Constructing vulnerability maps of material and energy pathways in deltas
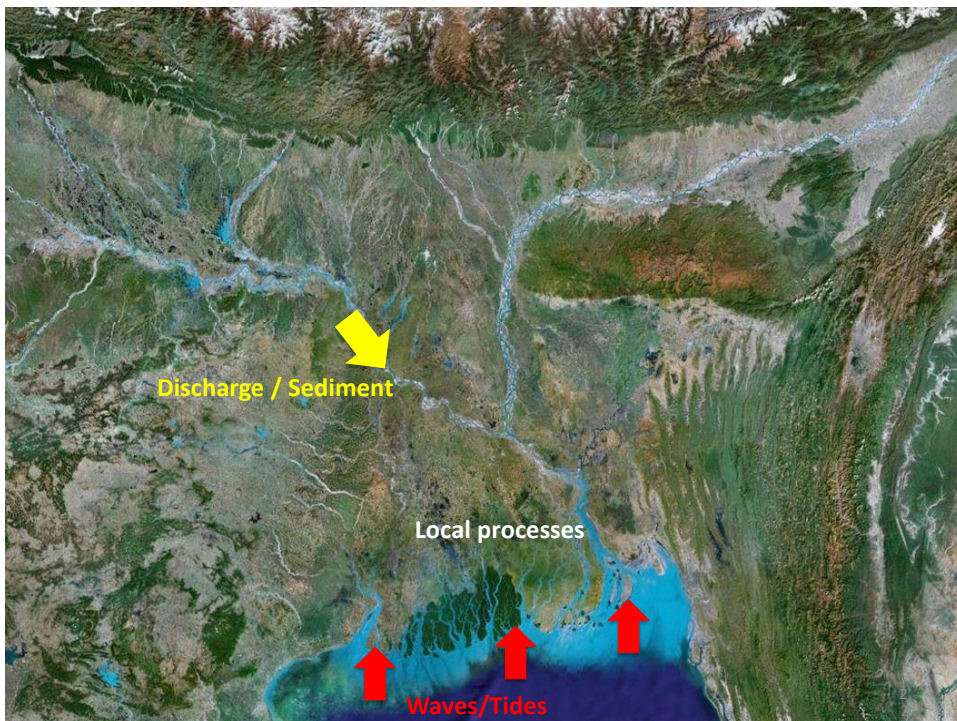

Deltas in Times of Climate Change II
Rotterdam. September 25, 2014
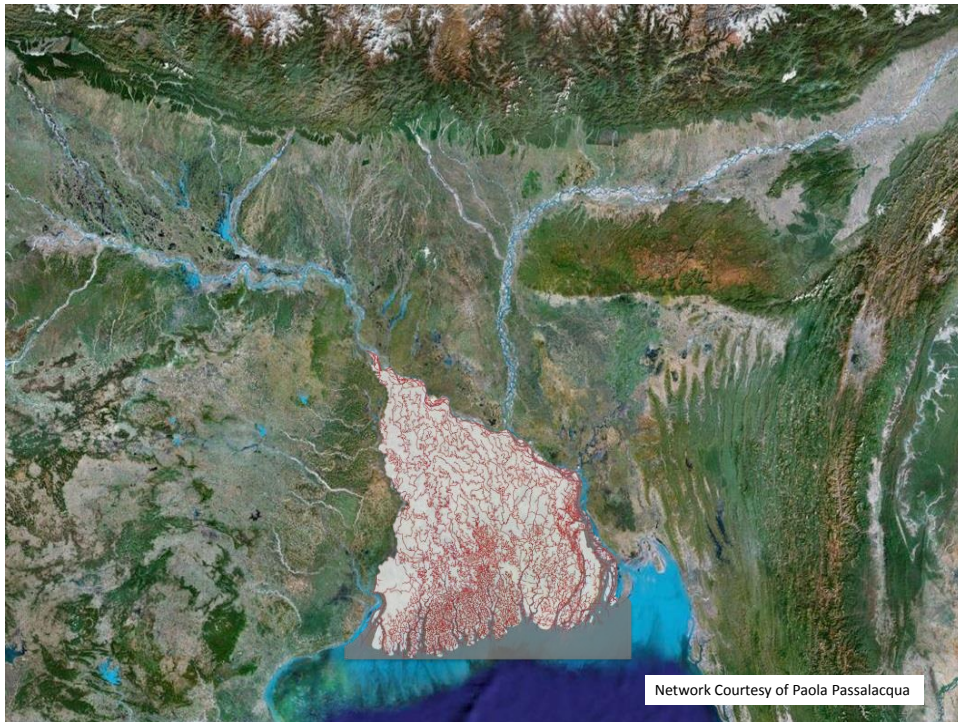
NSF   BELMONT FORUM

