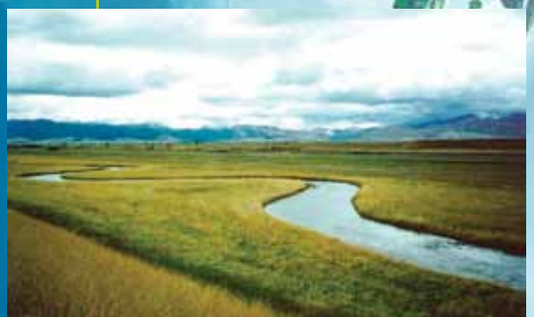
EARTH-SURFACE DYNAMICS



Background: Mississippi River Delta. Image taken 5/24/2001 by ASTER, the Terra Satellite's Advanced Spaceborne Thermal Emission and Reflection Radiometer. *Image: USGS National Center for EROS and NASA*

Inset photo left by Dan Marshall

Inset photo lower right by Jon Chapman

NATIONAL CENTER FOR EARTH-SURFACE DYNAMICS NCED

THE SURFACE IS THE ENVIRONMENT

Civilization, by its very nature, has involved reshaping the natural environment to fit human needs. We have altered landscapes to enhance food supplies, reduce exposure to natural dangers, and promote commerce.

Efi Foufoula-Georgiou

We have converted approximately 50 percent of the world's surface to grazed or cultivated cropland. We have built dams to control rivers for hydropower, irrigation, and flood mitigation. Nearly six times more water is now held in storage than occurs in free-flowing rivers. Climate change and a growing imbalance among freshwater supply, consumption, and population have dramatically altered the hydrologic cycle, a situation that may intensify over the next century.

During its nine-year tenure, the National Center for Earth-surface Dynamics (NCED) has ushered in a new era of investigation to better understand landscape dynamics and their response to change. Headquartered at the St. Anthony Falls Laboratory at the University of Minnesota, NCED has facilitated the development of a quantitative, predictive Earth-surface science through the integration of many fields: geomorphology, ecology, hydrology, sedimentary geology, engineering, social sciences, and geochemistry and through the synergistic combination of field investigations, physical experiments, and computational models.

"It is a paradigm shift that will enable us to address the challenges of the future and provide science-based solutions for adaptation and mitigation of environmental change," says center director Efi Foufoula-Georgiou.

The center's mission is to understand the dynamics of the coupled processes that shape the Earth's surface and furthermore, to use this knowledge to deliver the science-based solutions necessary for addressing environmental change. The research program is organized around three main themes looking at watersheds, stream systems, and deltas. "Our Deltas program seeks to understand the processes of delta dynamics in support of restoration of the Mississippi River Delta, as a prototype initiative that can contribute to the protection and restoration of the many threatened deltas around the world," says Foufoula-Georgiou. "Our research uses the subsurface stratigraphy of modern deltas to infer rates, spatial patterns, and mechanisms of natural delta building processes. Simultaneously, we perform experiments and field studies to develop predictive models of the processes by which deltas build land and maintain themselves and their associated ecosystems against subsidence and sea-level rise."

In one area of NCED work, results have revealed a major shift in sediment sources in the Upper Mississippi River system. Excessive loads of fine sediment and their associated turbidity, eutrophication, and degradation of water quality are common problems for rivers that drain agricultural lands. Identifying the causes of, and developing countermeasures for, the excess sediment is challenging in large watersheds due to their scale and complexity. "But adopting mitigation strategies without an understanding of watershed-scale sediment dynamics threatens to be wasteful at best and destructive at worst," notes Foufoula-Georgiou.

TRANSFER OF TOOLS

Methods to calculate the movement of sediment might sound like mere mud pies to some people, but it's an important outcome of center research.

"As humble as it may be, sediment is what a lot of the world is built on," notes Paola. Knowing how fast it flows from one place to another is critical to understanding how the earth's surface evolves—and how long, for example, a reservoir will remain in service, what will happen to the lake behind a dam, or how fast you could fill in drowned marsh land in a place like the Mississippi Delta.

The Army Corps of Engineers is expected this year to adopt some of NCED's sediment transport tools, which means the technology would become part of the national standards for calculating the flow of particles in rivers.

