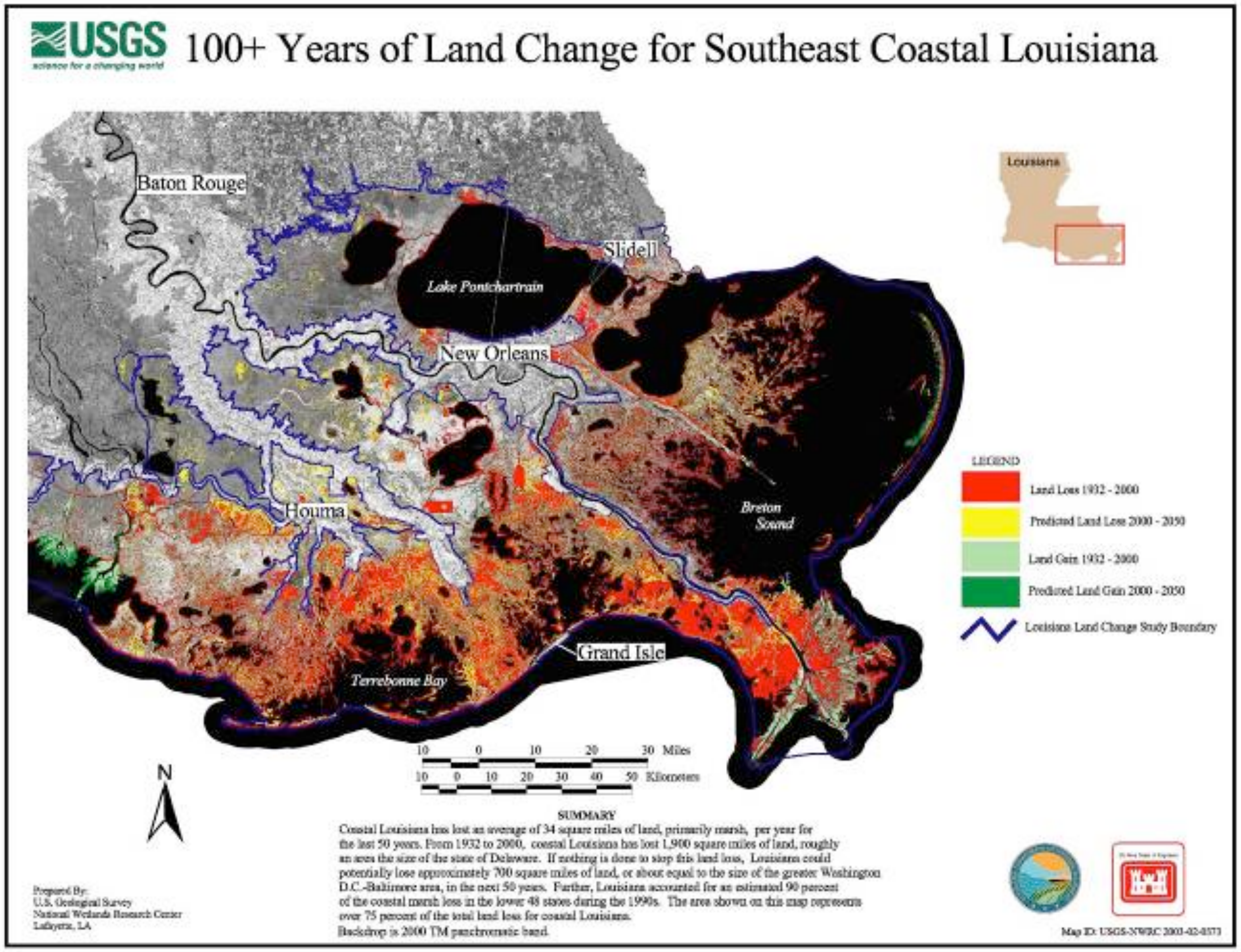
The fundamental issue in New Orleans is land loss, not dike failure



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Land loss converts storm surge from a problem to a catastrophe

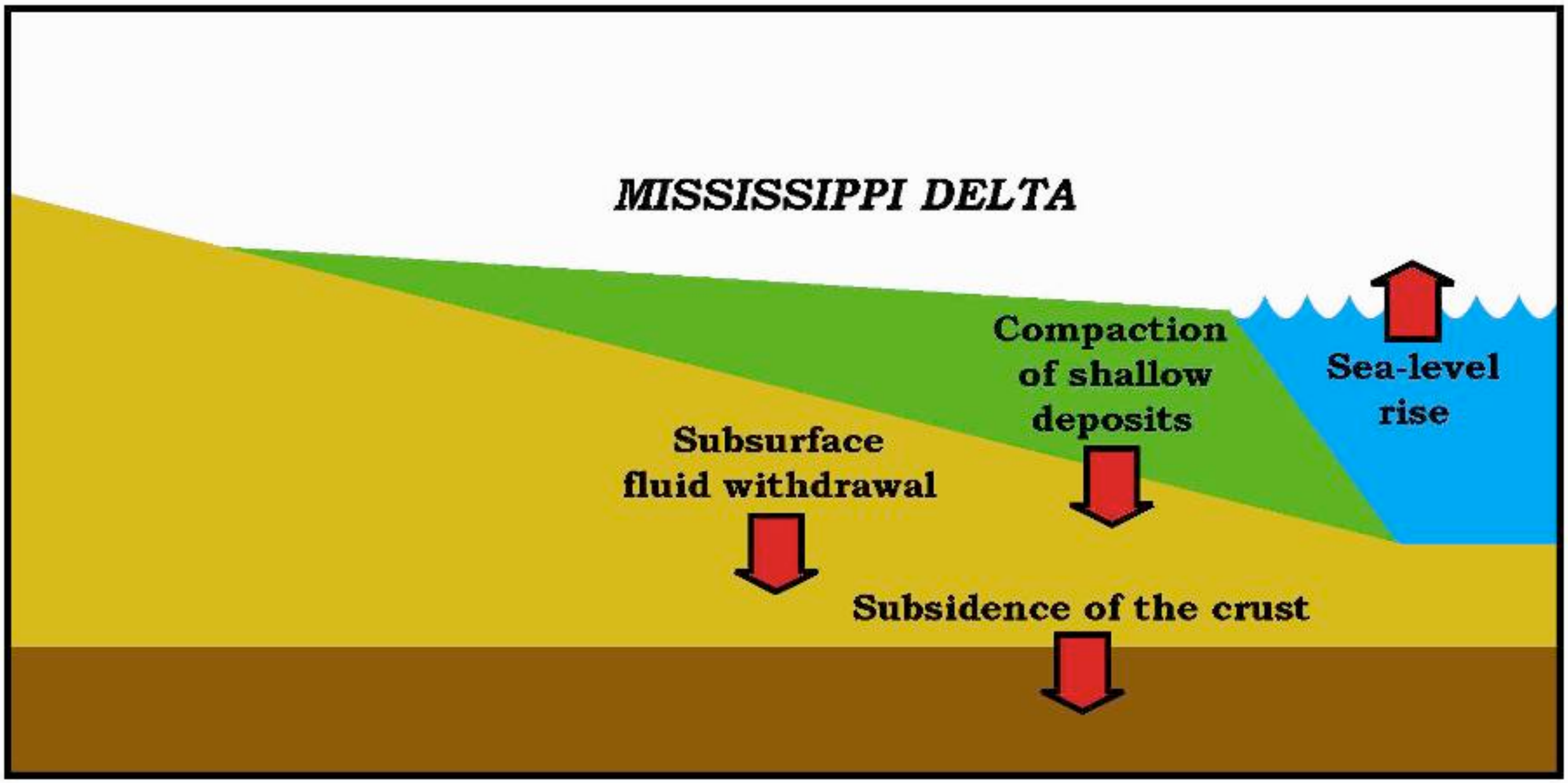
The root of the problem is the **disappearance of delta land** as **sediment that would replenish the sinking delta** is instead **channeled by dikes straight out to the Gulf of Mexico**.

This house is not in standing water because of storm surge!

As the land sinks and the gulf rises, sights like this are increasingly common. *(Credit: Willa Zakin)*

There is no hope of alleviating the storm surge problem without *building land.*

Causes of wetland submergence



thanks to Torbjorn Tornqvist, Tulane University

The problem in a nutshell

- The Mississippi Delta subsides by compaction and other processes
- Under natural conditions this subsidence is balanced by overbank deposition of sediment and channel avulsion.
- Currently, the mud that would construct the floodplain is held behind levees and delivered out to sea

This problem has been known for a long time…

Fischetti (2001),
Scientific American

"At this rate, New Orleans will be exposed to the open sea by 2090."

I believe the Bush administration should continue to withhold money for coastal restoration in Louisiana. The projects being served up by the U.S. Army Corps of Engineers are little more than traditional Louisiana pork.

Most of the Mississippi Delta, some 10,000 square miles, lies less than three feet above sea level. Beset by land subsidence and rising sea levels, much of this vast area will inexorably sink beneath the waters by the end of this century.

Congress should suspend all coastal funding until the Corps and Louisiana prepare a comprehensive and realistic land-use plan for the entire delta, applying modern science and fiscal discipline to determine what can and cannot be salvaged.