DELTAS SUSTAINABLE DELTAS 2015

Efi Foufoula-Georgiou
University of Minnesota
Department of Civil, Environmental and Geo- Engineering

Discharge / Sediment

Local processes

Waves/Tides

Network Courtesy of Paola Passalacqua

Questions

(1) How does delta connectivity (in geometry and dynamics) control the overall system robustness to change?

(2) Does connectivity of the delta tell us anything about the morphodynamics that established it?
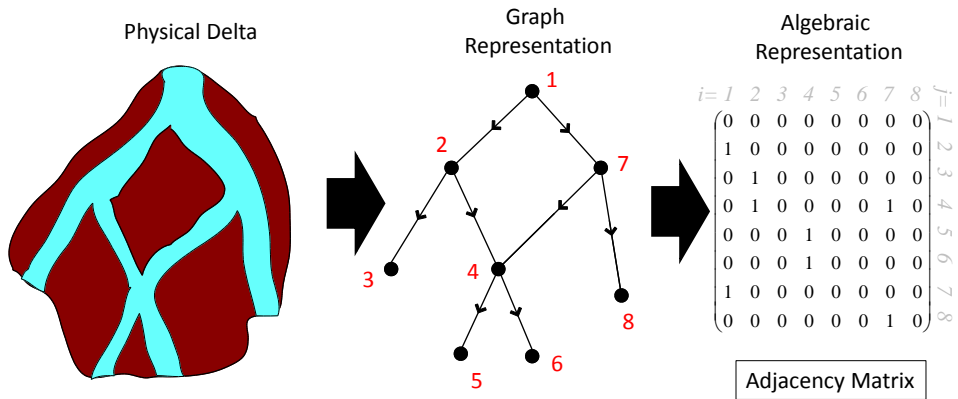
- **Approach:**

    Develop a framework that can allow probing into the delta system connectivity in a systematic way and evaluating system changes in view of changes in one or more of its connected components (vulnerability analysis)

- **We Propose:**

    1. A rigorous framework of delta network analysis:
        - Extracting subnetworks
        - Nourishment Areas
        - Upstream Areas
    2. Use this framework for building vulnerability maps
    3. Define metrics that capture the complexity of the topology and dynamics of the subnetworks, and enable us to establish a quantitative framework of comparison.

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Deltas as Graphs

Physical Delta
Graph Representation
Algebraic Representation

Adjacency Matrix

Transport and Vulnerability in River Deltas: A Graph-Theoretic Approach
A Tejedor, A Longjas, I Zaliapin, E Foufoula-Georgiou
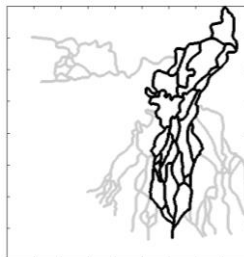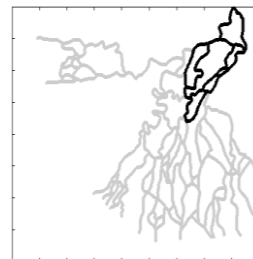arXiv preprint arXiv:1408.5834

