing on these cities' inherent capabilities. Cities have traditionally been the incubators of social and economic innovation, the fundamental building blocks of industrial and commercial growth, focal points for globalization and development, the key sites where new policies and approaches are conceived and attempted. Compact cities have the potential of greater internal efficiency and economies of scale than more diffuse settlements. And by concentrating the growing human population in a smaller area, megacities might help minimize human activity elsewhere and thus preserve rural areas that are necessary to provide food, natural resources, and ecosystem services (clean water, decomposition of wastes, etc.) for all of Earth's diverse life.

With increasing numbers of megacities inevitable, CGRER is also involved in non-research efforts that

Thoughts on Megacities from CGRER affiliates

Every day, megacities touch the lives of CGRER collaborators who live within them. Consider Narisara Thongboonchoo for example, a professor of chemical engineering in Bangkok who completed here PhD research at CGRER, who comments on the greater personal, societal, and environmental stress of megacities. Their hectic pace of living, she states, leaves less time to enjoy life. This sentiment is reflected by Chandra Venkataraman, chemical engineering professor in Mumbai (formerly Bombay) who spent her 2005 sabbatical at CGRER. She adds that harsh traffic conditions restrict access to cultural and educational activities. Both women comment that the size of megacities magnifies the difficulties of safeguarding their residents – for example it is more difficult to implement protective environmental regulations in very large cities, or to address the needs of increasing numbers of slum residents who receive high exposure to water and air pollution.

Narisara and Chandra have felt compelled to address megacity needs through their research. Chandra has extended her air-quality research to the human-health impacts of urban pollution and has become involved in other urban environmental concerns, such as the Mumbai urban transport project. Narisara in contrast has limited the scope of her air quality investigations to areas within city boundaries.

Collaboration with visitors such as these stretches the scope and solidifies the relevance of CGRER's climatic and air quality research. This is exemplified by CGRER's 2003 visitor Sijin (Tom) Lee, a Korean environmental engineering professor, who continues to work on addressing non-point-source water pollution of the Han River that flows through Seoul. There, as here in Iowa, such pollution is far more difficult to control than water pollution flowing from specific sites. Tom has been working with Jerry Schnoor to produce journal articles on this difficult topic.

consider their possible positive features and that reach toward their potential. This consideration is articulated through discussions and writings, expressed in the form of course work and journal papers. For example, this past July Greg Carmichael helped organize and teach a week-long course on air quality forecasting to about 50 practitioners (mostly government employees) in Lima, Peru. Virtually all of its participants were from Latin American megacities. This World Meteorological Organization course will be repeated annually in different parts of the world. Greg also recently coauthored a publication considering the air-quality impact of our cheap imports from China's Pearl River delta.[1] This article points out that a good quantity of China's air pollutants, whose long-distance transport eventually impacts air quality in the U.S., results from the western world's hunger for cheap consumer goods produced in megacities and exported from them.

Meanwhile Jerry Schnoor's efforts as the editor of the premier environmental science and environmental engineering journal *ES&T (Environmental Science and Technology)* have led him to open an *ES&T* office in Beijing and actively solicit articles concerning China's pollution and megacities. The most recent edition, resultingly, contains articles on particulate levels in Chinese megacities, organic aerosols from Chinese cities, and modeling of polycyclic aromatic hydrocarbons from coke production in Tianjin.

Traditionally, throughout history, cities have formed productive partnerships with rural areas: the countryside has provided natural resources and sites for waste processing and disposal, while cities have churned with cultural and intellectual creativity and fueled production. With humanity's shift toward urbanization, can this crucial balance between city and countryside be maintained? Can megacities, with all their vulnerabilities, serve as future engines of growth rather than decay? Can the demands and stresses of extremely large human populations be met by surrounding rural areas? These questions remain unanswered. However today's megacities, regardless of their growing numbers and size, and in spite of their goliath problems, may possibly provide key instruments for a healthier global future. Through research, teaching, and writing, CGRER researchers are working to help point toward a more positive global outcome for megacities, as for all human and non-human life.

[1] *ES&T Online Policy News*, 3/1/06, "Linking China's Air Pollution to Export Markets."

Basic information and statistics on megacities were taken primarily from these documents, which (with much other megacity information) are available online:

World Bank. 2003. *World Development Report 2003: Sustainable Development in a Dynamic Economy – Transforming Institutions, Growth, and Quality of Life*.

United Nations, Dept. of Economic and Social Affairs, Population Division. 2004. *World Urbanization Prospects, The 2003 Revision, Data Tables and Highlights*. ESA/WP 190.

SEEDS

In 2006, CGRER awarded six Seed Grants totaling $145,092 to six projects.

❊ *Ecological Intensification of the Industrial Bioeconomy: Sustainable Biofuel Production through the Integration of Perennial Crops with Advanced Biomass Conversion Technologies* ($18,074 awarded to Robert Anex – ISU Agricultural and Biosystems Engineering)

This project considers the use of native perennial grasses as biofuels for bioenergy. Researchers will evaluate the possibility of recovering key plant nutrients from such grass crops, and recycling these nutrients onto croplands. Such recycling of recovered nutrients could maintain highly productive farmland while reducing the use and impact of chemical fertilizers, limiting agriculture's environmental impacts, improving energy-use efficiency, and creating more sustainable agricultural systems.