BRUCE BABBITT
Washington

Washington Post, Friday, May 18, 2007

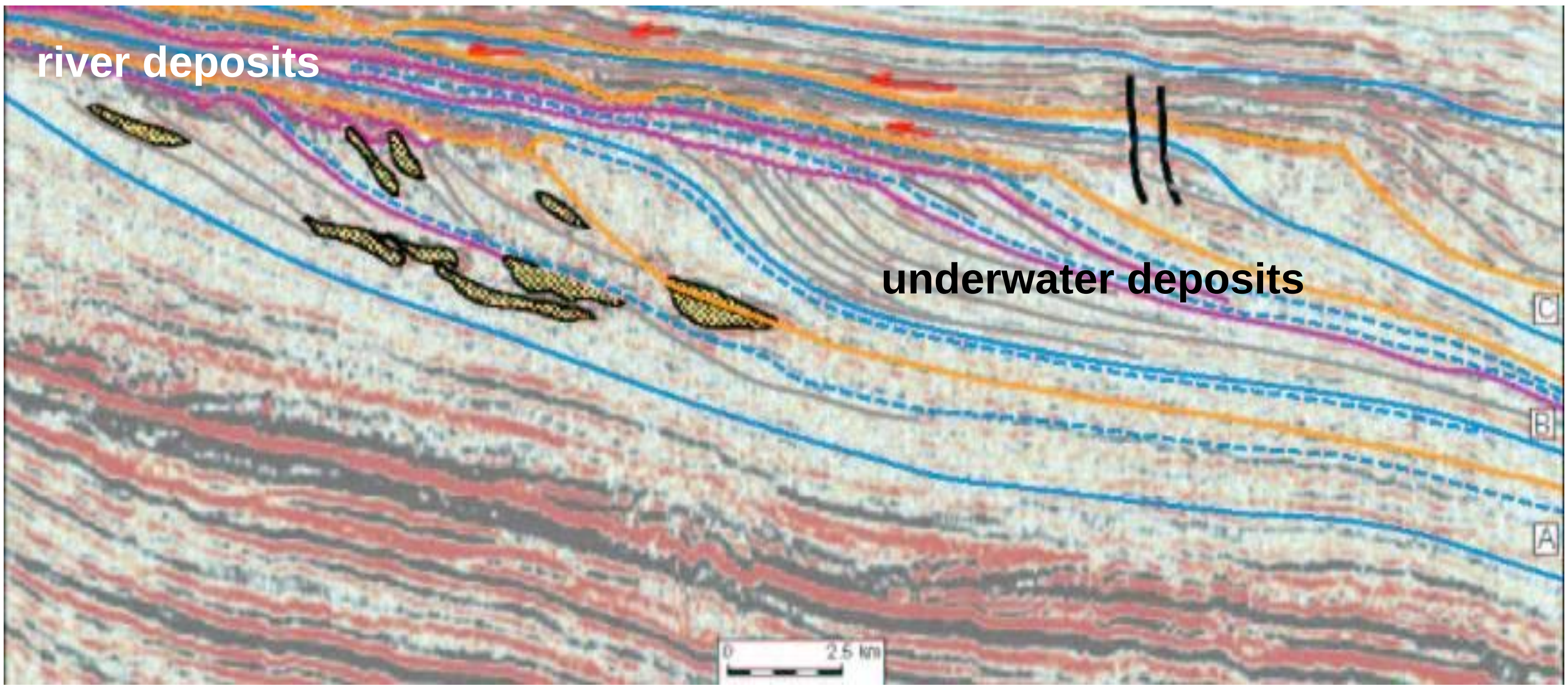
GEOLOGY

Katrina Study Stirs Debate on Coastal Restoration

Is it true that deltas are inevitably drowned by subsidence? Let's look at the record…

this lab experiment shows what the record of a delta looks like in cross section

Land loss by coastal drowning is neither inevitable nor "natural"



Cross-section of an ancient delta showing river deposits created during active subsidence

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A modern example: Wax Lake Delta, a healthy, growing delta less than 100 mi west of the Mississippi Delta

Since 1973, the Atchafalaya River has been receiving 30 ~ 60% of the sediment of the Mississippi River,

and the Wax Lake Delta has been receiving about half of the sediment of the Atchafalaya River.

The result: about 40 km2 of new land since 1973!

Wax Lake Delta is small relative to the whole delta complex

Can the Wax Lake example be applied to the main Mississippi Delta?

- We believe it can!
- There is sufficient sediment delivered by the Mississippi to maintain approximately 200 – 1000 square miles of wetlands and coastal forest against even high rates of subsidence (1 cm per year)

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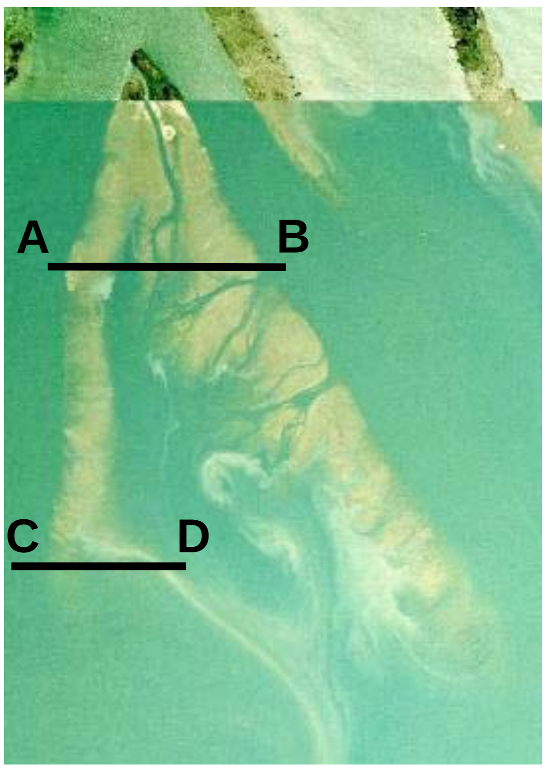
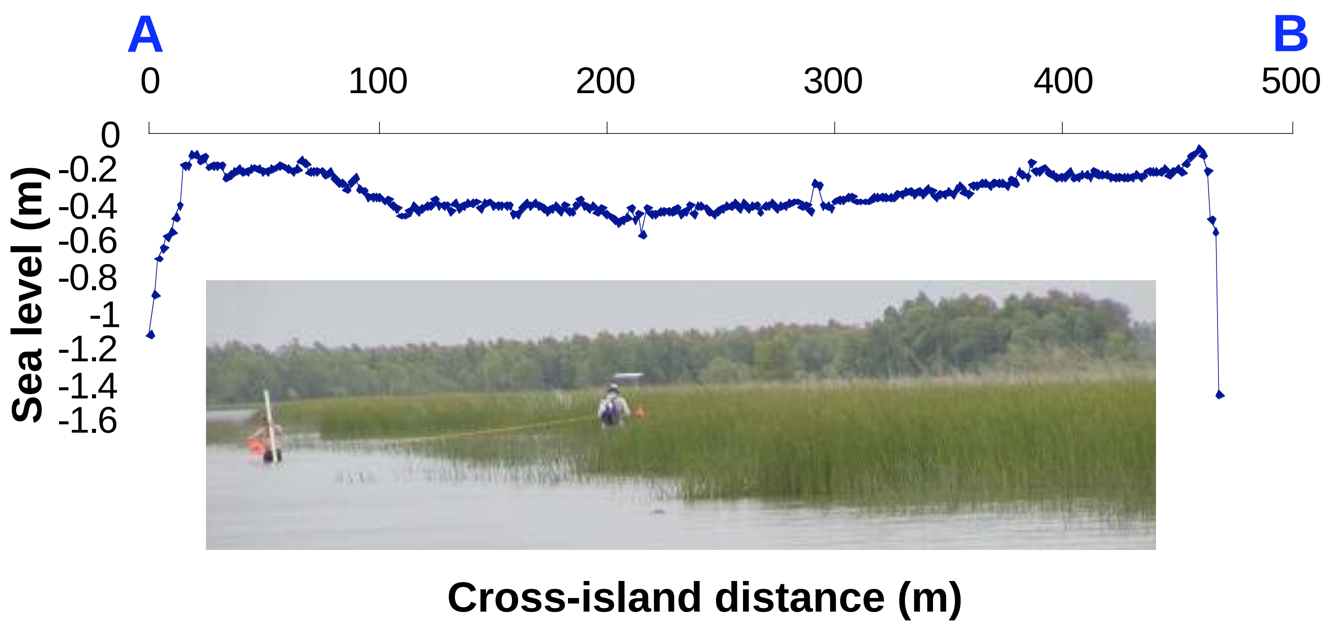
The National Center for Earth-surface Dynamics (NCED), headquartered at the University's St Anthony Falls Laboratory, is heavily involved in developing new tools for analysis and prediction of delta evolution