5

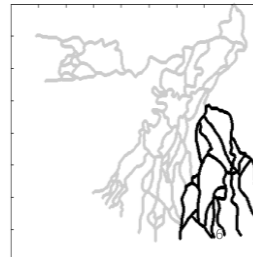# Delta Topologic Analysis

From Adjacency Matrix:
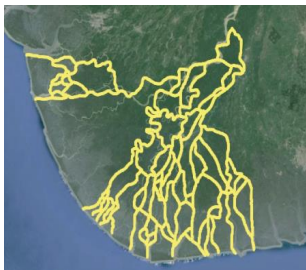
Extracting subnetworks
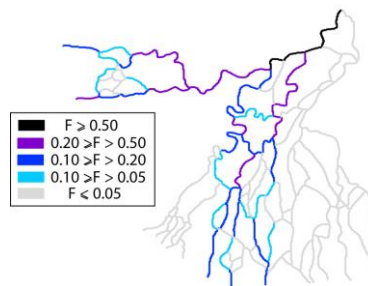
Upstream Areas

Nourishment Areas

Delta Dynamic Analysis

From Weighted Adjacency Matrix:

Steady Flux Distribution

■	F > 0.50
■	0.20 >F > 0.50
■	0.10 >F > 0.20
■	0.10 >F > 0.05
■	F < 0.05

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arXiv preprint arXiv:1408.5834

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Vulnerability to change

- How does a flux reduction at a given link affect the outlets?
- What links ("hot spots") cause the most drastic reduction to the outlets?

Wax Lake Delta
(Louisiana Coast, USA)
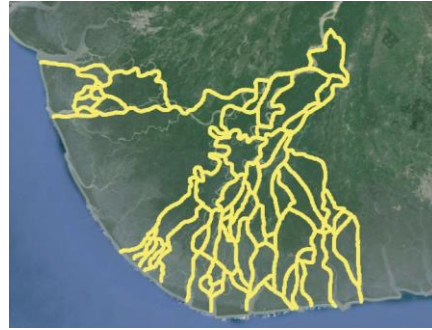
Niger Delta
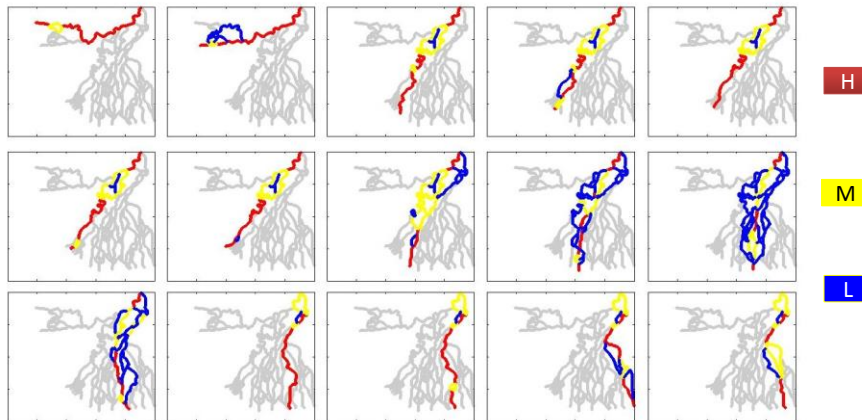(West Africa)