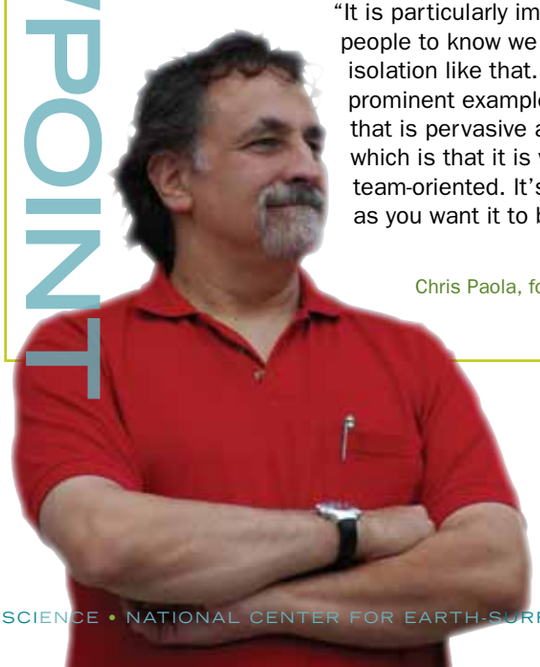
VIEWPOINT

Chris Paola

"When I interact with the public, particularly kids, they don't understand science is not done in isolation," says NCED researcher Chris Paola. "Most people think that scientists work by themselves in laboratories wearing white lab coats," he notes, "but science is one of the most intensively social disciplines there is.

"It is particularly important for young people to know we rarely work in isolation like that. The STCs are a prominent example of something that is pervasive across science, which is that it is very social, very team-oriented. It's as team-oriented as you want it to be."

Chris Paola, former NCED Director



To identify the sources and mechanisms of erosion and sediment transport in the Minnesota River Basin, NCED researchers constructed a sediment budget for the Le Sueur River, a tributary and primary contributor of sediment to the Minnesota River. Based on similar topographic history and land use, the sediment dynamics of the Le Sueur are likely representative of other tributaries to the Minnesota River. They found a" surprising shift" in sediment sources, suggesting that recent changes—including extreme precipitation events; installation of agricultural ditches and subsurface tile drains; and increased soybean cultivation and decreased evapotranspiration—have acted to amplify erosion of bluffs and stream banks. "The implication for landscape managers is clear," says Foufoula-Georgiou. "The strategy implemented for sediment reduction must first and foremost address the primary amplifier of erosion, the altered hydrology of the watershed."

On another front, NCED research on the swimming behavior of green algae has important implications for understanding toxic algal blooms. In lakes, deltas, and oceans, very thin surface layers of the water may contain concentrations of tiny phytoplankton up to two orders of magnitude above ambient concentrations. These layers are important "hot spots" of ecological activity.

Thin layers range in size from microns to centimeters vertically and can extend for kilometers horizontally, persisting for hours to days. The layers enhance zooplankton growth rates within coastal oceans and are essential for the survival of some fish larvae. At the same time, however, many phytoplankton species found in the layers are toxic, and they may enhance fish mortality and cause harmful algal blooms. So it's important to be able to predict the onset, lifetime, and destruction of thin layers, but a definitive explanation has eluded scientists. Since the layers are often found in oceanic regions where shear flows are prevalent, it has been hypothesized that hydrodynamic shear contributes to thin layer formation by disrupting the vertical migration of phytoplankton.

NCED researchers have discovered surprising swimming patterns of a kind of green algae that supports this hypothesis. They used a method called high-speed holographic particle image velocimetry to study algae swimming in situ in moving flows, and found that the organisms were moving in response to fluid flow. The researchers hypothesize that the shear-guided swimming minimizes drag and physiological stress. At high shear rates, the algal cells aggregate into two dimensional thin slices, identical in form to thin layers in oceans. □

CYCLES: TEACHERS DISCOVERING CLIMATE CHANGE FROM A NATIVE PERSPECTIVE

CYCLES is an approach for understanding and teaching about global climate change that reflects the similarities between Native American and scientific explanations of the natural world as interconnected processes that are cyclical.

In native culture, the medicine wheel symbolizes the interconnectedness of the Earth, air, water, and fire. This relationship is recognized in science through an Earth systems approach based on the interconnectedness of the geosphere, atmosphere, hydrosphere, and biosphere, with the energy flow of these systems derived from the "fire" of the Sun and the interior of the Earth.

CYCLES is a three-year program, facilitated by NCED researchers and currently co-funded by NASA, targeting middle and high school science teachers from reservation schools or schools with significant native student populations. The program incorporates satellite observations, regional and global models, and cultural experiences.

A cohort of 20 CYCLES teachers were selected in the summer of 2011 to pilot test this new approach over the next 3 years. During summer workshops, teachers are actively involved in doing climate change science, both in the field with local projects and with existing NCED and NASA data. Teachers also learn how to use computational tools to visualize and model climate change to answer questions about local and global effects of environmental change. During the academic year, teachers attend additional training days and are expected to implement lessons and activities from the summer workshops in their classrooms with support from the CYCLES staff.