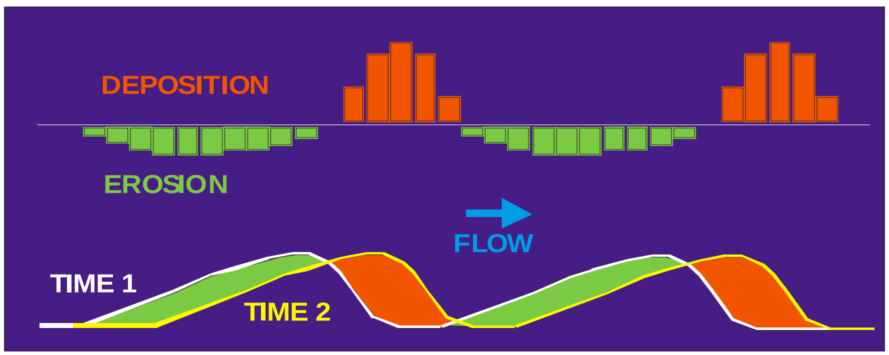


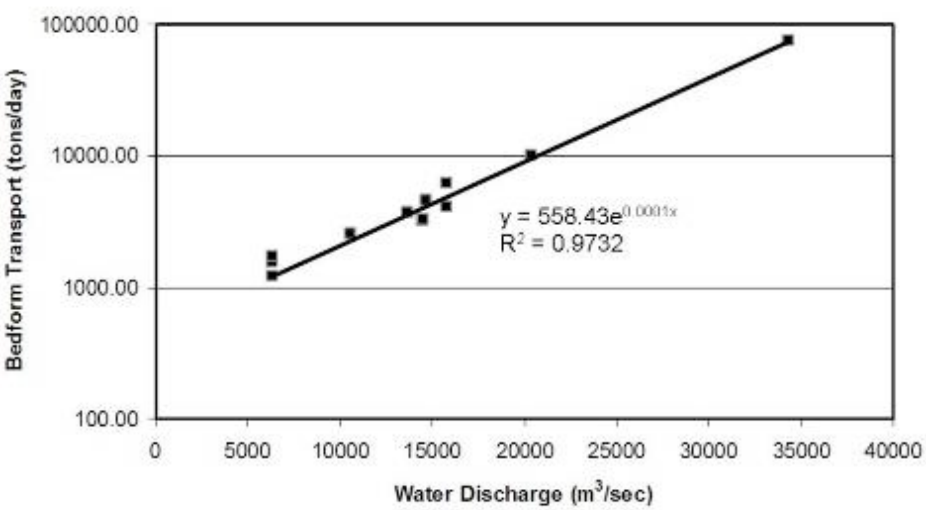


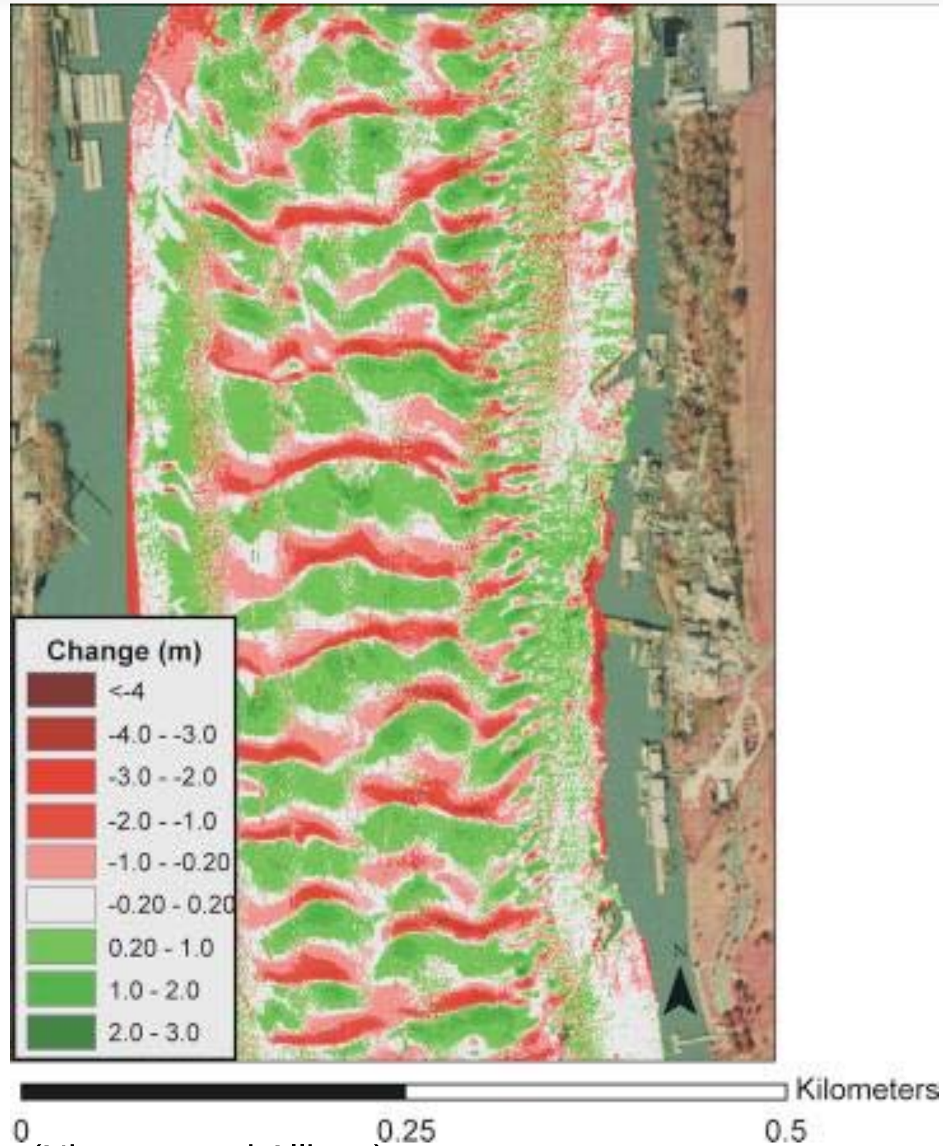
field work at Wax Lake Delta, 2007 May

Field data: sand supply

Bed material flux at NOLA

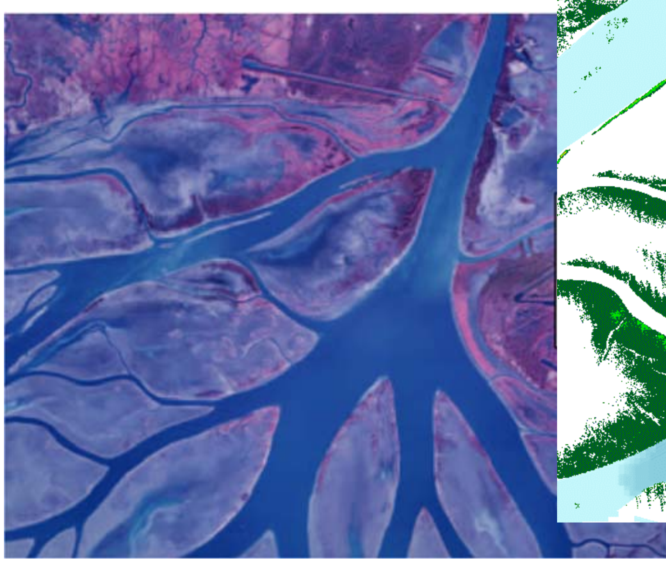


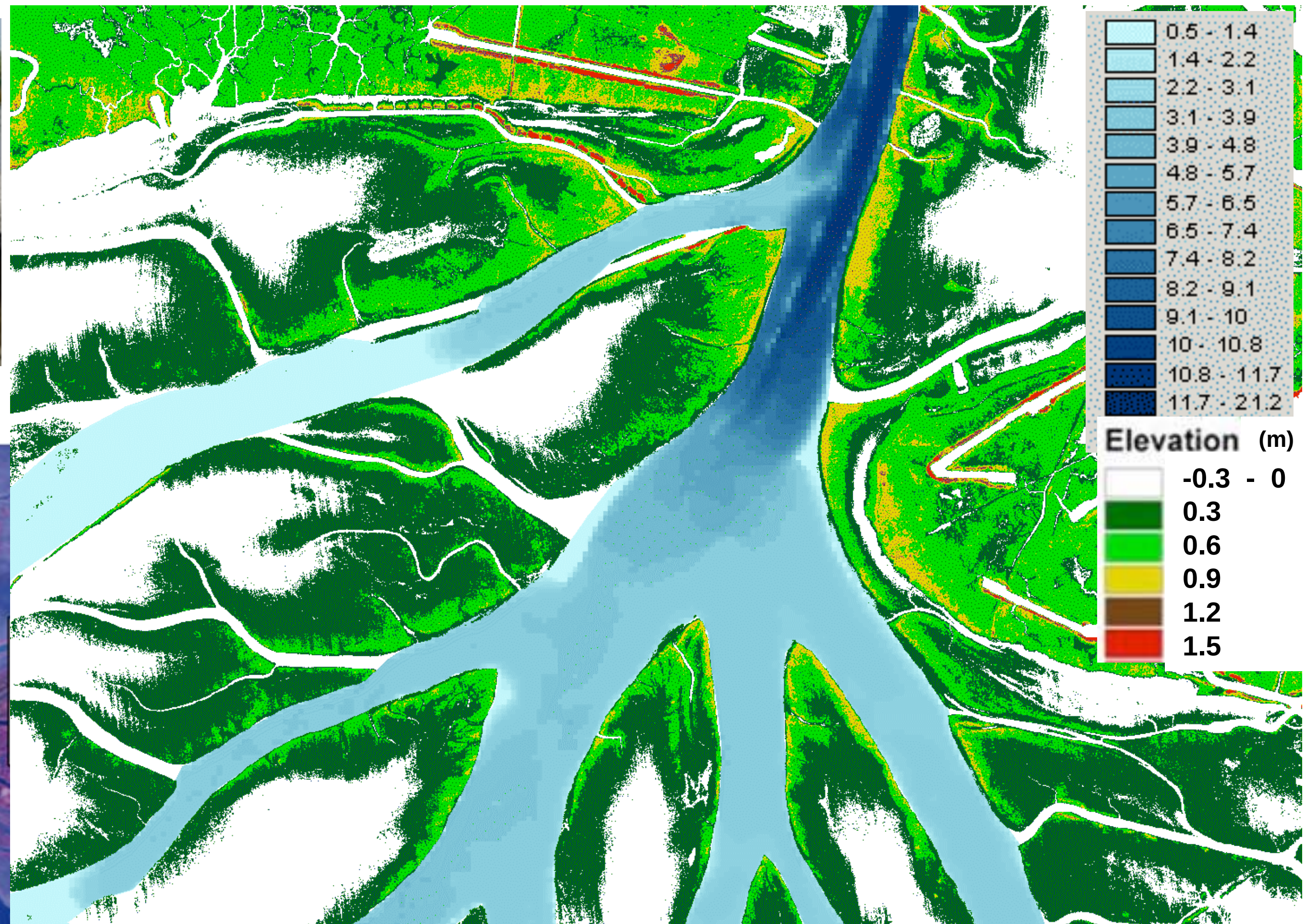




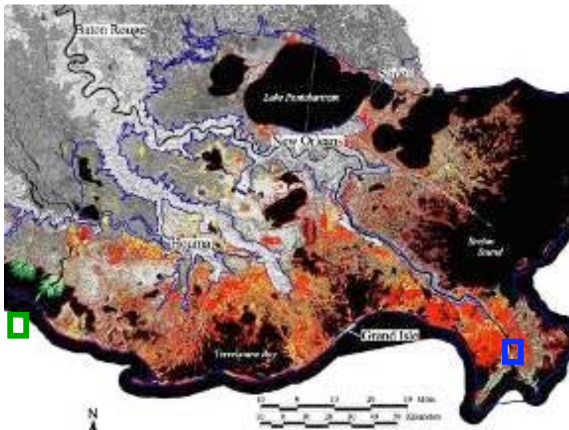
(Nittrouer and Allison)

Field data: delta topography





High-resolution subsurface data from industry



Pleistocene channelized deposits of Mississippi Delta [~ 1km depth in subsurface]

Schollnberger (1998)

Modern-day Mississippi bird's foot

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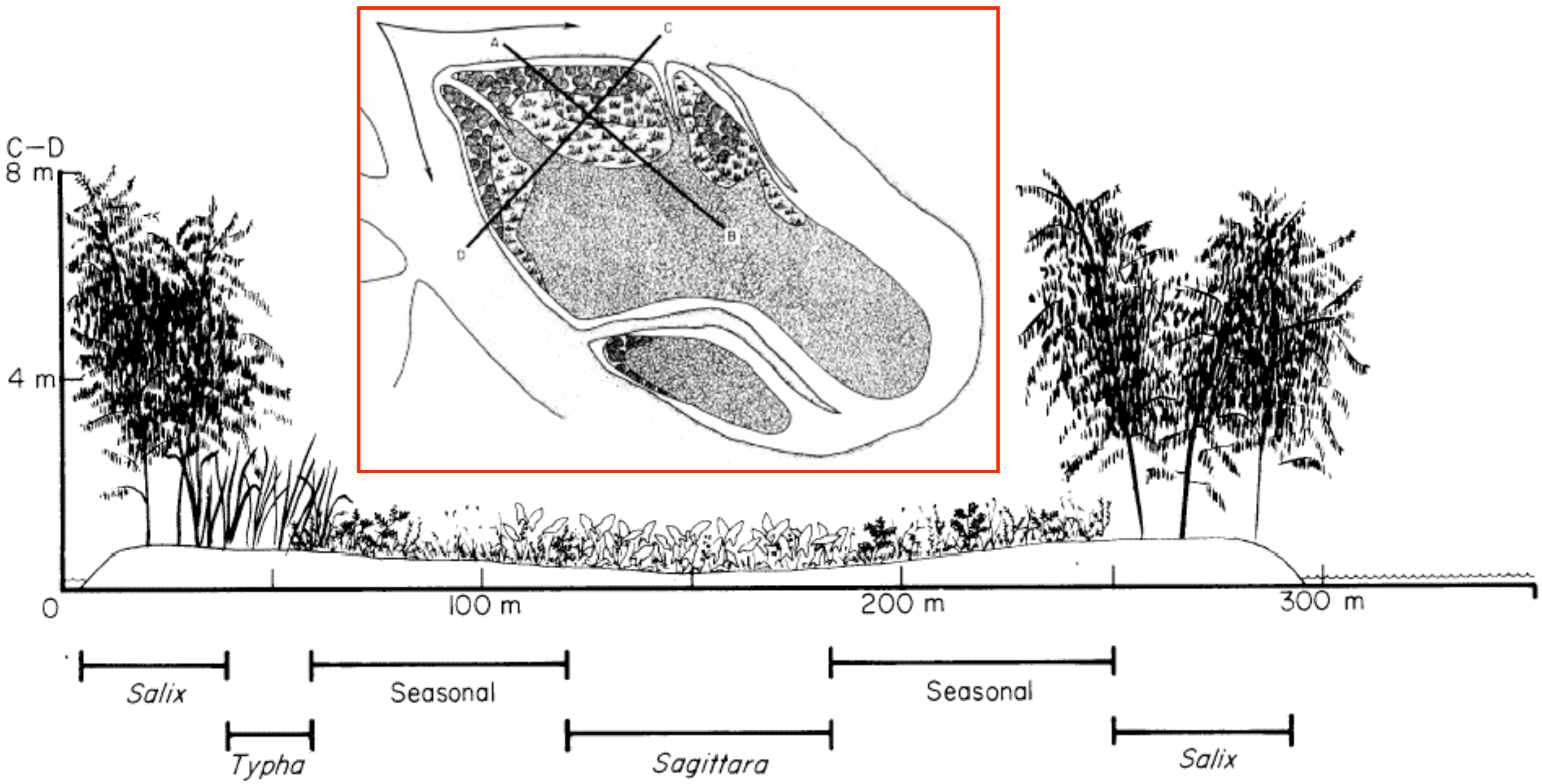
Connecting ecology to sedimentation and land building