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Vulnerability Maps

Wax Lake Delta
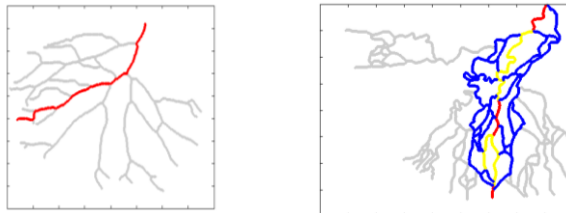

H

M

L
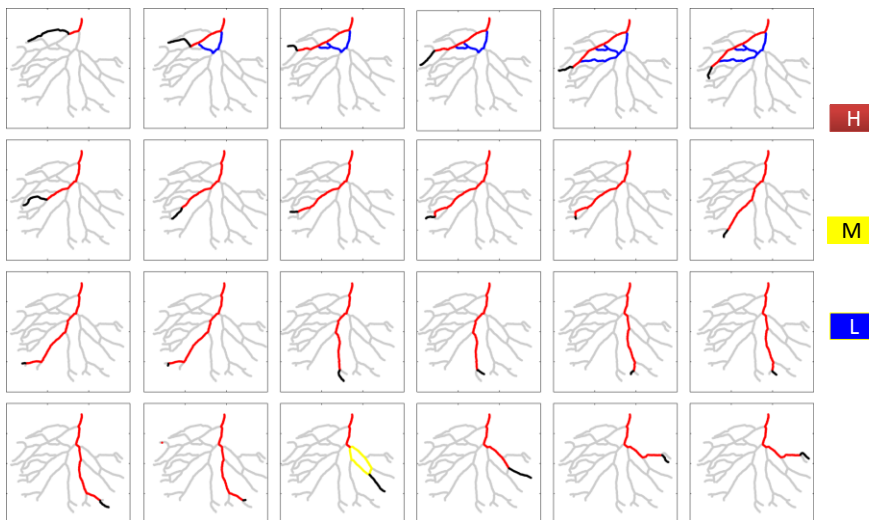
10

Vulnerability Maps
Niger Delta

H

M
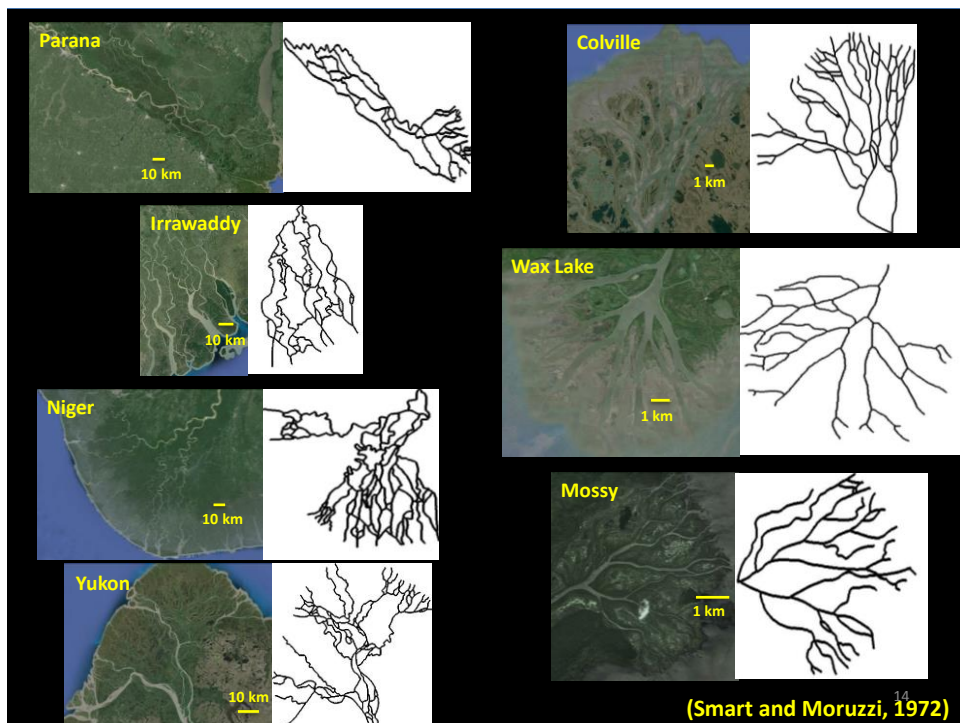
L

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Process => Shape => Vulnerability?

- Does vulnerability relate to the topology and dynamics of a deltas?

- What metrics capture the topology and dynamics of deltas?
- What does the topology and dynamics tell us about the physical processes that generated these deltas?

