Constructing vulnerability maps of material and energy pathways in deltas

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

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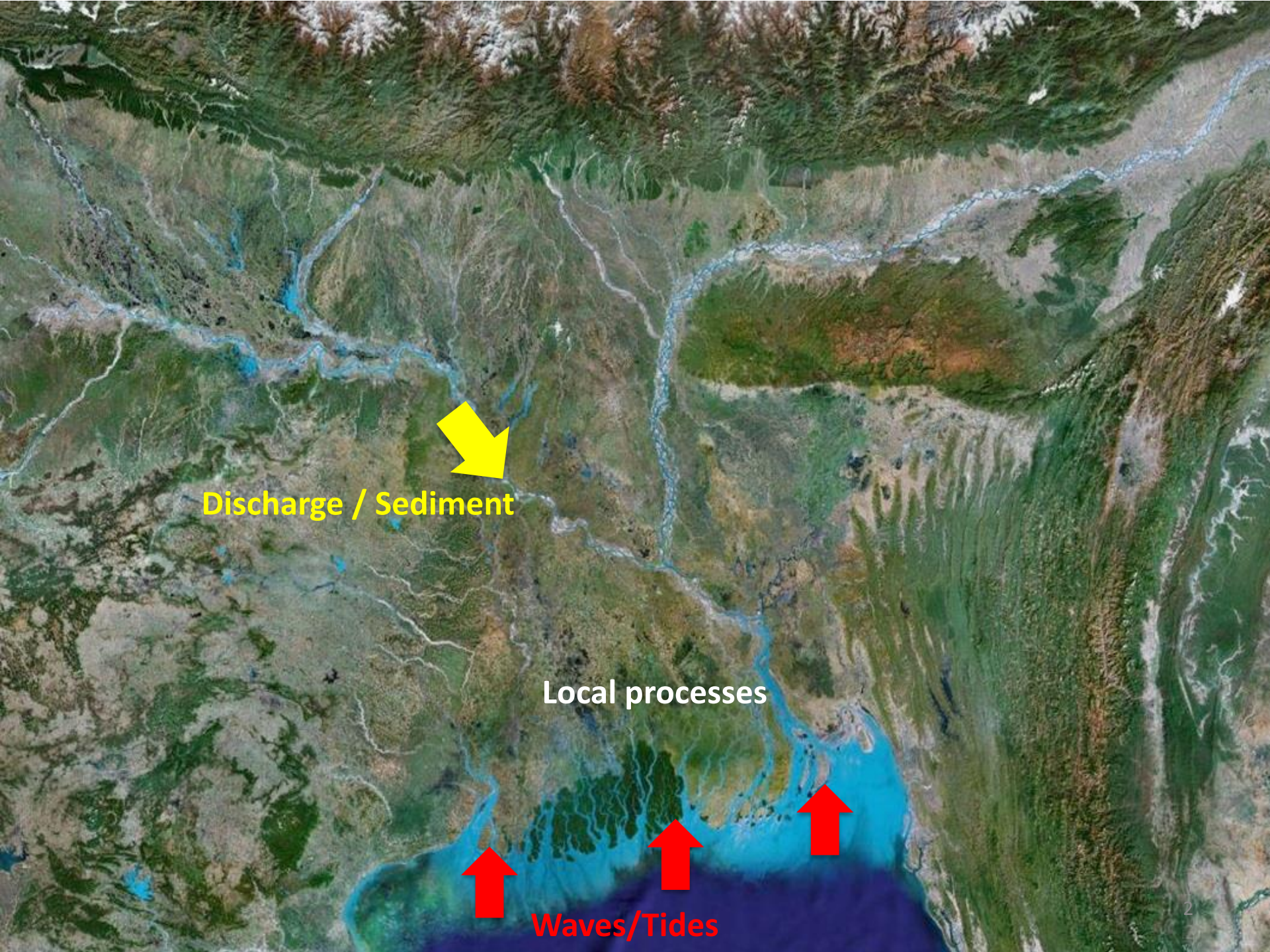

Discharge / Sediment
Local processes
Waves/Tides

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:**

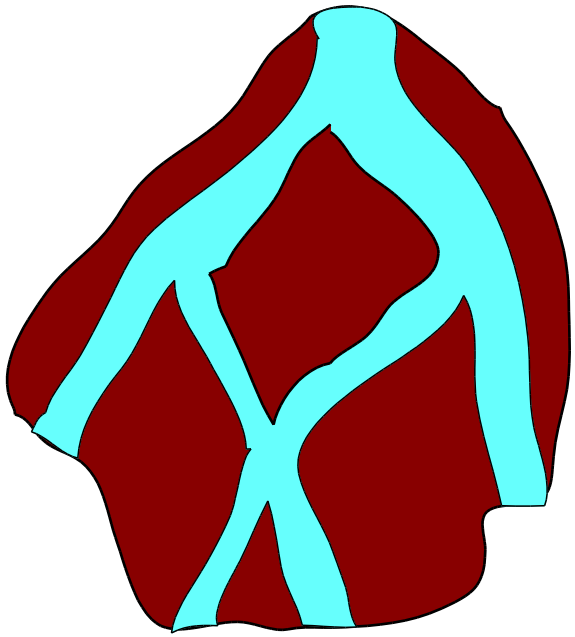
  Develop a framework that can allow probing into the delta system connectivity in a systematic way and evaluating system changes in view of changes in one or more of its connected components (vulnerability analysis)

- **We Propose:**

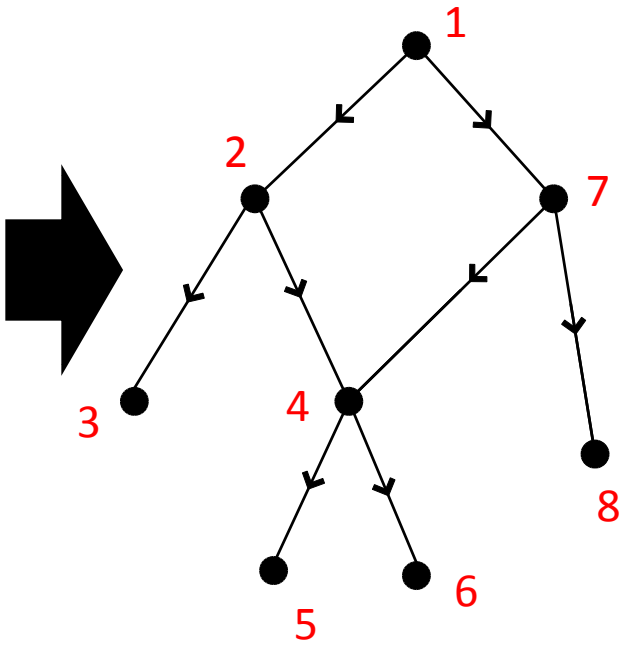
  1. A rigorous framework of delta network analysis:
     - Extracting subnetworks
     - Nourishment Areas
     - Upstream Areas
  2. Use this framework for building vulnerability maps
  3. Define metrics that capture the complexity of the topology and dynamics of the subnetworks, and enable us to establish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