(Johnson, Sasser, & Gosselink, 1985)

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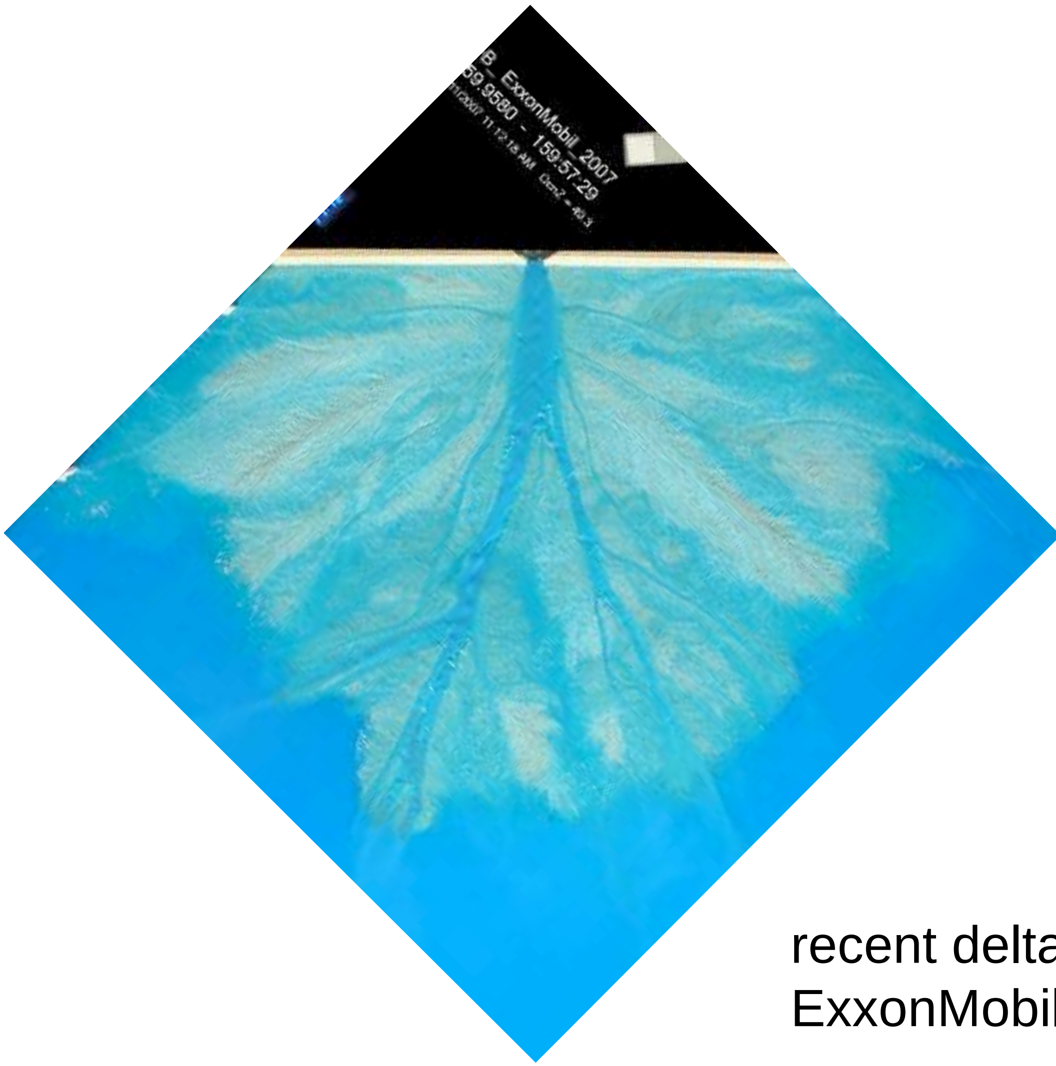
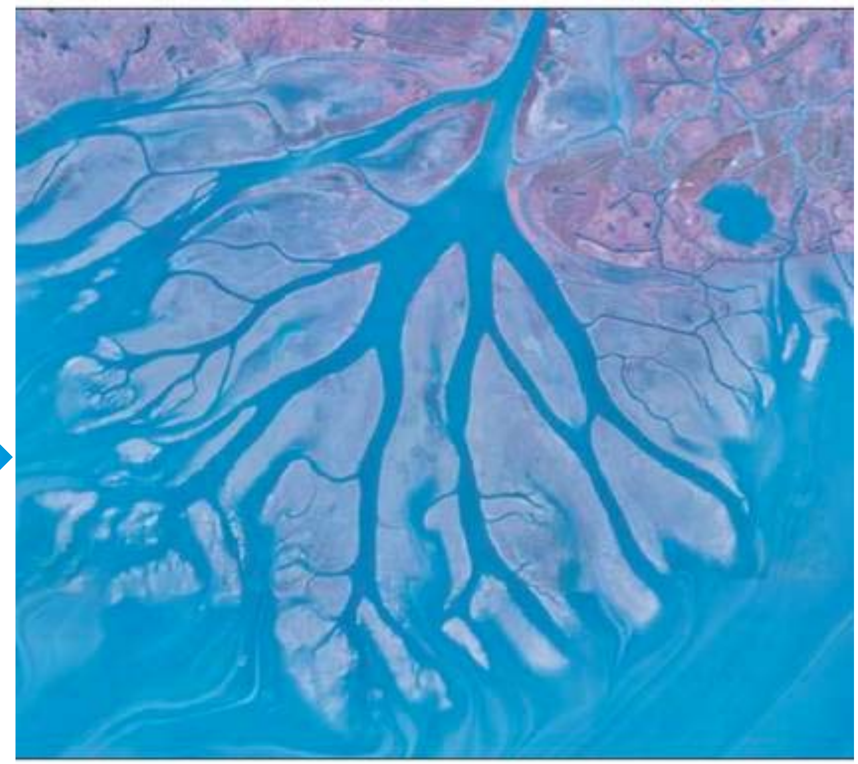
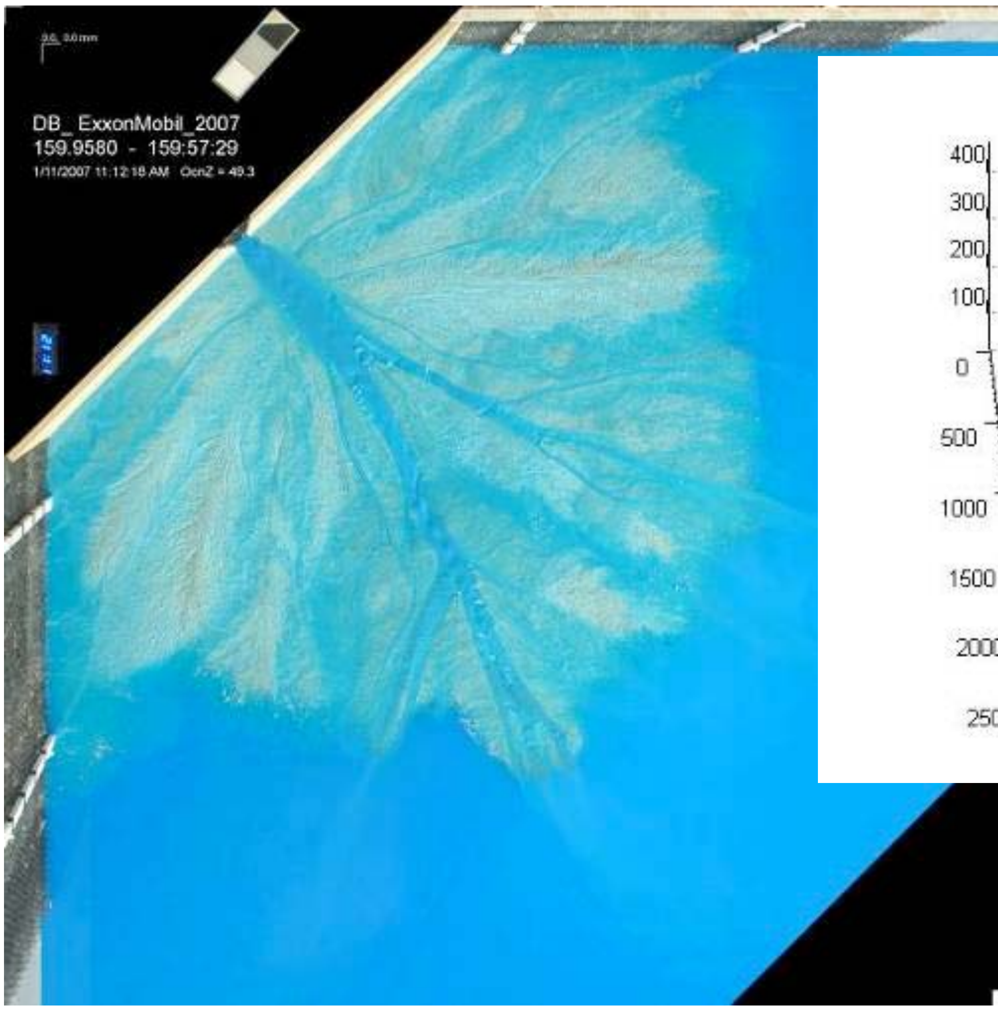
Deltas in the lab… … and in the field

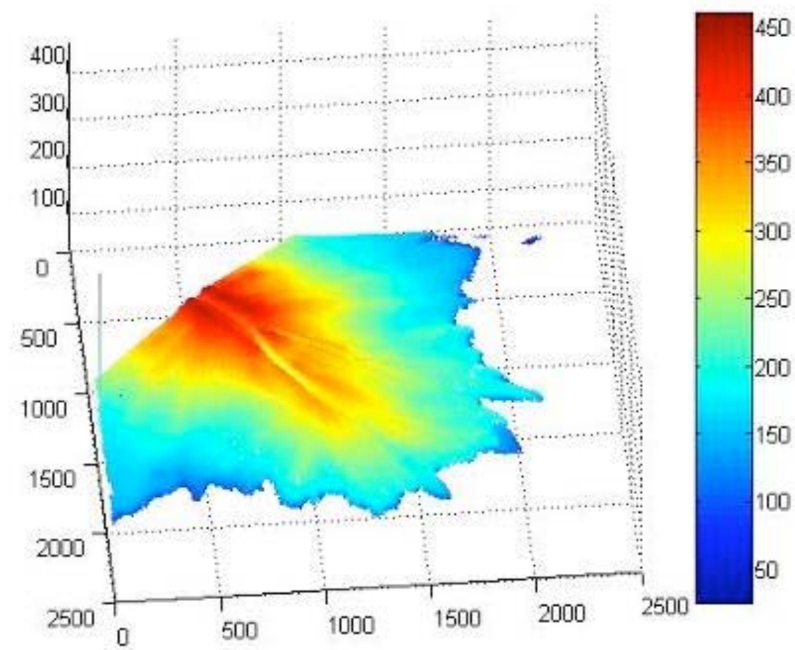




recent delta experiments in collaboration with ExxonMobil URC.