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(Smart and Moruzzi, 1972)
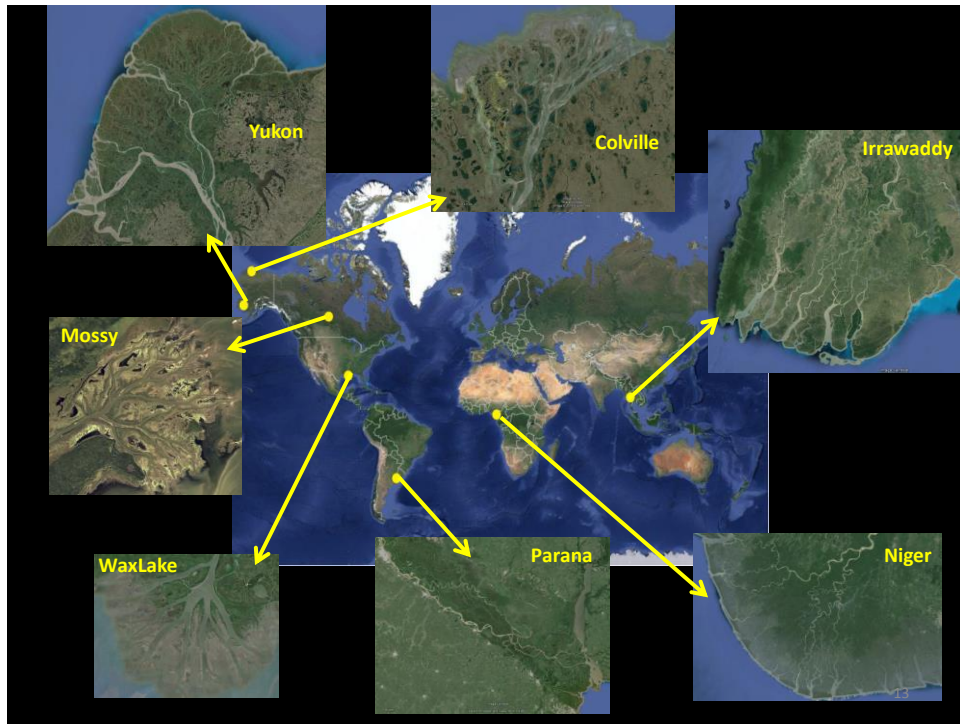
Geometric Complexity/Dynamic Exchange

1. Tree structure (Subnetworks are linear paths) versus loopy structure (Subnetworks contain multiple paths between the apex and the outlet)