Deltas as Graphs

Physical Delta



Graph Representation



Algebraic Representation

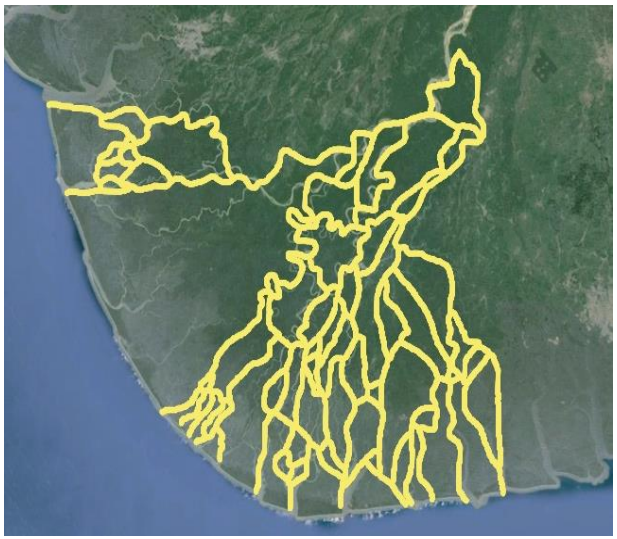
$i=$ / $j=$	1	2	3	4	5	6	7	8
1	0	0	0	0	0	0	0	0
2	1	0	0	0	0	0	0	0
3	0	1	0	0	0	0	0	0
4	0	1	0	0	0	0	1	0
5	0	0	0	1	0	0	0	0
6	0	0	0	1	0	0	0	0
7	1	0	0	0	0	0	0	0
8	0	0	0	0	0	0	1	0

Adjacency Matrix

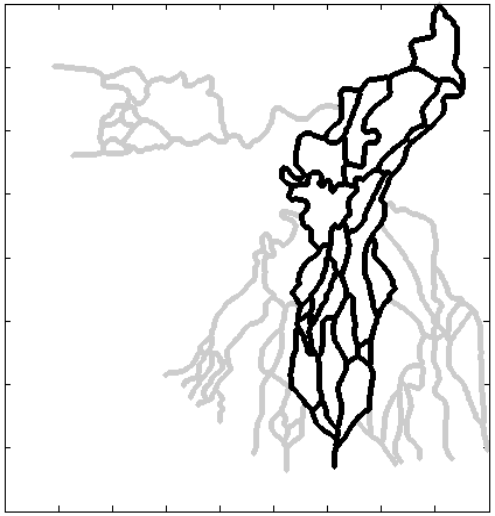
Transport and Vulnerability in River Deltas: A Graph-Theoretic Approach
A Tejedor, A Longjas, I Zaliapin, E Foufoula-Georgiou
arXiv preprint arXiv:1408.5834

Delta Topologic Analysis

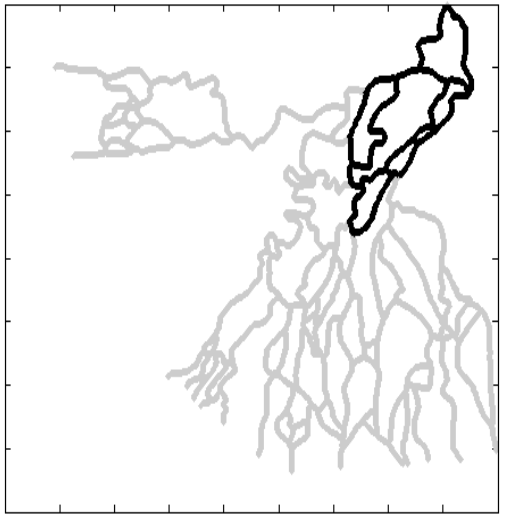
From Adjacency Matrix:



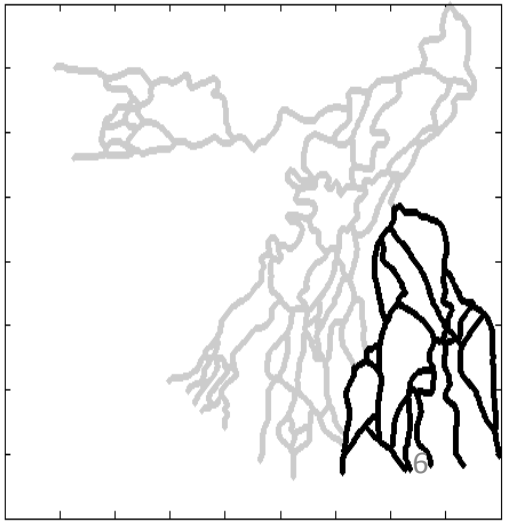
Extracting subnetworks



Upstream Areas



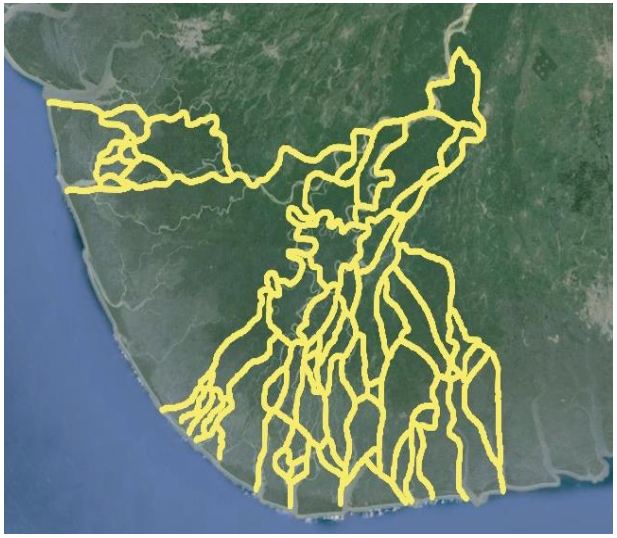
Nourishment Areas



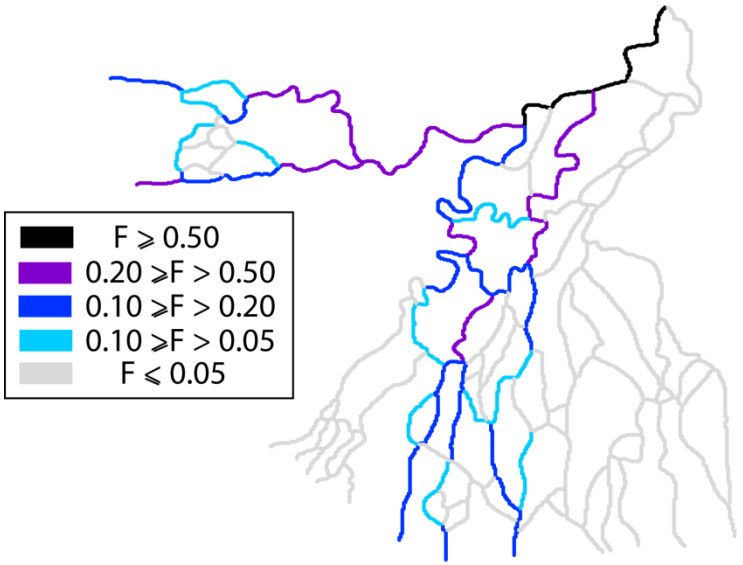
UNIVERSITY OF MINNESOTA
Driven to Discover
DELTAS
SUSTAINABLE DELTAS 2015

Delta Dynamic Analysis

From Weighted Adjacency Matrix:



Steady Flux Distribution



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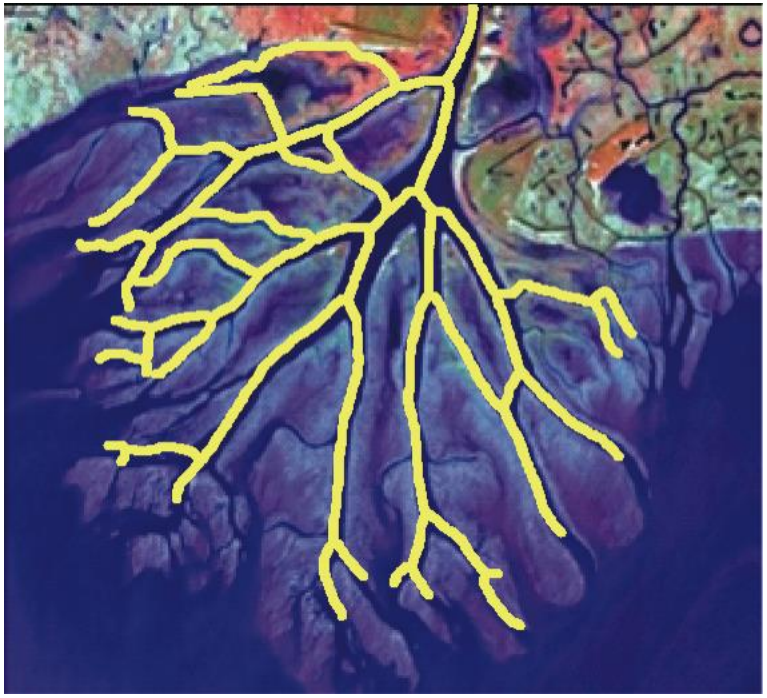
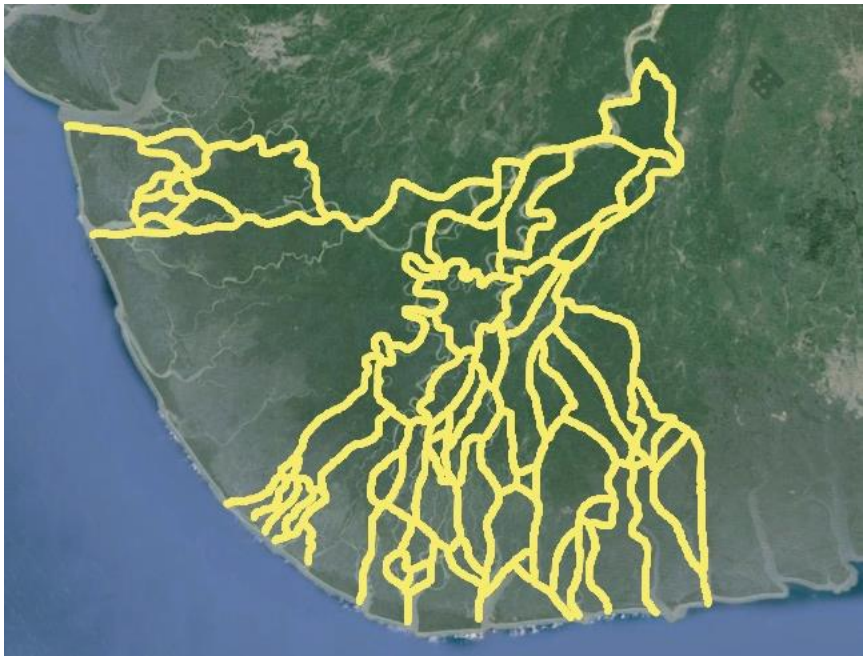
Vulnerability to change

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



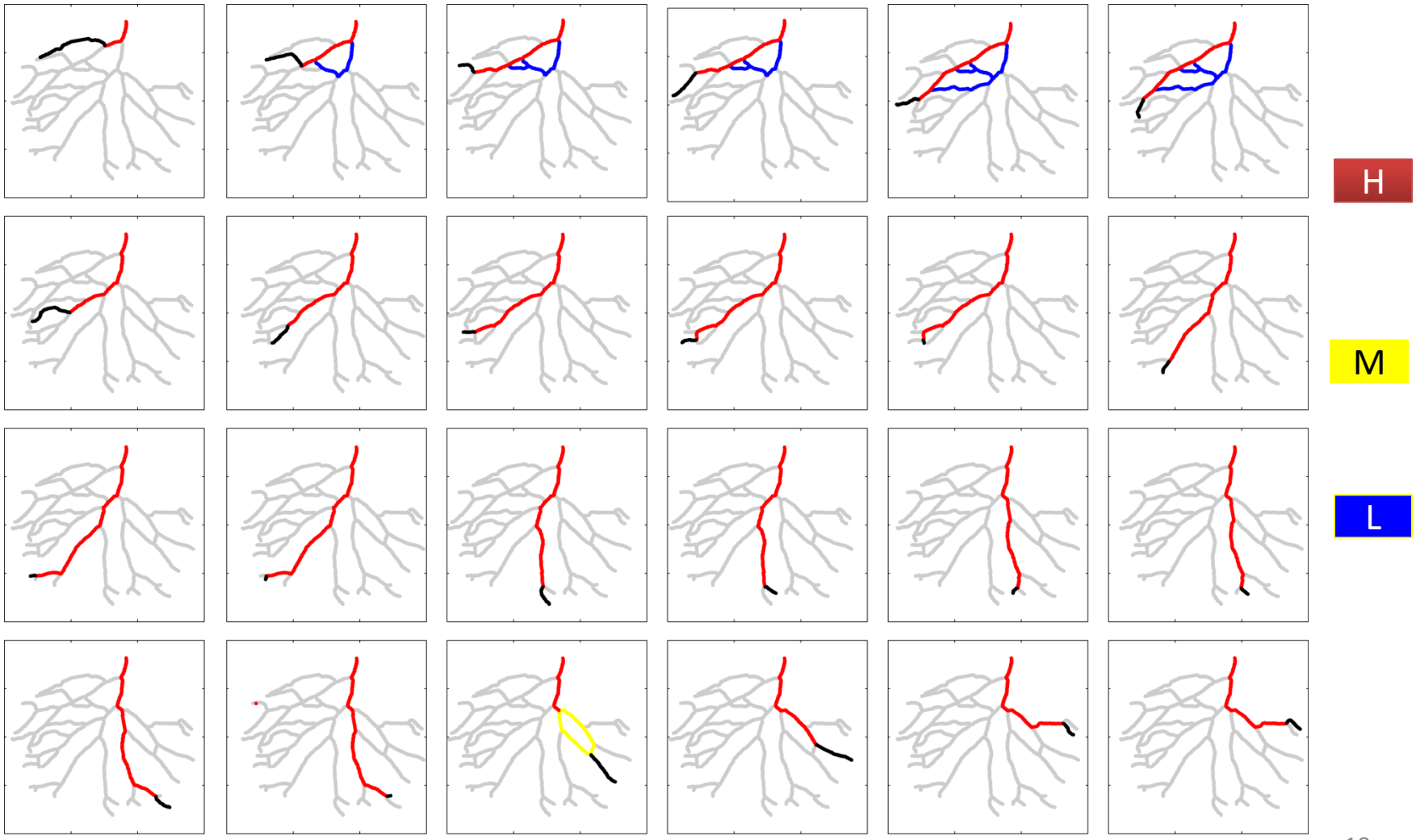
Wax Lake Delta
(Louisiana Coast, USA)



Niger Delta
(West Africa)