Experiments allow us to “speed up time”, and study delta evolution under controlled conditions





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Stability & maximum accretion of coastal wetlands related to:

1. Geomorphology
2. Hydrology
3. External forcing (sea-level rise + land-surface subsidence)

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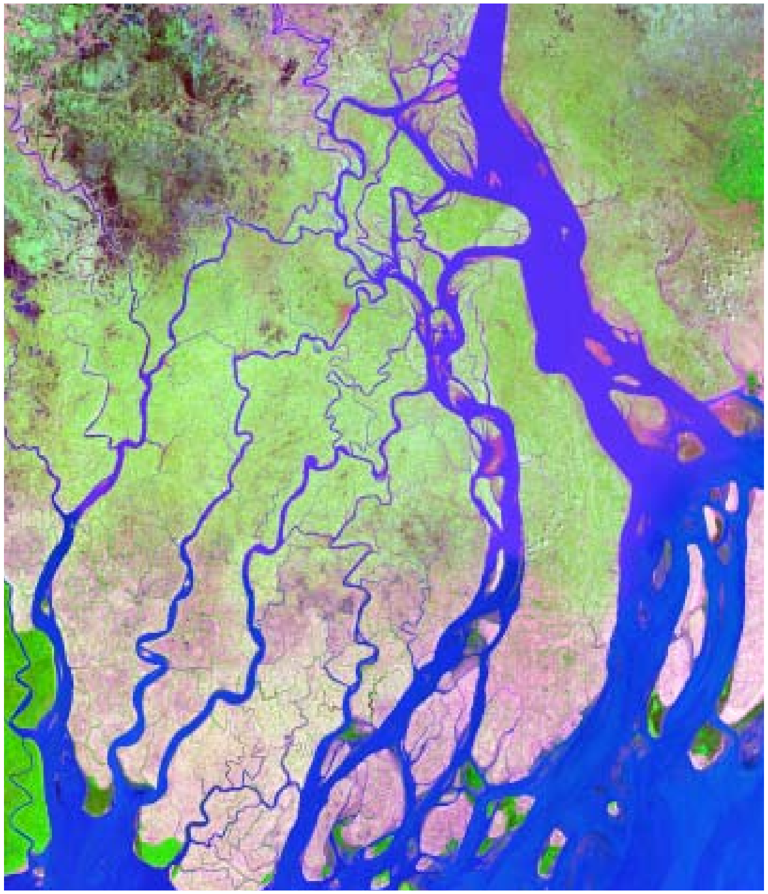
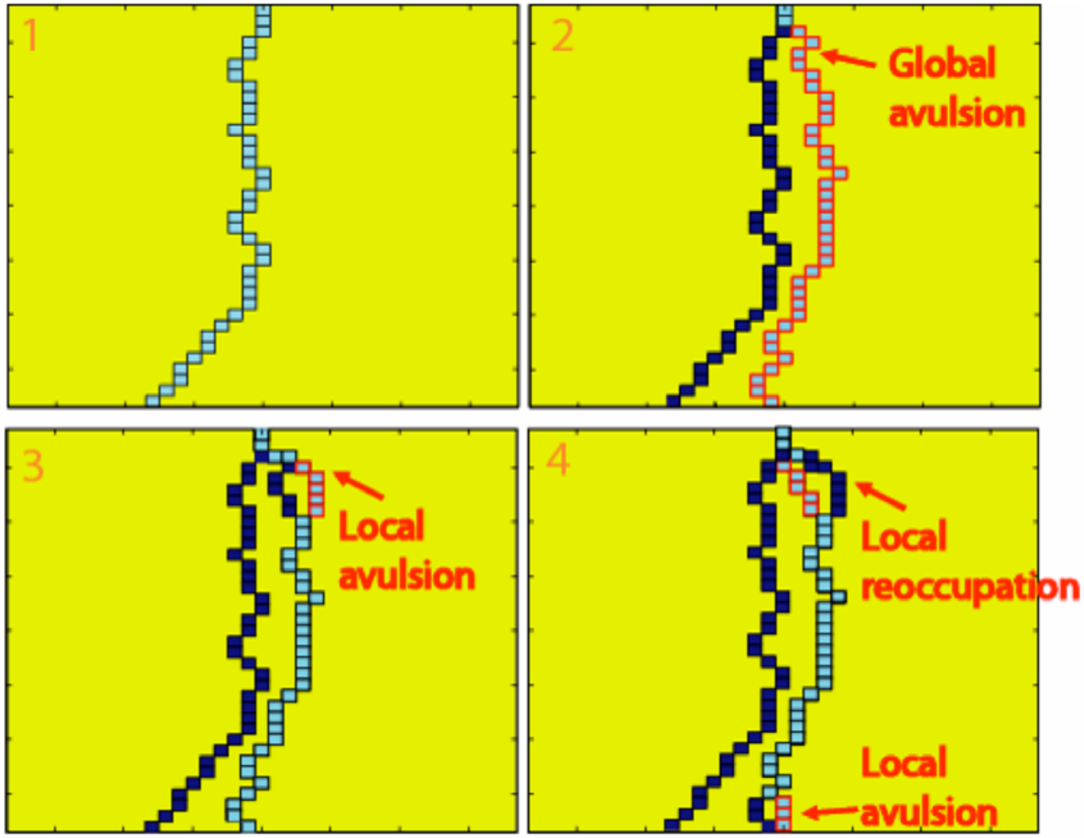
Channel Network Geometry: Distributary Channel Networks

Apply/modify established analysis methods to a new network form.



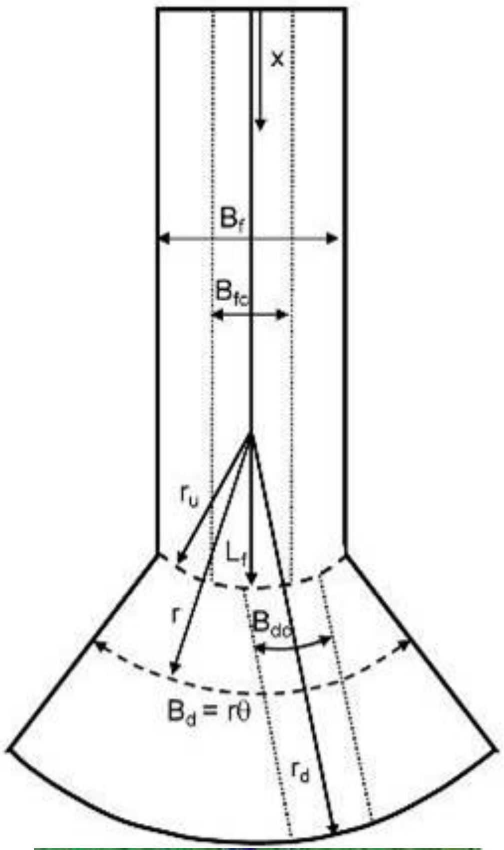
Feola, Rinaldo, et al in prep

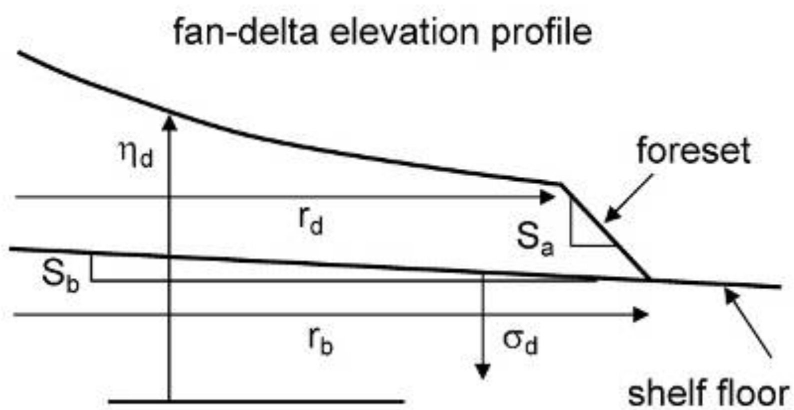
Develop numerical models capturing dynamics of depositional channel networks.