❊ *A Workshop to Assess Climate-Change Effects on the Ice Regimes of Northern Rivers* ($29,059 awarded to Robert Ettema and Allen Bradley, UI Civil & Environmental Engineering and IIHR-Hydroscience and Engineering)

Anecdotal information suggests that global climate change is altering the ice regimes of many northern rivers, and is increasing ice jam severity. This award will fund a 2006-07 workshop involving leading researchers from Russia, Canada, and the U.S. These experts will produce a substantial proposal for an international study of climate change impacts on ice regimes of northern rivers.

❊ *Assessing the Ecotoxicology of Nanomaterials and Identifying Biomarkers in Bacteria Exposed to Nanomaterials* ($27,959 awarded to Jiasong Fang – ISU Geological and Atmospheric Sciences)

Nanomaterials are increasingly being used in commercial products and environmental applications. This research will help assess the environmental risks and ecotoxicology of such extremely small particles. In particular, research will elucidate nanomaterials' stress on bacteria, determine imposed shifts in bacterial membrane fluidity and microbial communities, and identify reliable biomarkers for assessing nanomaterials' effects.

SEEDS continued

❊ *Equity in Relief: Urban Water-supply and Recovery from Tsunami during Suspended Civil War in Sri Lanka* ($30,000 awarded to Paul Greenough – UI History and Community & Behavioral Health, and Harish Naraindas – JNU University, India)

This project will examine the equity of relief distribution in three Sri Lankan cities following the December 2004 tsunami. Post-storm restoration of drinking water will be studied to determine if aid was allocated according to need or, as alleged by some, according to politics. Field studies will be followed by a workshop in Iowa City, where funding proposals for more extensive research will be developed.

❊ *Real-time, Personal Sampling for Airborne Nanoparticles* ($30,000 awarded to Thomas Peters – UI Occupational and Environmental Health)

Although short-term exposure to nanoparticles from traffic may be associated with cardiac sudden death, current sampling methods hamper efforts to directly assess this relationship. This project aims to develop a novel monitor to assess fluctuations in personal exposure to nanoparticles. The research may impact future regulation of such extremely small particles, and will foster interdisciplinar y research between Peters and UI health specialists.

Photo courtesy of USDA NRCS

❊ *Using the Past to Create a Sustainable Future for Agriculture: The Impact of Federal Farm Policy on Environmental and Social Landscape Change in Iowa* ($10,000 awarded to Lisa A. Schulte – ISU Landscape Ecology, Natural Resource Ecology and Management, and Paul Brown – ISU Agriculture and Natural Resources Extension)

The twentieth-century intensification of row-cropping has created a uniform landscape lacking in environmental and socio-economic resilience. This interdisciplinary project will detail how U.S. federal farm policies have socially and ecologically affected three rural Iowa townships between 1933 and 2002. Resulting historic insights can help create a vision of agricultural and rural sustainability, and may feed into revisions of federal farm policy initiatives.

Newcomers

CGRER has welcomed two new members in the past year:

MARC LINDERMAN
(UI Dept. of Geography)

Marc's doctoral research took him to China to perform spatial analyses of giant panda habitat. After receiving his PhD from Michigan State University in 2002, he spent three post-doctoral years in Belgium studying the inter-annual variability of vegetational productivity and phenology on the African continent. Marc became an assistant professor at the UI in 2005, bringing with him his expertise in using remote sensing (in particular analyzing satellite measurements taken over time) to monitor social and biophysical systems, and to better understand the interaction between human activity and Earth's biophysical systems. His current research includes evaluating land-use, biodiversity influences, and ecosystem processes at Iowa's Neal Smith National Wildlife Refuge; continued monitoring of global variability of vegetational activity; and examining the relationships between household activities, family structure, and land use and land cover change in China. Marc's interest in tracing changes in complex social and biophysical systems opens many opportunities for interdisciplinary collaboration with other CGRER members.

NARESH KUMAR
(UI Dept. of Geography)

Naresh came to the University of Iowa in 2005 from Brown University, where he had been teaching since 2002 and continues to be an adjunct faculty member. He was educated in India and England (PhD 1999, University of Durham). His dissertation addressed the spatial efficiency of infrastructure services and land-use changes in two districts located to the west of Delhi, India. Naresh's research now focuses on complex analyses of space-time dynamics of air pollution in the Delhi Metropolitan (see "The Mega-Challenges of Mega-Cities"). He also studies the short- and long-term health effects of air pollution. Naresh's multi-disciplinary studies bridge the gap between the social and natural sciences, and he complements both with his knowledge of field studies (use of varied monitoring devices, satellite data, and GIS). These interests and his ongoing concerns about Asian air pollution form a natural allegiance with CGRER's researchers, with whom he hopes to collaborate on future projects. ✣

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- Lou Licht
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- Wilfrid A. Nixon
- A. Jacob Odgaard
- A.N. Thanos Papanicolaou
- Gene F. Parkin
- Michelle Scherer
- Jerald L. Schnoor
- Richard L. Valentine

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- Garry R. Buettner

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- David Bennett
- Naresh Kumar
- Marc Linderman
- George P. Malanson
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- R. Rajagopal
- Gerard Rushton

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- Holmes A. Semken, Jr., Emeritus
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- You-Kuan Zhang

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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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