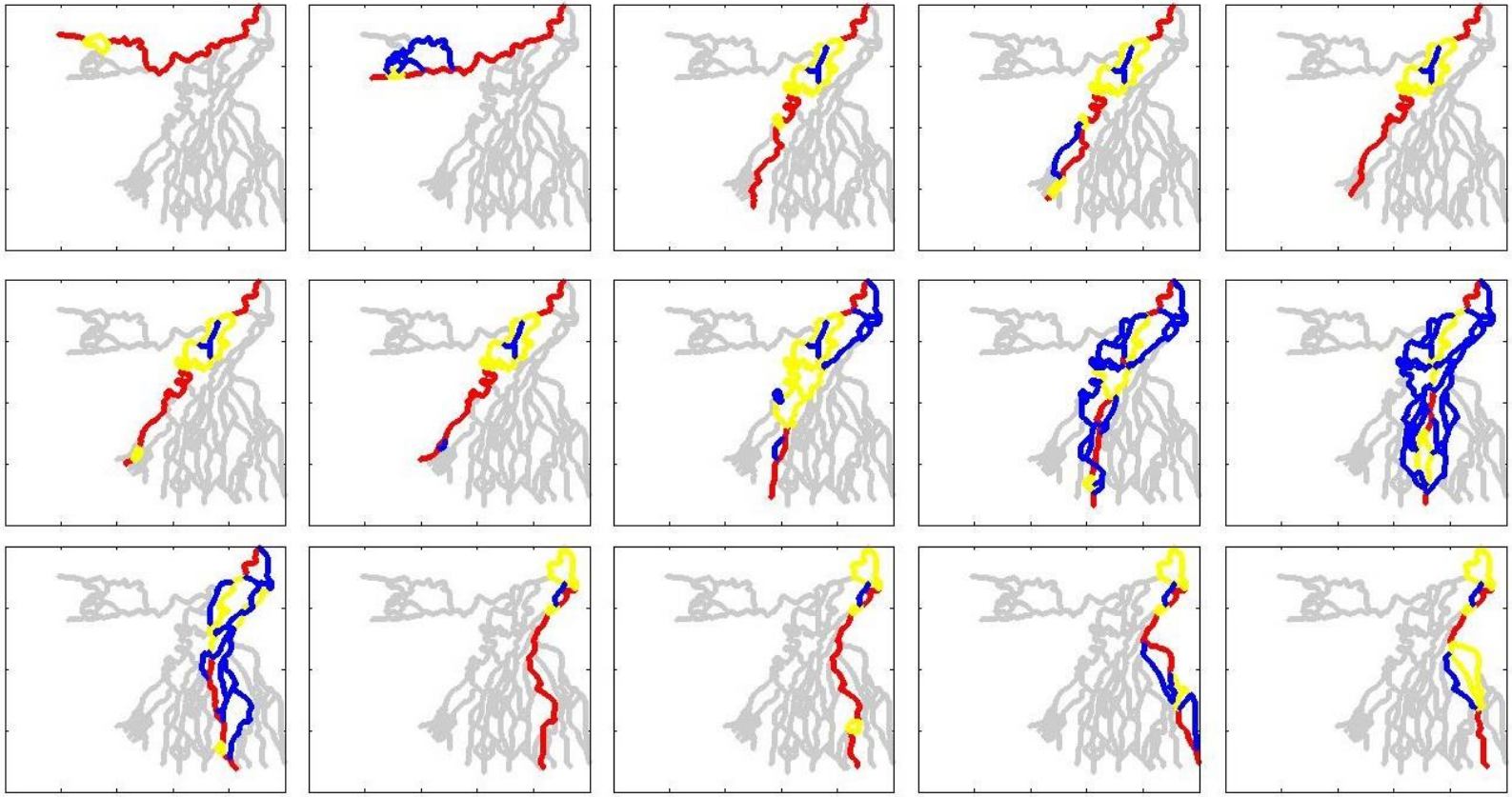
Vulnerability Maps

Wax Lake Delta



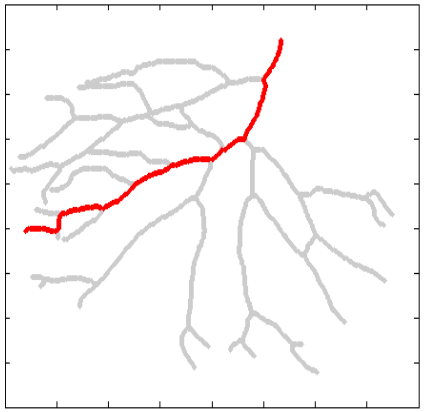
Vulnerability Maps

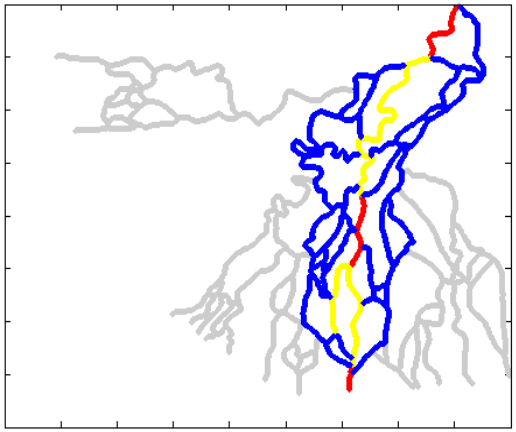
Niger Delta



Process => Shape => Vulnerability?

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



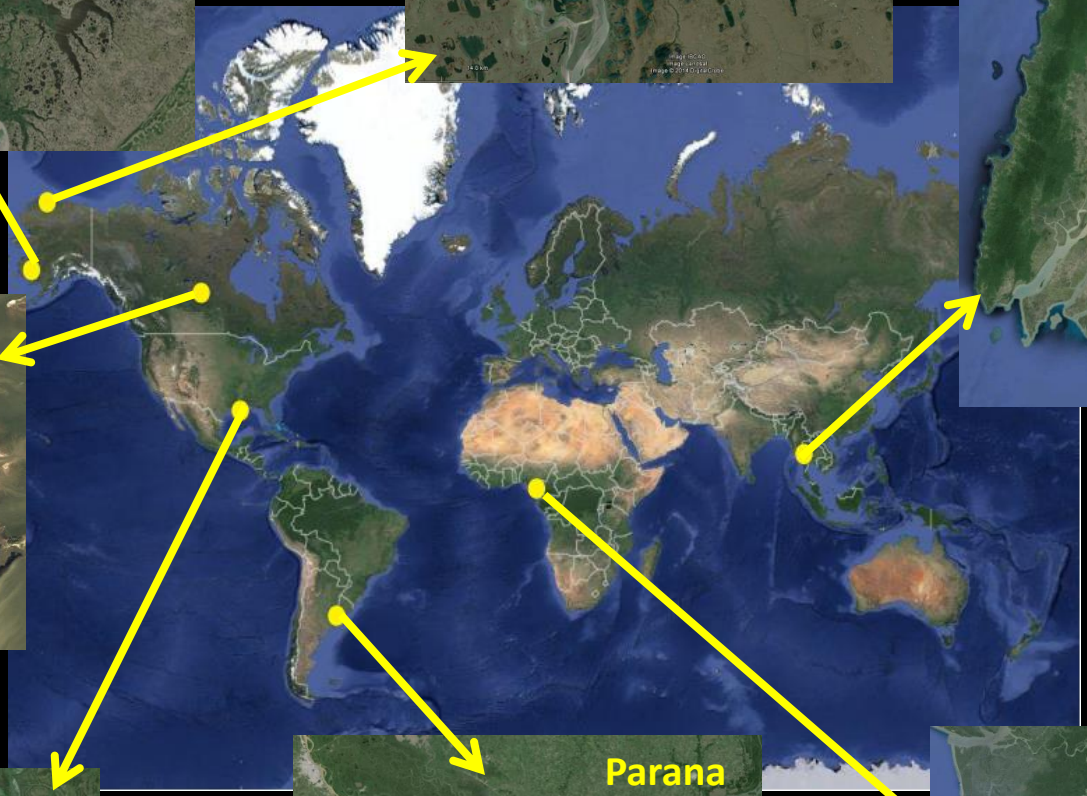


- What metrics capture the topology and dynamics of deltas?
- What does the topology and dynamics tell us about the physical processes that generated these deltas?

