National Center for Earth-surface Dynamics

THEN AND NOW: 2002 to 2012

Efi Foufoula-Georgiou -- On behalf of the NCED family
Year 9 site visit
May 17-18, 2011
NCED Reflections: 2002-2011

- The vision, the premise [2000]
- Life is never the same after an STC [2002]
- The true meaning of transformative research
- The true meaning of synthesis research
- So what has NCED accomplished?
- What is to be lost beyond 2012?

NCED in one day:
- 35,000 ft overview – Efi
- 10,000 ft overview – 5 IP leaders
- 1 ft zoom in – students and post-docs
• Big ideas get refined but they remain true to their core …
The big idea

**Theme:**

the Earth’s surface (“critical zone”) is the environment. But we cannot quantitatively answer even relatively simple questions about its response to climatic and other changes, or provide tools to manage it effectively. Why?

**Problem:**

Earth-surface science has been hindered by disciplinary fragmentation and a tradition of descriptive research and training

**Solution:**

a center focused on developing an integrated, predictive, quantitative understanding of Earth-surface dynamics

Year 2 site visit – Chris Paola
NCED’s purpose:

to catalyze development of an integrated, predictive science of the processes shaping the surface of the Earth, in order to transform management of ecosystems, resources, and land use.
• NCED’s Vision and Mission statements have been refined and much talked about but the core work and approach to accomplishing that vision has remained the solid same …..
NCED Vision

To predict the coupled dynamics and co-evolution of landscapes and their ecosystems, in order to transform management and restoration of the Earth-surface environment.

Focus on channels and channel systems as they link disparate environments, and structure landscapes and ecosystems at all scales.
The journey of a center

• Center = a collection of people, approaches, disciplines, and research facilities towards a common goal

• The “journey of a Center” is a set of individual journeys (personal and professional) interacting non-linearly and transforming each other

NCED’s journey: Then and Now
Then

Now

Then

Now
The NCED Immediate Family (PIs)
The NCED Extended Family (Affiliate Scientists) and keeps growing....
The NCED Administrative Backbone

Education and Diversity is not delegated or managed from an office; it becomes your life!

Thank you!
Center-added value

✓ Whole > Sum (parts)?

\[ X_1 = \text{productivity of PI 1} \]
\[ X_2 = \text{productivity of PI 2} \]

\[ X = X_1 + X_2 \]

\[ X = \text{productivity of center} \]

\[ \text{Mean}(X) = \text{Mean}(X_1) + \text{Mean}(X_2); \]

\[ \text{Var}(X) = \text{Var}(X_1) + \text{Var}(X_2) + \text{COV}(X_1, X_2) \]

Whole > sum of its parts Iff COV (+)
“CRUDE LOOK AT THE WHOLE”
THE KEY TO UNDERSTANDING COMPLEXITY

“...if the parts of a complex system or various aspects of a complex situation, all defined in advance, are studied carefully by experts on those parts or aspects, and the results of their work are pooled, an adequate description of the whole system or situation does not usually emerge.

The reason, of course, is that these parts or aspects are typically entangled with one another.

We have to supplement the partial studies with a transdisciplinary “crude look at the whole.”

Murray Gell-Mann, Let’s call it plectics

(2003 – Year 2 site visit Foufoula’s presentation)
A crude look at the whole: Then and Now

Years:
- 0: initial development
- 2: ongoing defined project
- 4: project produced synthesis paper
- 8: well-established project with shared students or multiple papers

Diagram notes:
- Lines indicate connections between different projects or entities.
- Different line widths represent the stages of project development.
NCED: Then and Now

Transformation metrics:

-- 158 MS/PhD students graduated, 50 post-docs
-- 49 placed in academic positions
-- 550 journal publications/ more than half co-authored
-- 378 underrepresented students in science camps
-- 11 underrepresented students now in graduate school
-- 8 NAISEF grant award winners (out of 32 nation wide)