Jerolmack & Paola 2007

Initial morphodynamic model for the evolution of the Wax Lake Delta

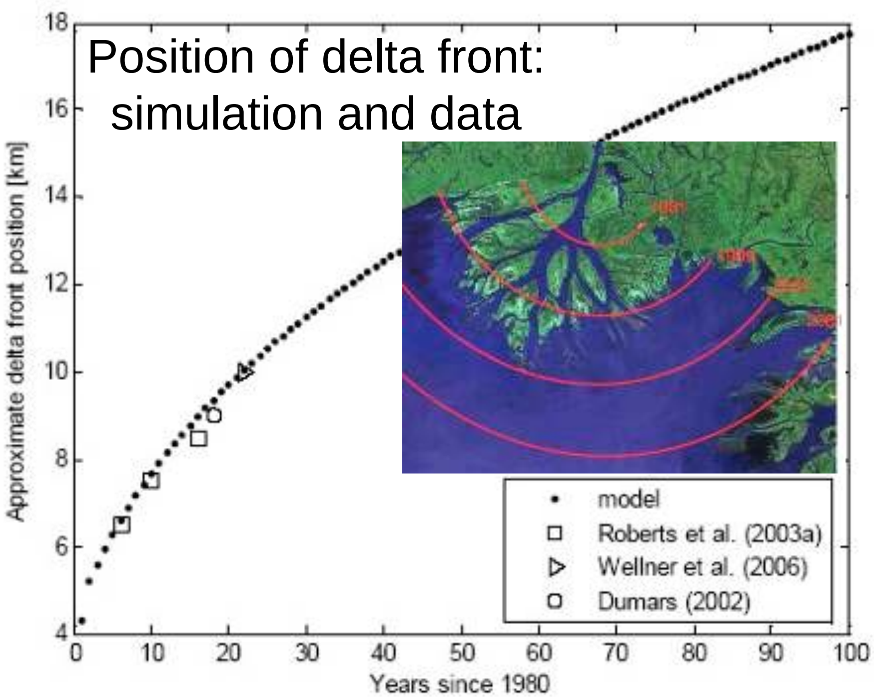


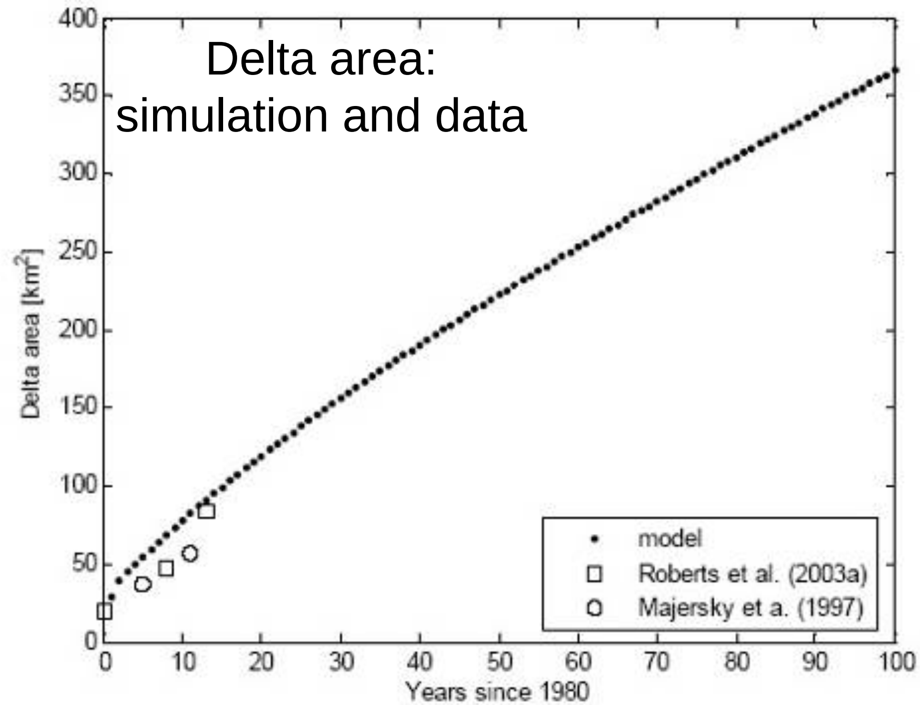


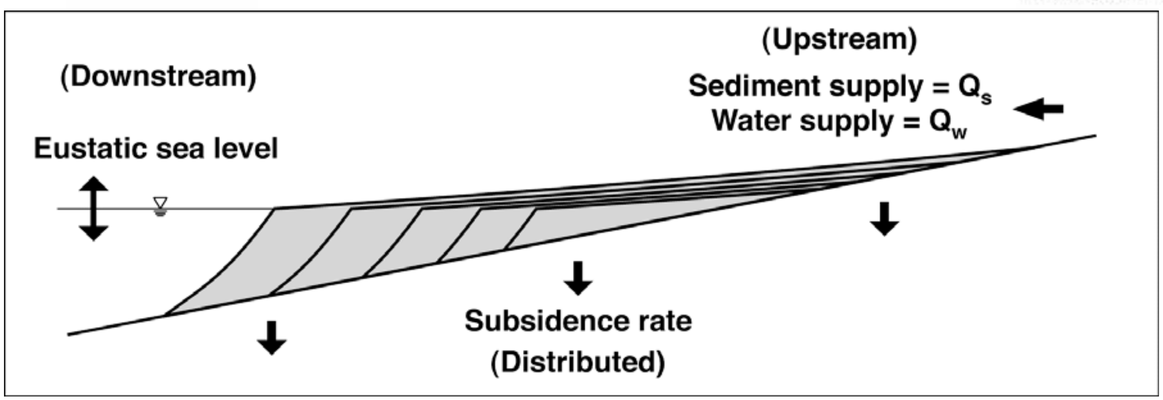
$$(1-\lambda_{pf})\left(\frac{\partial \eta_f}{\partial t}+\sigma_f\right)=-\Omega_f\,\frac{I_f(1+\Lambda_f)}{B_f}\frac{\partial Q_{tbff}}{\partial x}$$

$$(1-\lambda_{pd})\left(\frac{\partial \eta_d}{\partial t}+\sigma_d\right)=-\Omega_d\,\frac{I_f(1+\Lambda_d)}{B_d}\frac{\partial Q_{tbfd}}{\partial r}$$

Preliminary results from the land-building model







Steady state self-maintaining delta area

current sediment discharge	1.25E+08	tons/yr	0.22	GT/yr	2.20E+08	T/yr	La coastal/U
	1.13E+11	kg/yr	0.23	GT/yr	2.30E+08	T/yr	from James
mineral density	2650	kg/m^3	0.1245	GT/yr	1.25E+08	T/yr	from Mead A
mineral volume	4.26E+07	m^3/yr			100 acres = 0.4046873 km^2		
assumed final porosity	0.3				100 acres = 0.1562506467211431 mi^2		
total volume	6.09E+07	m^3/yr					
retention fraction	0.35						
usable topset volume	2.13E+07	m^3/yr					
subsidence rate	0.01	m/yr					
peat fraction	0.4						
topset area	3.55E+09	m^2					
	3.55E+03	km^2	1000 acre = 4.04685 km_				
	1.28E+03	mi^2	1 km_ = 247.105 acre				

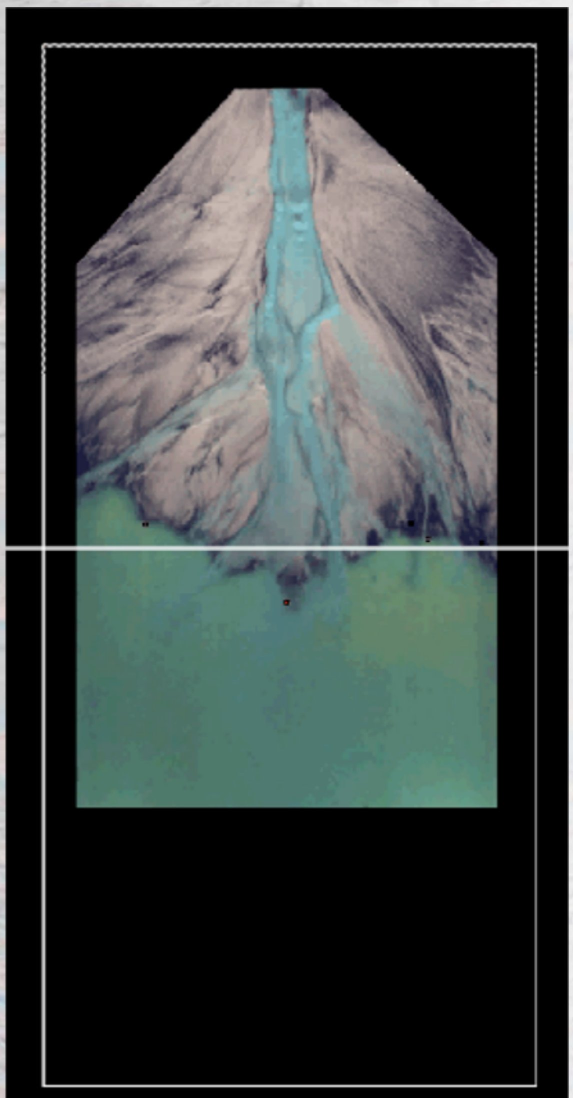
Other estimates		
2.00E+07	tons/yr	Meade Allison sand

So – can we do it?

All the information we have – from experiments, computer models, the modern Wax Lake Delta, and the history of the Mississippi Delta, suggests that partial restoration is possible, and not prohibitively expensive, *if* we can learn to work with nature, not against it

Wonsuck Kim, Univ. Illinois/NCED

XES 02



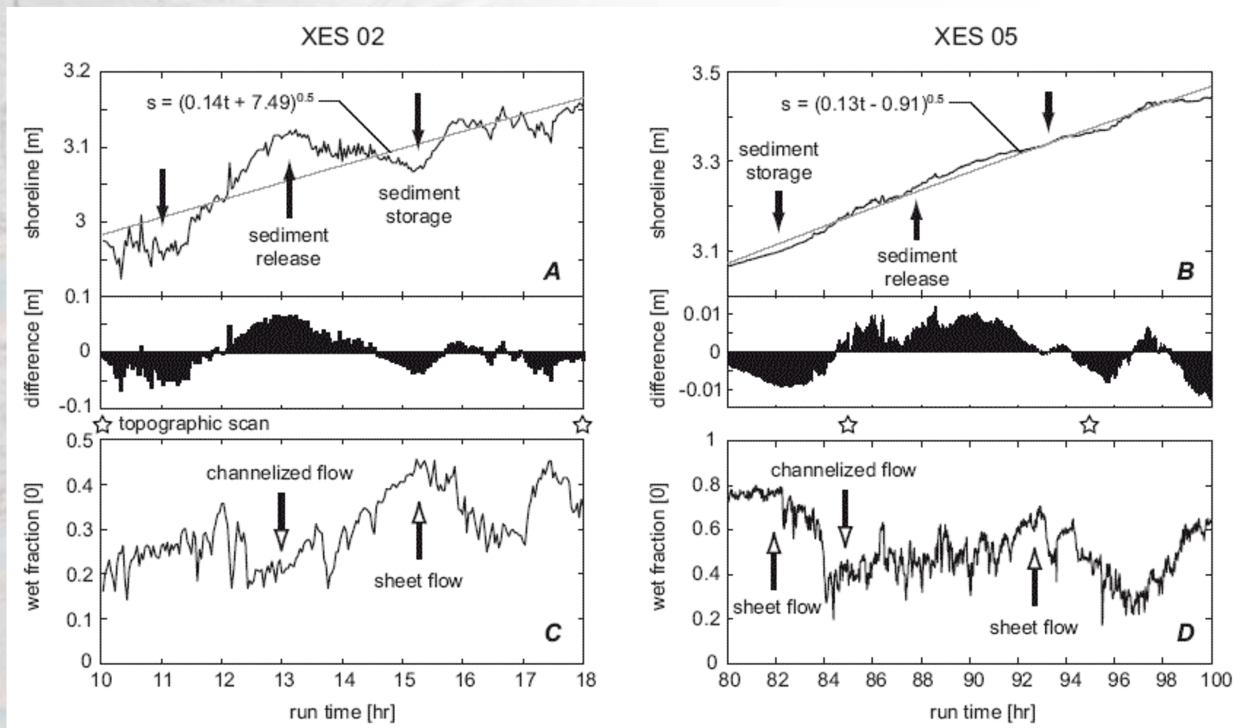
(Kim et al. JGR 2006)

Strong autogenic signals in laterally averaged shoreline migration

- variability persists even when the "**local noise**" is eliminated
- The autogenic signal in the shoreline migration rate varies by a factor of **3** depending on **the shoreline migration direction**

Rather than there being a single 'equilibrium' fluvial slope for given imposed conditions, natural topset slopes fluctuate.