Yukon

Colville

Irrawaddy

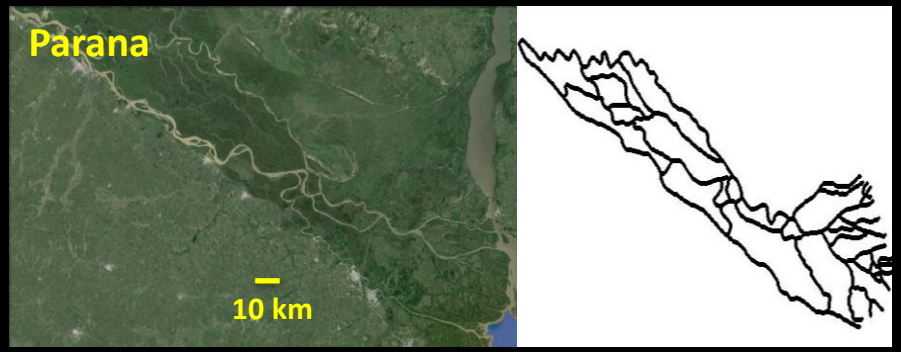


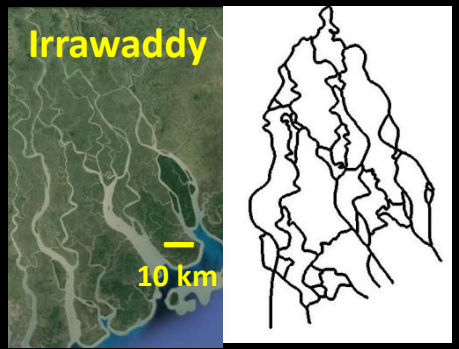
Mossy

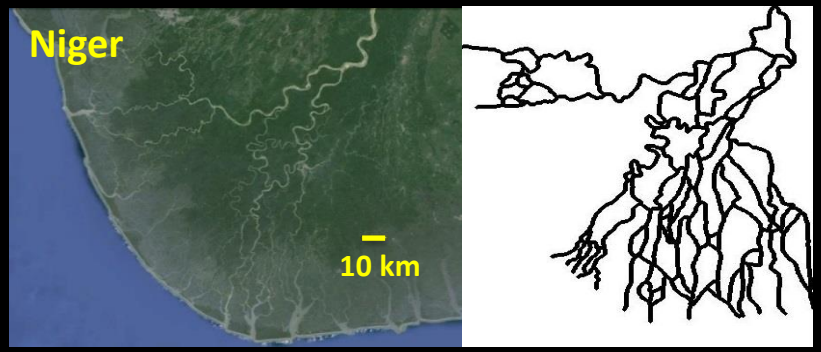
WaxLake

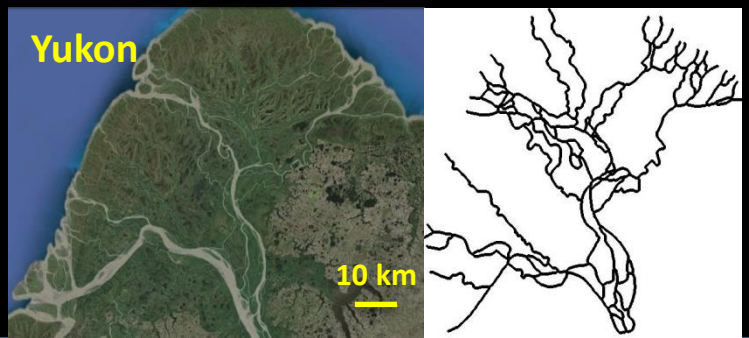
Parana

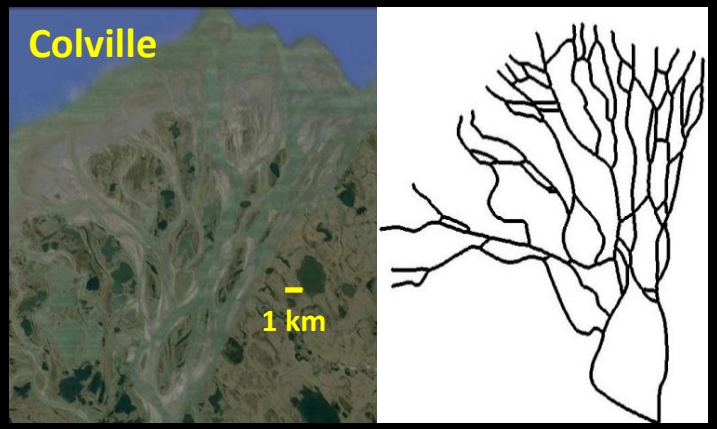
Niger

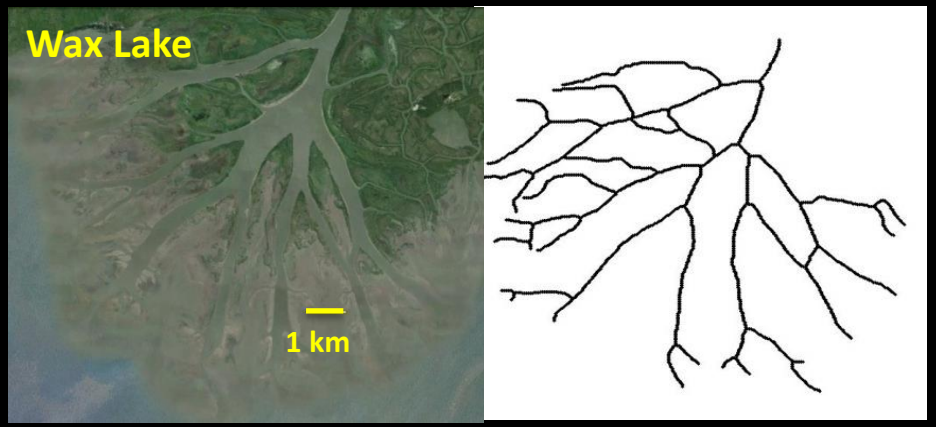


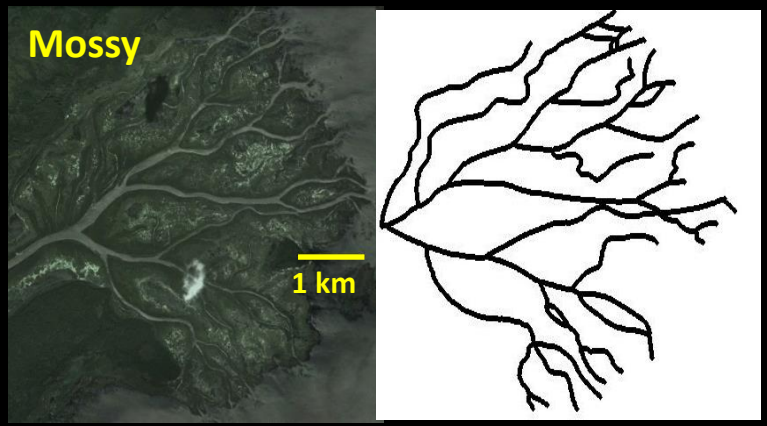










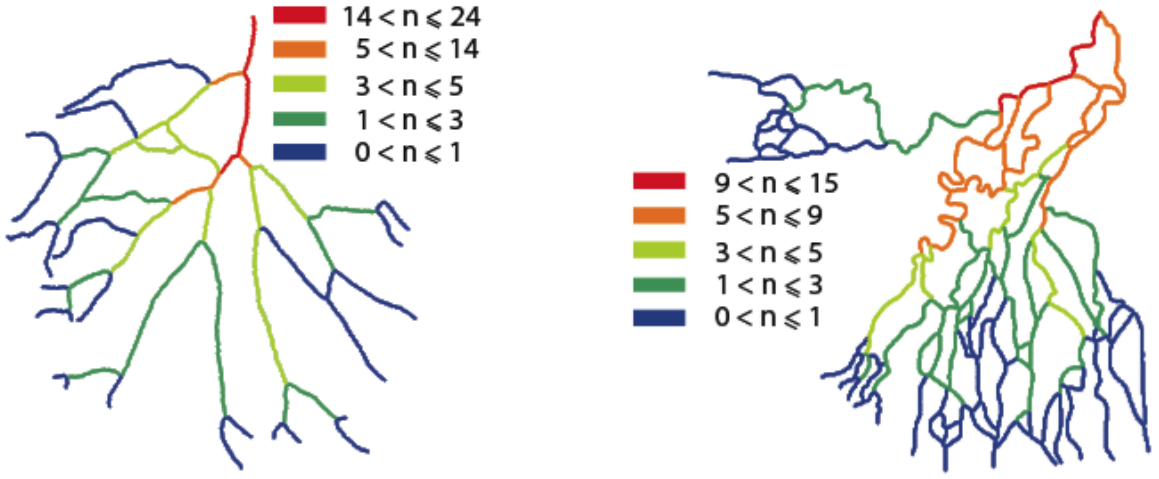


(Smart and Moruzzi, 1972)

Geometric Complexity/Dynamic Exchange