-- 800+ participated in short courses and partner group meetings
-- 100+ scientists in 3 multi-disciplinary working groups
-- 22 PIs in 9 institutions
-- liaison with 9 other community efforts
-- a major conference for young scientists in ES (MYRES:80 delegates)
-- 16 (10 grad, 6 undergrad) students studied abroad
-- 280,000 visited the SMM BBY
-- 4,000,000 visited Water: H₂O=Life
-- 2 NAS, 20 disciplinary awards
-- 60 REU and summer interns
-- 1.5 TB served on NCED’s web site

-- First degree in water resources in a Tribal college
-- Created the Partnership for River Restoration in the Upper Midwest
-- Created the Geoscience Alliance
-- Created post-baccalaureate program in SR
--
NCED’s core values

• NCED core values:
  -- working at the frontier
  -- dedicated to excellence and community growth
  -- an agile and adaptive organization
  -- mentor a diverse workforce: the next generation
  -- taking science to practice

**Working at the frontier**: imagining the future, embracing risk, promoting creativity and initiative at the interfaces of disciplines

**Dedicated to excellence**: nothing less than the best in intellect, performance and commitment of the center as a community resource

**Agile and adaptive**: strategic shifts, recruit new talent

**Diverse workforce**: create the next generation of leaders in ESD

**Science to practice**: create sustained partnerships, science-based approaches to pressing problems, educate the public
NCED Organization

3 Integrated Programs (IPs)
- Desktop Watersheds (DW) IP -- Watersheds
- Stream Restoration (SR) IP - Streams
- Subsurface Architecture (SA) IP – Deltas

3 Initiatives
- Education Initiative
- Knowledge Transfer Initiative
- Diversity Initiative
To discover and advance the fundamental relations needed to predict landscape evolution and to model the coupling of ecosystem, landscape, and land-use dynamics.

Watersheds

IP leader: Bill Dietrich
IP manager: Collin Bode
To advance the science and practice of stream restoration by conducting and coordinating research and by working with agency and industry partners to identify information needs, develop improved tools, and transfer this knowledge into practice.

IP leader: Peter Wilcock
IP manager: Don Baker
To use information from modern systems, experiments, and stratigraphic records to develop a predictive understanding of delta evolution, and apply this understanding to delta restoration.

IP leader: David Mohrig
IP manager: Jim Buttles
Knowledge Transfer Initiative

Distributed across all IPs
KT Manager: Deborah Hudleston
Visitor’s Program: Sara Johnson

To create and maintain two-way communication with application stakeholders and the broader research community to inform NCED research and disseminate NCED results
Education Initiative

Education Director: Karen Campbell

To bring Earth-surface dynamics to life for a broad spectrum of learners, in order to educate future leaders in NCED’s key mission areas of land, resource, and ecosystem management.
Diversity Initiative

Diversity Director: Diana Dalbotten

To increase participation by under-represented groups in NCED until minority representation is continuously reflective of the US national population.
The NCED Nexus of Institutions
A mountainous steep terrain (ACRR)

Angelo Coast Range Reserve

32 km² managed by UCB

Chosen by NCED in 2002 to field-test our predictive ecogeomorphic models of channels and channel system evolution.

Hotspot of activity

291 researchers last year; total of 1,952 researcher user days

Wireless infrastructure

NCED has invested extensively in long-term environmental monitoring at the ACRR. At this time, ~1000 sensors fully functional and online.

Capacity building

NCED has continued investment at ACRR through renovation of aging facilities and equipment.
A human impacted landscape (MRB)

Le Sueur River Basin

2,880 km² in the Minnesota River Basin
chosen by NCED in 2008 to study sediment dynamics on a watershed scale

Excessive sediment loads
7% of the MRB by area, yet contributes 30-40% of the total suspended sediment load of the Minnesota River and Lake Pepin.

Testbed for HANC hypothesis
Large set of water, sediment, and biotic responses to well-defined and pervasive natural and anthropogenic changes

Socioeconomic significance
Direct implications for sustainable watershed management and policy
A vulnerable coastal environment (WLD)

Wax Lake Delta

250 km² located in coastal LA
WLD chosen by NCED in 2007 to develop methods to predict delta evolution in support of sustainable restoration of the Mississippi River Delta

Model for natural delta growth
WLD provides an excellent template for delta land-growth prediction because the delta has evolved naturally

A species-rich community
WLD provides an excellent opportunity to examine linkages between geomorphology and ecology in a coastal restoration context

Broader Impacts
Sustainable solutions to delta restoration
A State-of-the-art Experimental Facility

St. Anthony Falls Laboratory

A “Jewel on the River”
SAFL provides an ideal site for a variety of experimental flumes and channels.