Wet fraction vs. Shoreline migration: XES 02 & 05

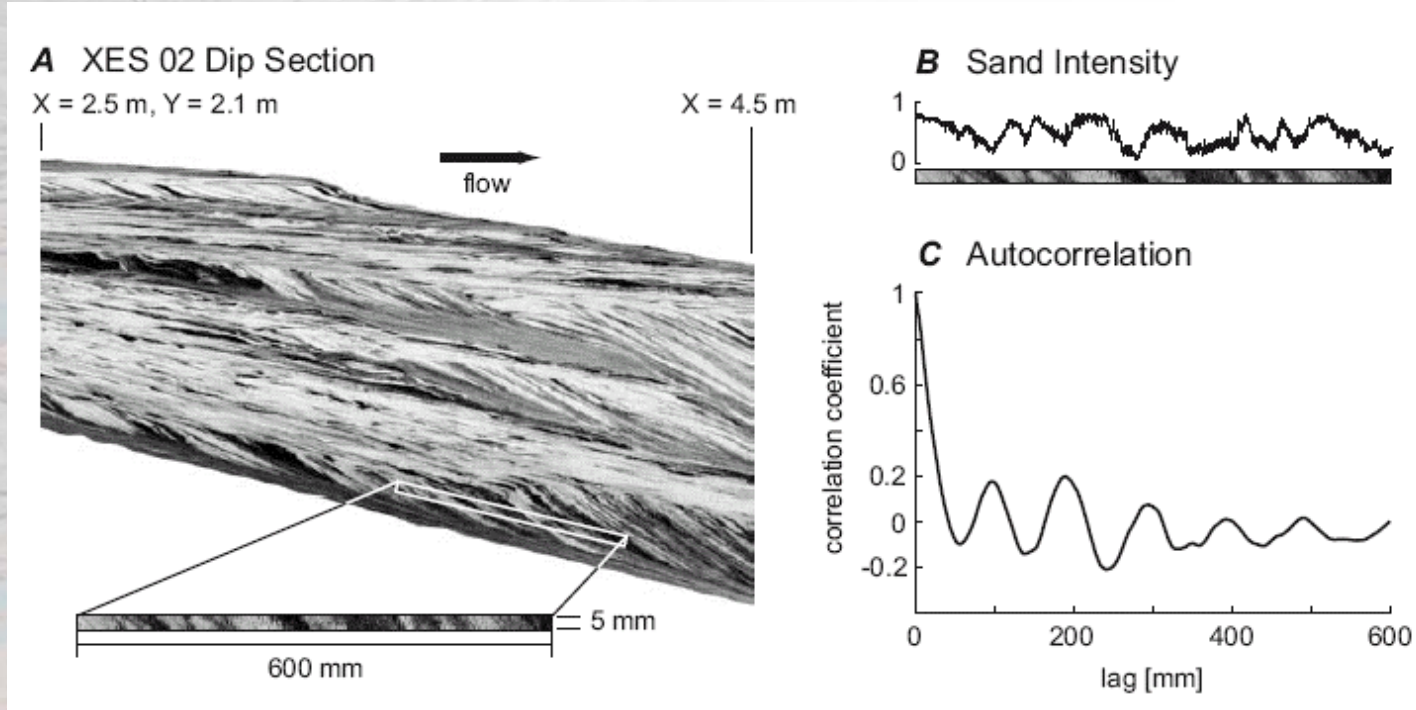


Wet fraction:

Magnitude = 15 ~ 45% in XES 02; 20 ~ 75% in XES 05

Period between sheet- and channelized flow
= 2 ~ 3 hr in XES 02; 8 ~ 10 hr in XES 05

Cyclic sedimentation: XES 02



Regular switching between sand- and coal deposits

- Wavelength of 100 mm
- Variability in sediment transport efficiency in the fluvial system

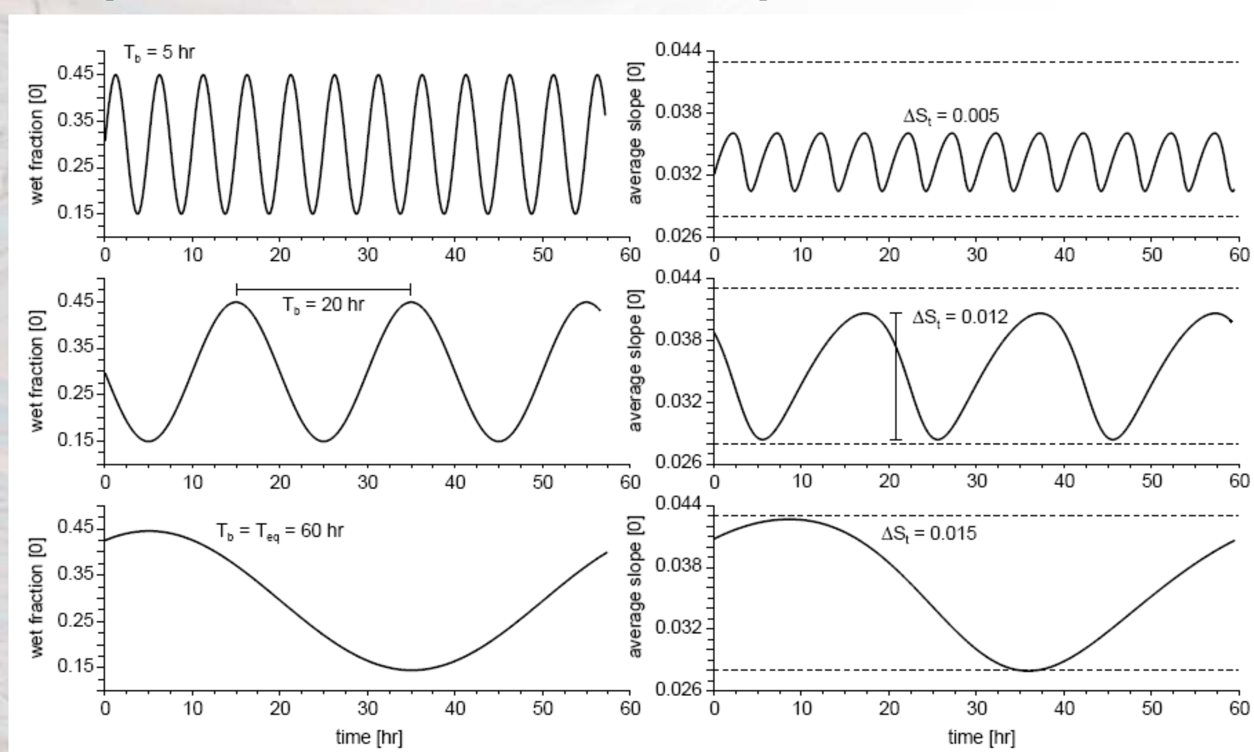
XES 02:

$\Lambda \cong 100$ mm, $S_{ch} = 0.036$, $\Delta S_t = 0.004$, $\Psi_s = 0.0456$ m^3, $T_{ap} = 2.5$ hr

Mathematical Model: Dynamic

Rearrange of the slope equation to calculate Q_s

$$Q_s = \sqrt{RgD}D\chi(t)B_t \cdot \alpha_s \left[R^{-1}\alpha_r^{-2/(3+2p)} S_t^{(2+2p)/(3+2p)} \left(\frac{Q_w}{\sqrt{gD}D\chi(t)B_t} \right)^{2/(3+2p)} - \tau_c^* \right]^n$$



Result: internally generated variation in shoreline migration

L = 500 km

$S = 10^{-4}$

ΔS = 5% of S

Release sediment,

$\Delta V = 1/2\ \Delta S\ L^2\ B = 0.625\ (km^2)\ B\ (km)$

Shoreline progradation

= 12.5 km (within 50 m water depth)

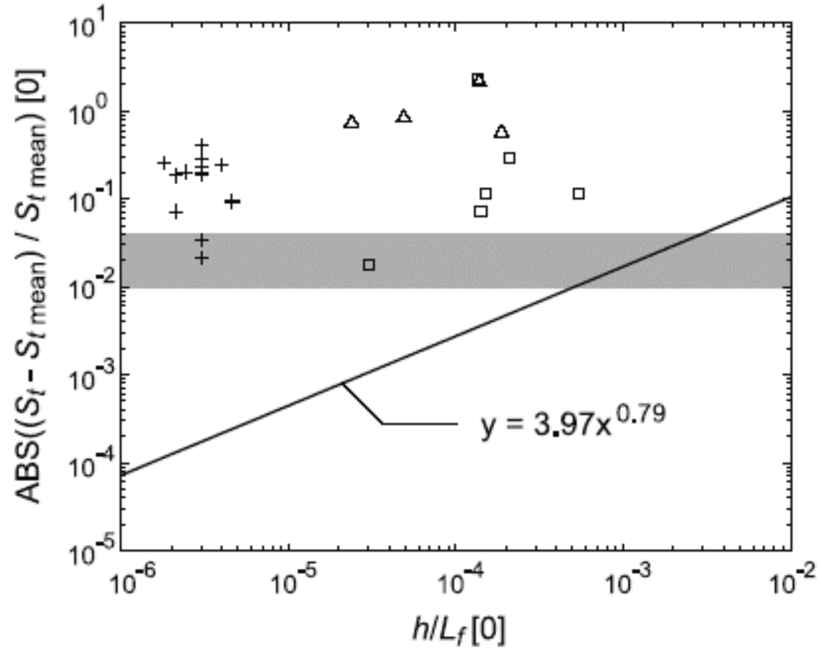


Figure 13. Plot of slope variability in field-based measurements. Data comprise the Po River delta (squares), reported in the work of *Nelson* [1970], the Mississippi River (crosses), reported by *Aslan et al.* [2005], and the Niger River delta (triangles), reported by *Abam and Omuso* [2000].

Three-dimensional numerical modeling of deltas

Irina Overeem, James Syvitski, Eric Hutton, Sergio Fagherazzi

Environmental Computation and Imaging Facility, INSTAAR, University of ColoradoBoston University, Department of Earth Sciences, MA

Why Numerical modeling?

- The sedimentary record of deltas is complex and 3D, making it difficult to infer the development of stratigraphy.