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

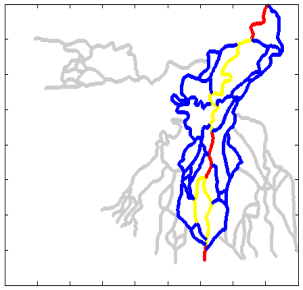
2. How many Links (Flux) are shared among the different subnetworks. (Do some deltas consist of a set of pretty independent units/subnetworks, versus others that consist of a 'core' that is common to all the subnetworks?)

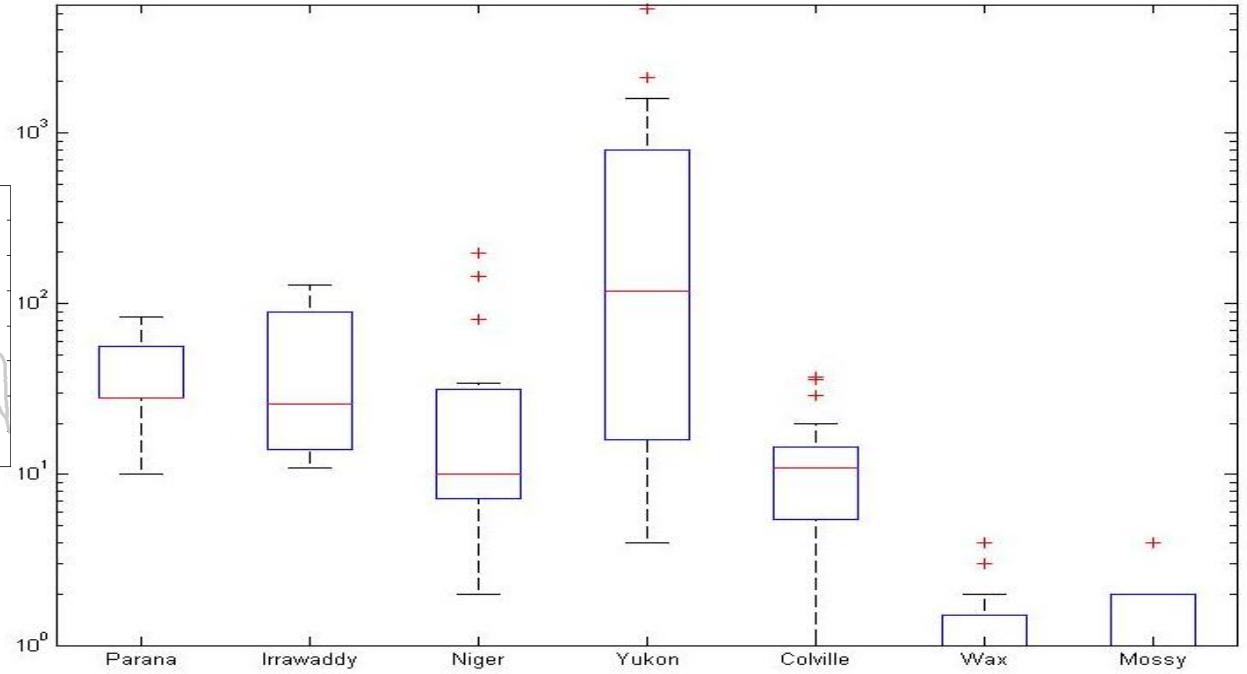


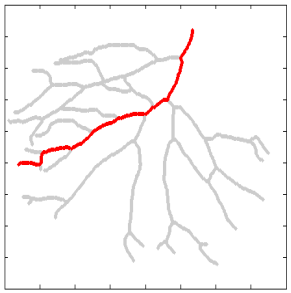
(n is the number of subnetworks to which a given link belongs)