2. How many Links (Flux) are shared among the different subnetworks. (Do some deltas consist of a set of pretty independent units/subnetworks, versus others that consist of a 'core' that is common to all the subnetworks?)
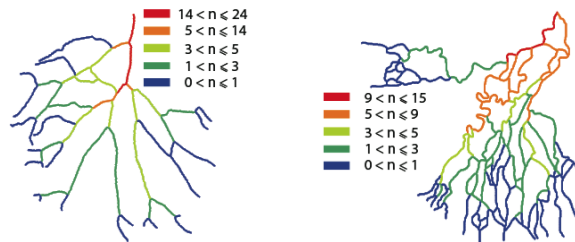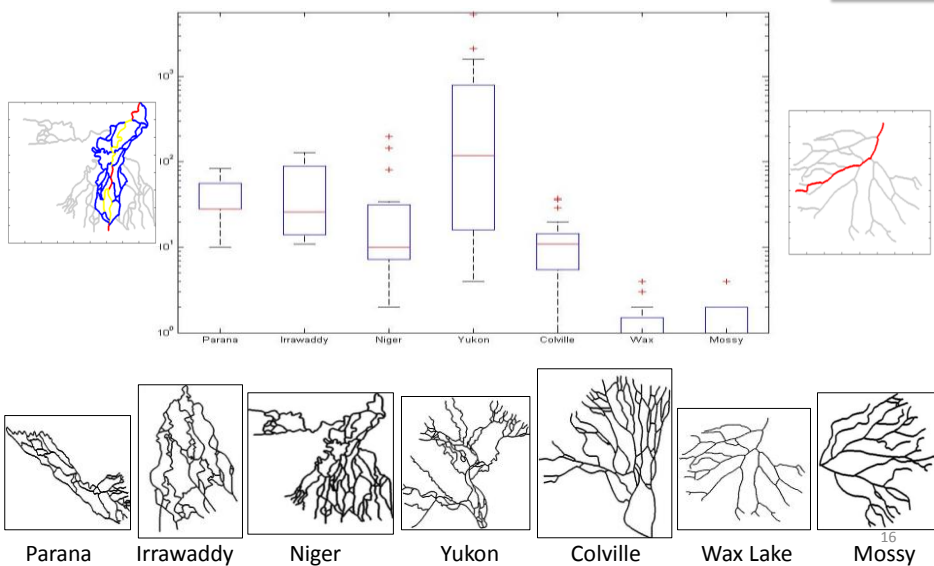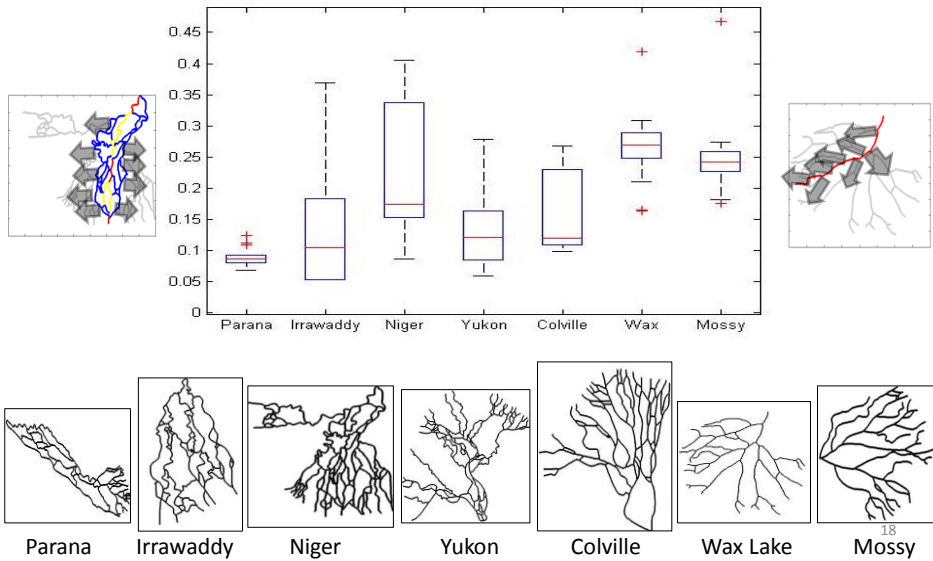

(n is the number of subnetworks to which a given link belongs)