StreamLabs
a suite of research laboratories (physical and virtual) designed to help researchers from a broad spectrum of disciplines better understand stream processes + OSL

Experimental Earthscapes Basin
utilizes a dynamically subsiding bed and an electronic measurement system to document deposit evolution.

EcoFluids Laboratory
allows researchers to study the interactions among fluid mechanics, microbiological processes, and chemical reactions that are mediated by biological organisms.
A nexus of linked Laboratories

St. Anthony Falls Lab

Richmond Field Station

Ven Te Chow Lab

UTA Jackson School Lab
NCED: Educating a broad audience
A prototype partnership between academia and a Science Museum
Science Museum of Minnesota

Big Back Yard
a 1.75-acre outdoor park that uses miniature golf to teach visitors about how river systems sculpt the Earth’s surface.

Water: H₂O = Life
two traveling exhibits that demonstrate the role water plays in shaping the land and human communities.

Science on a Sphere
a 6-foot video projection system that displays dynamic images of the Earth’s surface using an animated globe

Future Earth Initiative
NCED is working with the SMM and five other STCs to demonstrate what it means for humans to live in the Anthropocene Epoch.
NCED: Increasing diversity in Geosciences

Native American STEM Programs

**gidakiimanaaniwigamig**
camps include a mix of lab science and field science programming, focusing on introducing the students to the scientific method and Native American culture.

**giiwed’anang**
part of the AISES Alliance, *giiwed’anang* works to promote minority participation in STEM fields by providing education opportunities and academic guidance.

**manoomin**
engages Native American students, teachers, and community members in a research project aimed at understanding the ecological conditions beneficial to the growth of wild rice

**Geoscience Alliance**
a national alliance whose mission is to broaden participation of Native Americans in the geosciences.
NCED: The Next Generation

REUs ... to MS/PhDs... to synthesis post-docs ... to faculty

Intensive Research Experience
a 10-week summer program providing exposure to real-world laboratory and field settings. In addition, students complete a report and poster at the end of the field campaign.

Team Oriented, Team Mentored
Students organized around two teams: Team Delta (Adv: Twilley) and Team Stream (Adv: Sotiropoulos).

Diversity
70% minority participation to-date
We want to see more of Efi. She is so cool. We should market Efi booblehead dolls.
Engaging the public: NCED’s “SIP of Science”

“The Sip of Science series features discussions that bridge the gap between science and culture in a setting that bridges the gap between brain and belly. Food, beer, and learning are on the menu in a happy hour forum that offers the opportunity to talk with researchers about their current work, its implications, and its fascinations.”

The series takes place the second Wednesday of every month.
Summer Institute on Earth-surface Dynamics

Mentoring the Next Generation of Earth-surface Scientists

2009: Complexity and predictability in earth systems
2010: Rivers and Vegetation
2011: Coastal processes and dynamics of deltaic systems
2012: Prediction under environmental change

...
Leading the community in new directions
Promoting Synthesis and Discovery

A overview paper on deltas

Special Issue on River Flow Dynamics: Physical and Ecological Aspects
NCED as a player in Community Growth

- CZOs
- JGR-ES
- NCALM
- CSDMS
- Flume on the Mall
- SIESD
- UMSRS
- Geoscience Alliance
- STRESS
- 2002
- F-2-F
- CUAHSI
- Water Planet
- MYRES
- AGU Focus Group
- 2012
- NRC Landscapes on the Edge
NCED Strategy for Resource Management

A minimalistic management approach geared towards synthesis and integration

Education
- Synthesis post-docs
- Support for 3 IP managers
- Support of administrative staff
- Basic multi-PI experiments
- Research Field site development
- Data acquisition and model building
- Community efforts
- Visitors Program
- Knowledge transfer
- New initiatives

PIs

Diversity

SMM
NCED Synthesis and Discoveries
Breakthroughs in three Grand Challenges

1. Discovery of the linkages between physical, chemical, and biological processes over a range of scales and environments

2. Predictive understanding of ecosystem response to environmental change

3. Application of understanding to guide management decisions for resilient ecosystems
How does debris flow incise into bedrock?