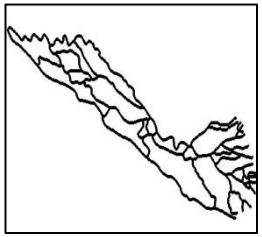
Geometric Complexity

Alternative Paths

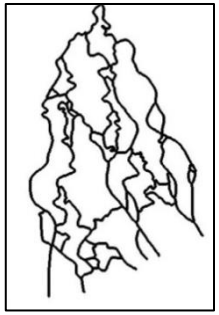




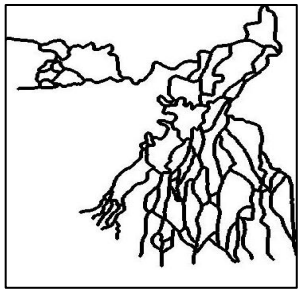




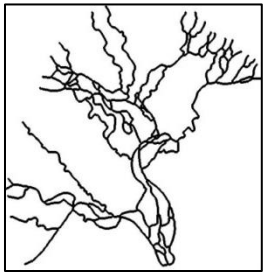
Parana



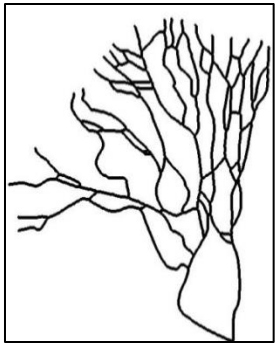
Irrawaddy



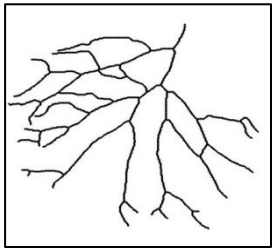
Niger



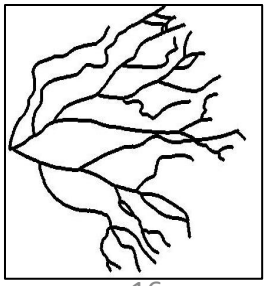
Yukon



Colville



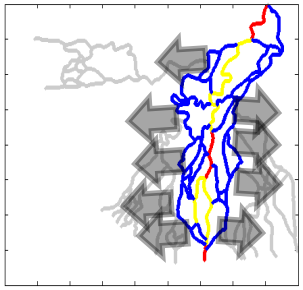
Wax Lake

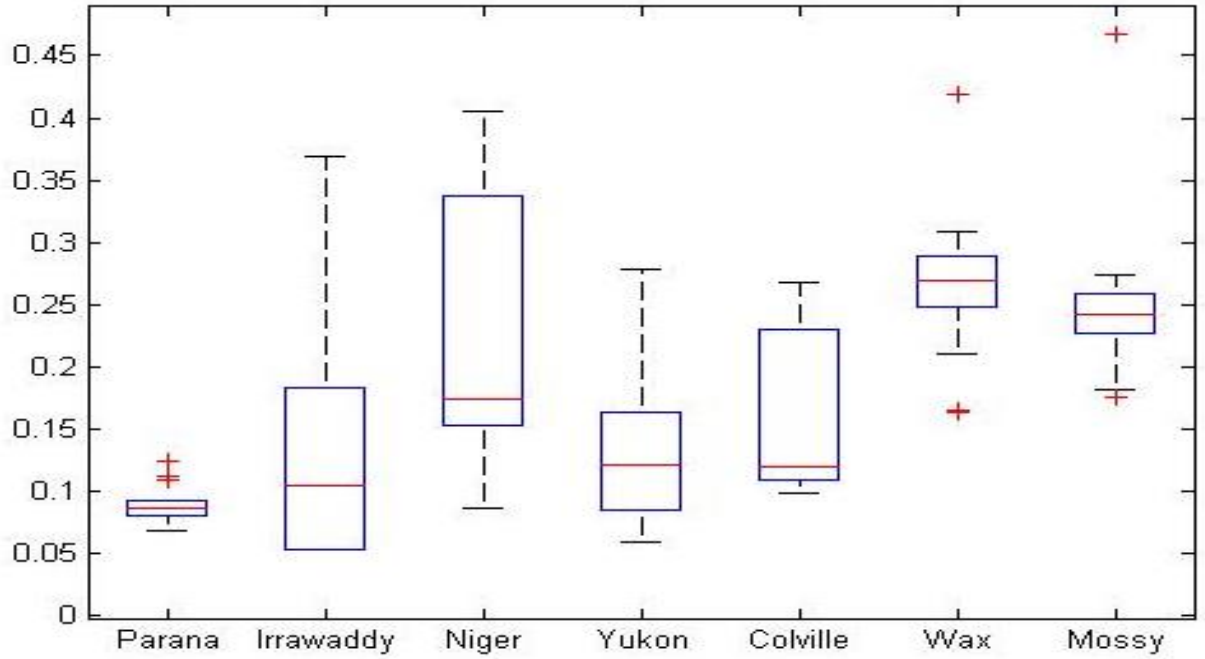


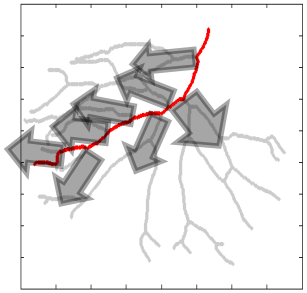
Mossy

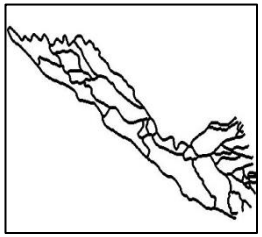
Dynamic Exchange

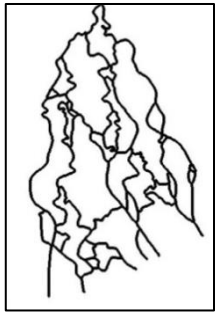
Leakage

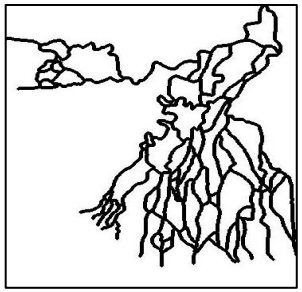


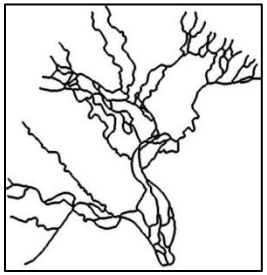


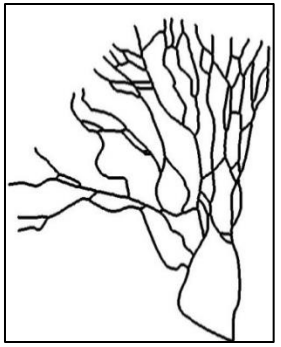


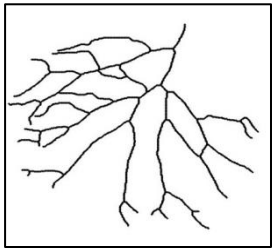


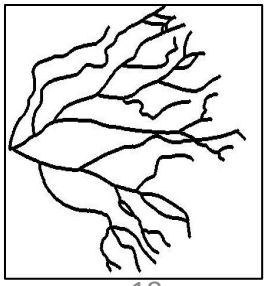






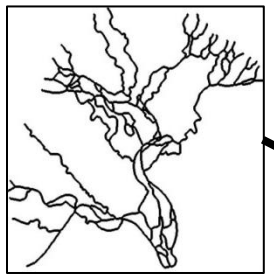




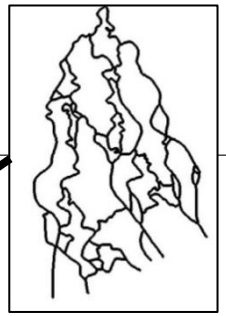


Parana Irrawaddy Niger Yukon Colville Wax Lake Mossy

“2-D Geo-dynamic Space” for Deltas

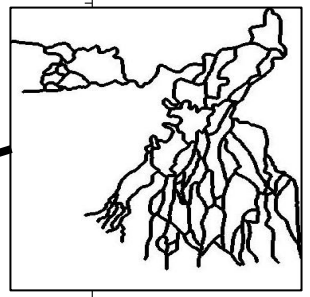


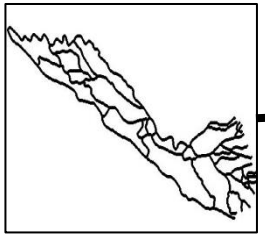
Yukon



Irrawaddy

Niger





Parana

Geometric Complexity

10^3

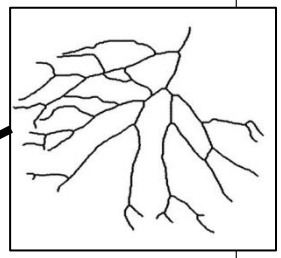
10^2

10^1

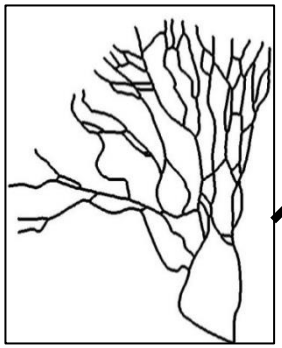
10^0

0 0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5

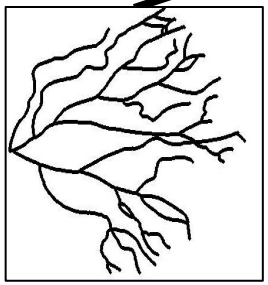
Dynamic Exchange



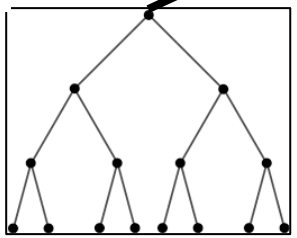
Wax Lake



Colville



Mossy



Binary Tree