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Geometric Complexity

Alternative Paths

Parana   Irrawaddy   Niger   Yukon   Colville   Wax Lake   Mossy

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Dynamic Exchange

Leakage

| Parana | Irrawaddy | Niger | Yukon | Colville | Wax Lake | Mossy |

"2-D Geo-dynamic Space" for Deltas

Yukon

Parana

Colville

Mossy

Niger

Irrawaddy

Wax Lake

Binary Tree

Dynamic Exchange

Geometric Complexity
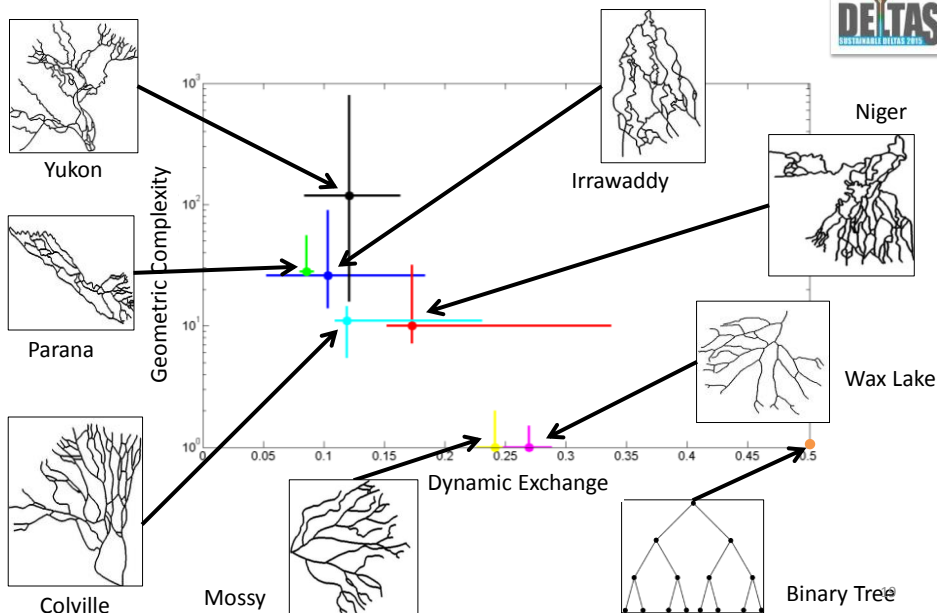
Open Problems

- Do "physically similar" deltas fall close-by into this 2D Geo-dynamic space for deltas?
- What does the "position" and "variability" in the 2D Geo-dynamic space reveal about the morphodynamic processes that created a delta?
- Do deltas with substantial anthropogenic influences deviate from prestine deltas in the 2D Geo-dynamic space?
- Can the age/size of a delta be revealed by its position into this 2D Geodynamic space?
- How does this position relate to vulnerability to change?

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Take home message

- Deltas are networks of connected pathways that deliver fluxes from the apex to the deltaic surface to the coast.

- This connectivity makes a difference in how vulnerable / robust they are to changes

- We have presented a framework that allows us to efficiently study these systems as "graphs" in order to systematically:
  - ✓ Compute the distribution of fluxes
  - ✓ Define subnetworks
  - ✓ Define Nourishment networks
  - ✓ Define Contributing networks
  - ✓ Evaluate scenarios of change
- We have established quantitative metrics that account for topologic and dynamic characteristics of deltas.

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Need automatic tools to extract delta networks from remotely sensed images

Network Courtesy of Paola Passalacqua

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Thank you!

Alejandro Tejedor
University of Minnesota

Anthony Longjas
University of Minnesota

Ilya Zaliapan
University of Nevada, Reno

Irina Overeen
University of Colorado, Boulder

Fabrice Renaud
United Nations University
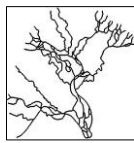
John Dearing
University of Southampton

Transport and Vulnerability in River Deltas: A Graph-Theoretic Approach
A Tejedor, A Longjas, I Zaliapin, E Foufoula-Georgiou   arXiv preprint arXiv:1408.5834   24

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Geometric Complexity vs. Map Robustness

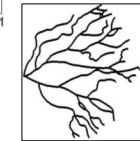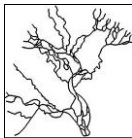**Alternative Paths**
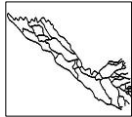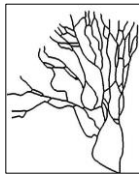
Yukon
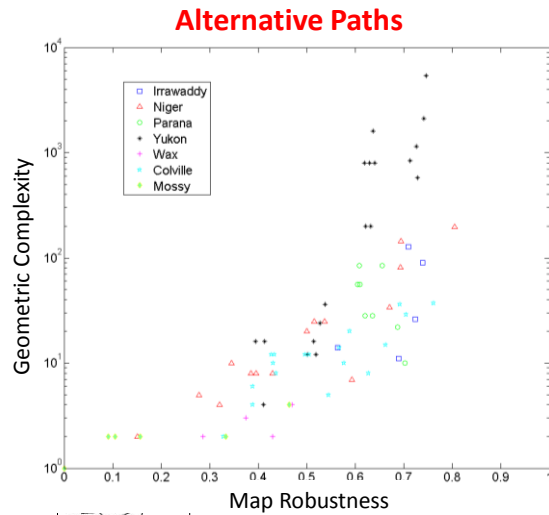
Parana
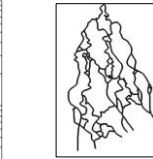
Colville
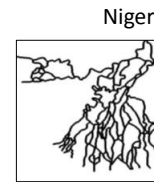
Wax Lake

Irrawaddy

Niger

Mossy

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Dynamic Exchange vs. Map Robustness

Leakage

Yukon

Parana

Colville

Wax Lake

Irrawaddy

Niger

Mossy

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