Local short-lived dynamic impacts are important in predicting erosion.
How does the river network organize fluxes and whole ecosystems?

- Where in the landscape do functionally significant ‘ecological regime’ changes occur?
- Where would boundaries shift with environmental change?
Do dynamics change system connectivity?

Emergent scales of system participation in transport dynamics
How can extreme variability and multiple scales of motion be incorporated into geomorphic transport laws?

\[ \mathbb{P}(V \geq v) \sim v^{-\alpha} \]

\[ g(l) \sim l^{-\alpha} \]

\[ \phi^* (x, t) = \int_0^x g(l) \phi(x - l, t) \, dl \]
How does vegetation and landscape co-evolve?

Wax Lake Delta
How does mixed sediment move downstream and how does it affect biotic life?

Fine sediments reduce growth and survival of juvenile steelhead.
Do microorganisms feel turbulence and how does this affect nutrient cycling?

Small-scale turbulence significantly modulates algal and bacterial nutrient uptake and growth.

Ignoring the effect of turbulence in models of population dynamics can result in significant biases in nutrient cycling predictions at the reach scale.

Shear guided swimming by green algae
Critical Processes: Thresholds of sea level together with subsidence that limit ability of wetlands to increase elevation and maintain stable position in the landscape.

What is the role of plant–sediment interaction in wetland stability?
How to explore high resolution topography for improved modeling?

Ω: Surface described by the regularized LIDAR data through nonlinear filtering.

Cost function $\psi$: cost of traveling on the curve $C$.

Geodesic curve curve with minimal cost, among all possible curved connecting the two point $a$ and $b$.

Example of river network extraction on Skunk Creek, South Fork Eel River basin, CA
How to explore high resolution topography for hazard prediction and control?

- GeoNet: A tool for river network extraction from LiDAR
- Mapping of river banks and floodplains
- Mapping of shallow landslides
- Mapping of deep-seated landslides
- Mapping roads
NCED Solutions
(Science-based solutions to real-world problems)
What causes the decline of Coho in the Eel River?
How to reduce sedimentation to Lake Pepin?

Minnesota River
- 38% of water supplied to Lake Pepin
- 81-88% of sediment supplied to Lake Pepin

Le Sueur River
- ~ 1/3 of sediment supplied to Minnesota River

Pre-settlement: 81% Mn R
Present: 88% Mn R

Engstrom & Allmendinger, 1997
Kelley & Nater, 2000
How to build a sustainable Mississippi Delta?

Is It Feasible to Build New Land in the Mississippi River Delta?

What if the Mississippi River levees were cut below New Orleans? What if much of the water and sediment were allowed to flow out and build new delta? Could deltaic land loss be reversed, and indeed restored?

Using a conservative sediment supply rate and a range of rates of sea level rise and subsidence, a physically based model of deltaic river sedimentation [Kim et al., 2009] predicts that approximately 200–1200 square kilometers of new land (exposed surface and in-channel freshwater habitat) could be built over a century (Figure 1).

Sinking into the Sea

The Hurricane Katrina disaster of August 2005 highlighted a problem recognized for decades. The Mississippi River delta is sinking into the sea [e.g., Pinhey, 2001]. In natural systems, large, fine-grained deltaic subsidence due to sediment compaction, building, and other effects. Subsidence is counteracted by overbank sediment deposition and avulsion into low areas. The result is a delta in which subsidence and sedimentation balance over time.

Below the U.S. Army Corps of Engineers Old River Control Structures in southern Louisiana, engineered levees on the Mississippi River prevent overbank deposition and sudden changes in the course of the river (Figure 1). The sediment that would have been deposited on the delta is instead eroded at sea, resulting in an overall negative sediment balance across the region, leading to land loss.

To date, however, arguments neither for nor against controlled avulsions have been supported by quantitative models predicting evolution of the deltaic landscape as a function of sediment supply, subsidence, and sea level rise rates, delta topography-bathymetry, and other key factors. To gain new insight, scientists are using quantitative sediment transport and delta building models.