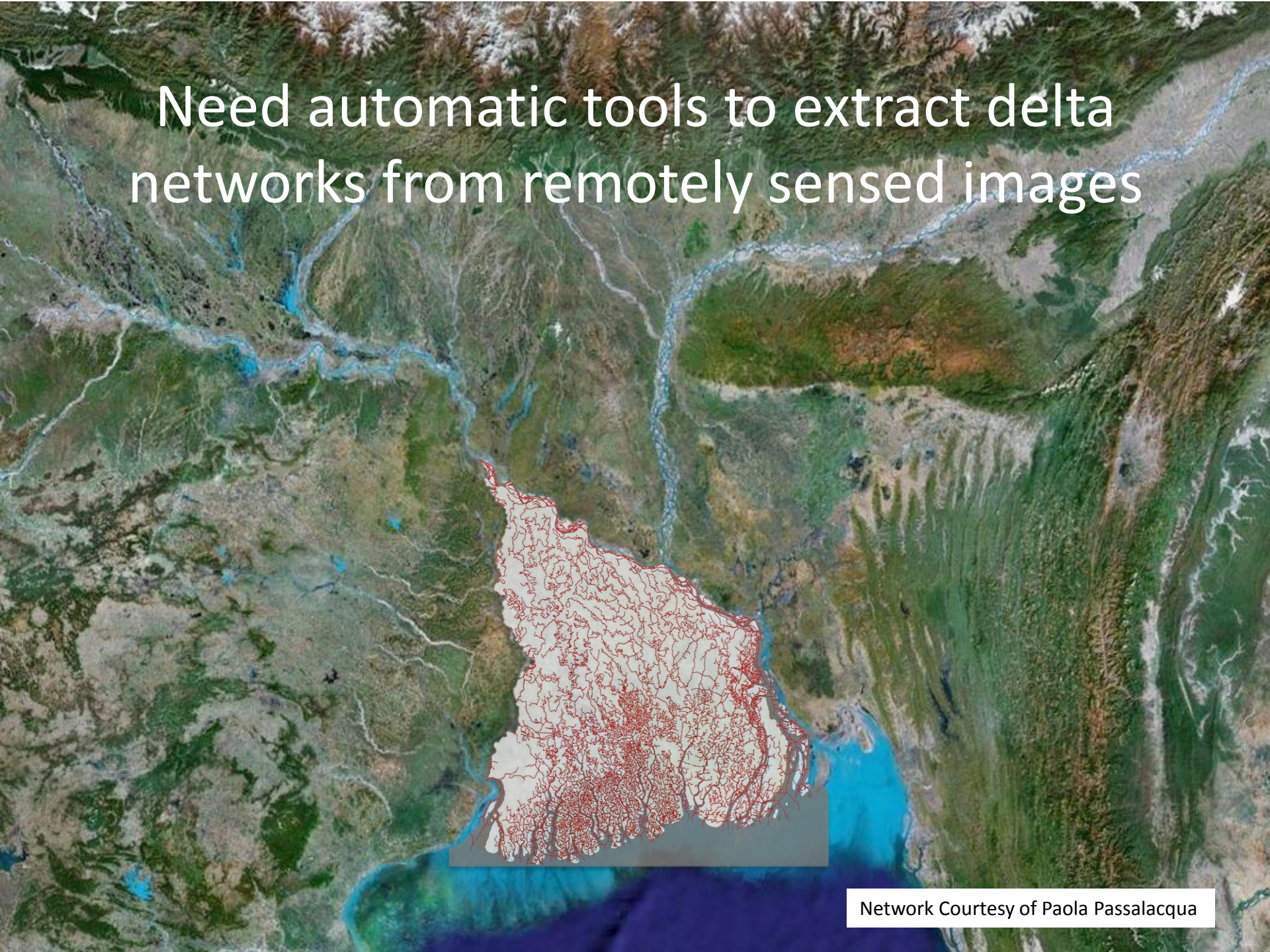
Open Problems

- 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?

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.

Need automatic tools to extract delta networks from remotely sensed images



Network Courtesy of Paola Passalacqua

GeoNet: Geomorphic Feature Extraction

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Links

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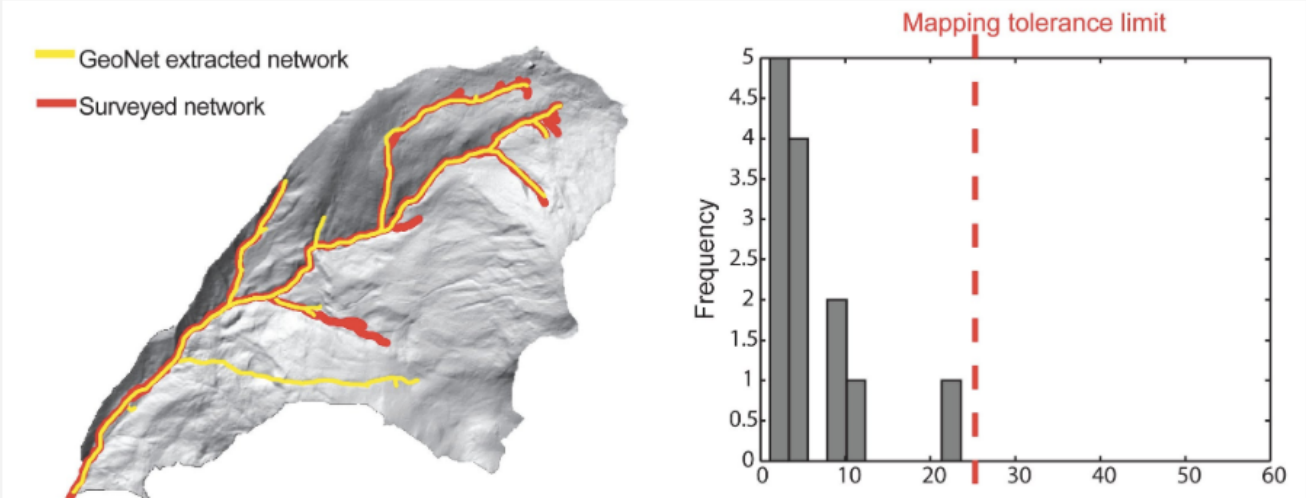
Home

Welcome to GeoNet

GeoNet is a computational tool for the automatic extraction of channel networks and channel heads from from high resolution topography. The most recent version is GeoNet 2.0, which followed GeoNet 1.0 and GeoNet 1.0.1.

GeoNet combines nonlinear filtering for data preprocessing and cost minimization principles for feature extraction. The use of nonlinear filtering achieves noise removal in low gradient areas and edge enhancement in high gradient areas, i.e., near feature boundaries. After preprocessing, GeoNet extracts channels as geodesics—lines that minimize a cost function based on fundamental geomorphic characteristics of channels such as flow accumulation and curvature. Please see our Publications for details on the method.

GeoNet can be downloaded through the Download page. The package contains example data sets and scripts to run them. Information on how to run GeoNet on other data sets can be found in the How-to page.



Thank you!

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