GRADUATE CERTIFICATE PROGRAM IN STREAM RESTORATION FILLS AN EDUCATION GAP

On a sunny day in central Minnesota, thirteen students armed with equipment and waders set up their cross-section lines and begin to measure channel topography. They are starting an investigation on the Maple River, where a local landowner has complained about bank erosion. The Department of Natural Resources wants to enhance fish habitat, and the Minnesota Pollution Control Agency hopes to reduce turbidity and improve water quality of the river.

These students are the first participants in the Stream Restoration Science and Engineering Graduate Program (SRSE), started by NCED at the University of Minnesota (UMN).

Stream restoration requires a complex understanding of engineering, physical, biological, and social sciences, yet few practitioners have such integrated training in these fields. NCED aims to fill that gap with a new year-long, interdisciplinary program, which completes its first year in June 2007. The certificate may be taken as a stand-alone qualification or incorporated into a master's or doctoral program. It is currently the only year-long graduate degree in the country specifically aimed at stream restoration, according to NCED.

WELCOME TO THE ANTHROPOCENE

BY PATRICK HAMILTON, DIRECTOR, GLOBAL CHANGE INITIATIVES, SCIENCE MUSEUM OF MINNESOTA

Humans now are the dominant agents of global change.

This idea has emerged as a main message over the course of nine years of collaboration between the National Center for Earth-surface Dynamics (NCED) and the Science Museum of Minnesota (SMM).

The work began first with the creation of the "Big Back Yard." This 1.75-acre, outdoor environmental science park at the museum opened in 2004 and is centered on a nine-hole mini-golf course that helps people explore human/landscape interactions as they follow the movement of water and sediment from the uplands of North America to the Gulf of Mexico.

NCED and SMM then turned their attention to the creation of a major traveling exhibit about water organized in partnership with the American Museum of Natural History (AMNH). "Water: H2O = Life" opened at AMNH in late 2007 and focuses on the fundamental importance of water on our planet, the growing stresses humans are placing on global freshwater supplies and the innovations available to help address our planetary water challenges. Two copies of the Water exhibit now are touring venues around the world.

NCED and SMM's latest collaboration is "Future Earth"—exhibits, Internet kiosks and public programs to help audiences appreciate that collectively all seven billion people on Earth now rival natural processes in modifying the planet, that a diverse portfolio of technological, economic, social and political innovations is needed for people to successfully adapt to and mitigate the global changes that humans have set in motion, and that Earth now is home to the wealthiest, healthiest, best educated, and most innovative, creative and interconnected cohort of humans in history. The "Future Earth" exhibit opens at SMM in fall of 2011.

Entry to the *Water: H2O = Life* exhibit displays messages on a curtain of fog. *Image: American Museum of Natural History*

The Big Back Yard.
Image: Science Museum of Minnesota

This dataset (http://sos.noaa.gov/datasets/extras/facebook.html) was created by an intern at Facebook who plotted 10 million pairs of friends on Facebook. The result is a stunning map that shows the connections between people and highlights the regions with readily available access to the internet. Africa, with limited internet access is rather dim, while China, with many internet users is dim due to the use of a popular Chinese social networking site and government restrictions. From the creator upon refining the visualization - "After a few minutes of rendering, the new plot appeared, and I was a bit taken aback by what I saw. The blob had turned into a surprisingly detailed map of the world. Not only were continents visible, certain international borders were apparent as well. What really struck me, though, was knowing that the lines didn't represent coasts or rivers or political borders, but real human relationships. Each line might represent a friendship made while traveling, a family member abroad, or an old college friend pulled away by the various forces of life." *Image: Courtesy of Facebook*

Eric Jolly

PRESIDENT, SCIENCE MUSEUM OF MINNESOTA

Since joining SMM in 2004, museum president Eric Jolly has worked to cultivate a close working relationship with NCED, in part through the negotiation of a memorandum of understanding (MOU) that facilitates communication between SMM and UMN. Toward this end, Jolly has drawn upon his experience as a psychology professor and university administrator. He is a nationally acclaimed leader in the field of science education and science literacy.

"The MOU allowed us to have a portal," Jolly explains. "It can be difficult to find a way in to a major research university-to an outside institution, a university can be overwhelming. You don't know exactly where to go-it's not intuitive. Having an MOU helped that," he says.

"There's a reciprocity in this that's pretty astounding," says Jolly. "I consider this one of the best examples of public-private partnerships in the country."

The energy that the players bring to the collaboration is infectious. "People have accused me of having too much fun," says Jolly. "I get to play scientist, educator, keeper of incredible treasures, and it's all aimed at my passion: science as an essential literacy for our youth—science education as a civil right in many ways."