EOS, Kim et al., 2010

Land loss since 1932 (2,000 Km2)
NCED Industrial and Agency Partnerships

PRRSUM = Partnership for River Restoration in the Upper Midwest
NCED Deliverables

- Ripple, ShalStab, ShaRun, GeoNet
- River morphodynamics modules → CSDMS
- Delta Land Building Manual
- Stream Restoration Decision Analysis and Design Guidance
NCED Legacies

1. Transformed the field of earth-surface dynamics: an integrative interdisciplinary predictive approach based on a seamless dialogue between experiments, theory, modeling and field observations to test hypotheses and models, guide field work, and bring science into restoration practice

2. Trained the next generation of interdisciplinary quantitative leaders

3. Developed state-of-the-art research infrastructure and tools as a community resource

4. Created a successful framework for engaging Native Americans into Geosciences

4. Established a paradigm for Museum-academia partnership to bring “earth surface science” to larger audiences
NCED as a world resource ...

Terrain-based modeling within Google!

- NCED - Google.org collaboration to implement NCED tools ShalStab, ShaRun, and GeoNet within Googles’ Earth Engine API

- An entry point for the earth sciences community to “democratize” data and terrain-based models for water, hazard, and ecosystem predictions ...
Beyond Borders
NCED’s Influence Around the World
ICED: a nexus of institutions committed to international collaboration in research, data exchange, and graduate education on Earth-surface Dynamics

Deltares partnership +
IPGP: Inst Phys Globe Paris
Univ of Padova
Univ Natural Res and Applied Life Science
Extensive international exchange in research and students

NCED as a catalyst of a Research Coordinating Network on Earth-surface Dynamics

RHNSS: Rivers for Humans and Nature -- Science for Sustainability

… to foster an integrative approach to river science, from source to sink, from science to implementing solutions, from social to cultural, and from research to education and policy.

… We propose to start with a prototype research coordination network that focuses on three large rivers of the world and their deltas: the Mississippi River in the United States, the Danube River in Europe, and the Parana River in South America.
Improve the resilience of world’s deltas

... to focus attention on the vulnerability of deltas worldwide and to promote and enhance successful international collaboration that will support more effective and efficient responses to the increasing pressures in river deltas worldwide ...

Initiative is currently in progress, proposed at the World Delta Forum, Oct 2010, motivation paper in circulation, seeking support by ICSU ...
EAB advice

Feb. 2011 report .... “NCED has a community identity and a momentum and it would be a great loss to lose a connection to NCED facilities and approach ...”

Proposed 3 organizational models for continued growth of the community:

1. **Community Center for Earth-surface Dynamics (CCED)**
   -- retain a critical mass of synergistic activities, maintain the ESD community access to experimental infrastructure, teach others the NCED experimental approach, and continue to bring different disciplinary groups together ...

2. **International Research Coordination Network (ICED)**
   -- An organization of institutions committed to international collaboration in research, data exchange and graduate education in ESD...

3. **National Community Earth-surface Dynamics Laboratories (CESDL)**
   -- A collection of experimental facilities and labs for linked eco- and earth surface studies that provide continued training and tools to the community...
2010: ARI-R² grant to create a world-class laboratory for energy and environmental sustainability.
NCED research naturally leads to future directions in Climate and the Energy-Environment Nexus

- Hydrokinetic energy in tidal systems: environmental impacts and mitigation
- Hydrocarbon and resource exploration in coastal regions: ecosystem and socio-economic impacts
- Resilient Coastal Landscapes
- Hydraulically mediated biomass for biodiesel
In all, the STC infrastructure is the glue that holds centers together. Without sustaining support, the partnerships that blossomed and were at the core of the center are at risk. As graduation of an NSF STC looms, the loss of partnerships nurtured over almost a decade jeopardizes continuing fulfillment of the STC’s objectives.
Thank you!

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- NCED graduate students

- NSF Directors and Program Managers

- **8 Site Visit Teams – Thank you!**

- **8 EAB Advisory Committee Meetings – Thank you!**
NCED: 2002-2012 + Beyond

NCED site visit, May 17-18, 2011