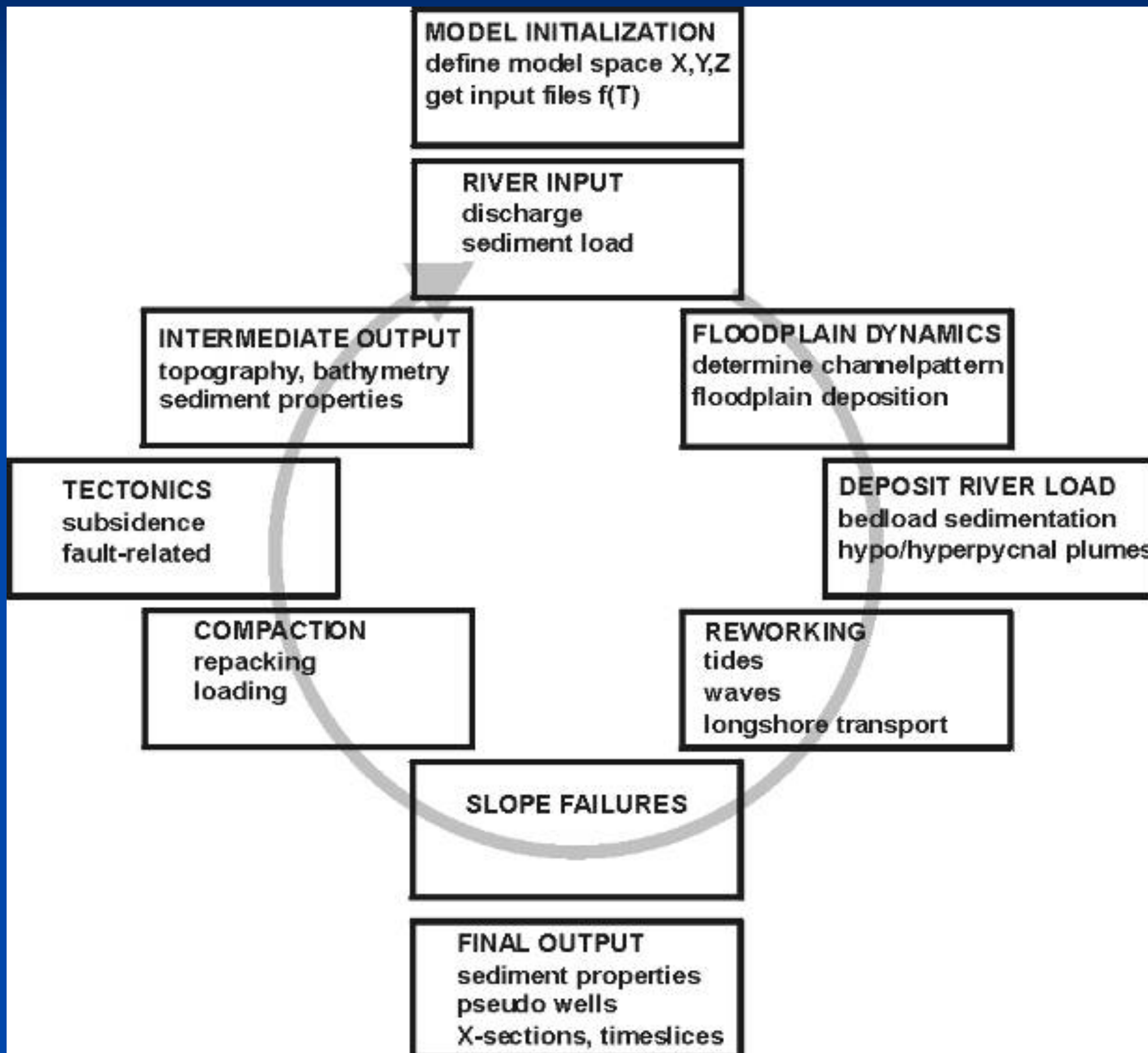
  The complexity is due to the interacting processes:

  1. fluvio-deltaic systems are by-pass zones
  2 the coastal zone is strongly modified by erosion and re-deposition by storms, waves, and fluvial incision.
  3 River channels and delta lobes switch their location over time.
  4 Tectonics are spatially variable (occurrence of faults, differential movement)

  Numerical simulation models allow indirect experimentation on the influence of forcing functions and boundary conditions.

  Understanding the deltaic sedimentary architecture facilitates the modeling of oil, gas or groundwater bearing reservoirs.

Modeling Flow: input-engine-output



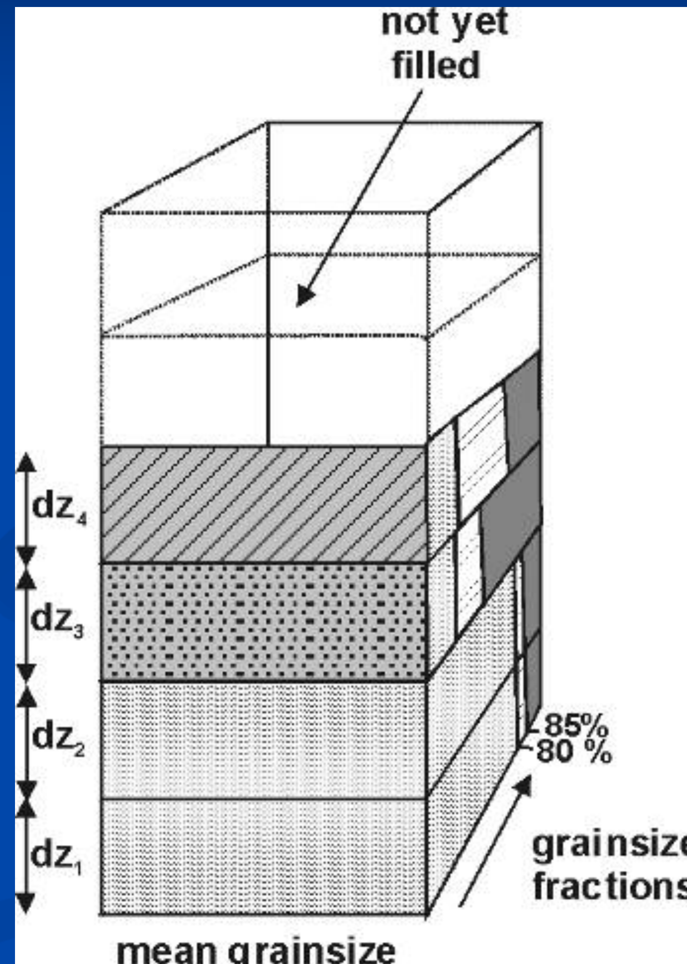
Model Output

User-dependent

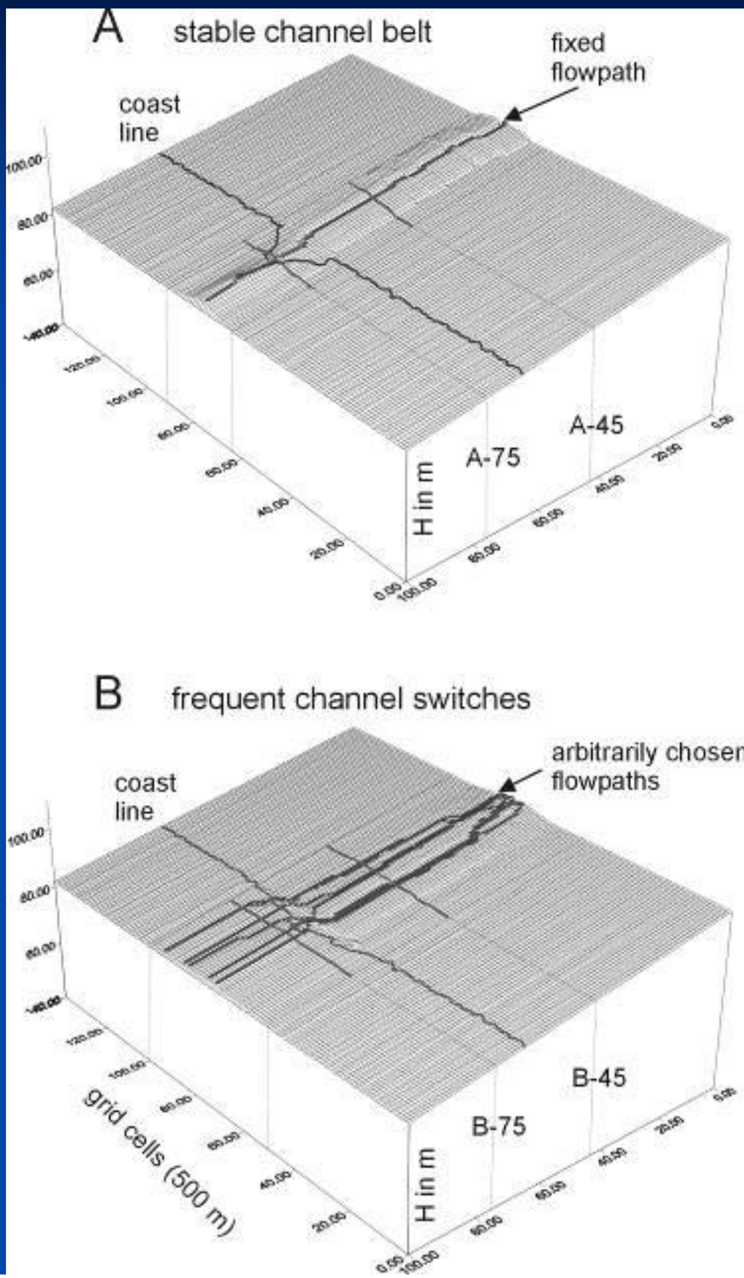
(grain-size, age, porosity, facies, permeability)

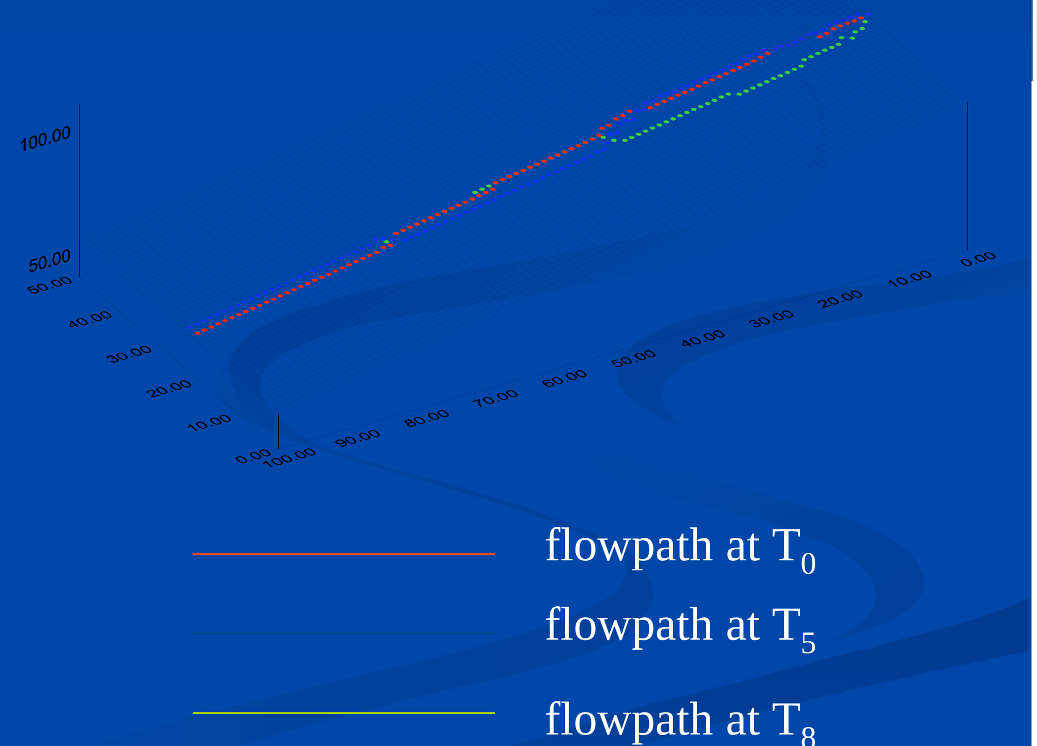
Visualization including:

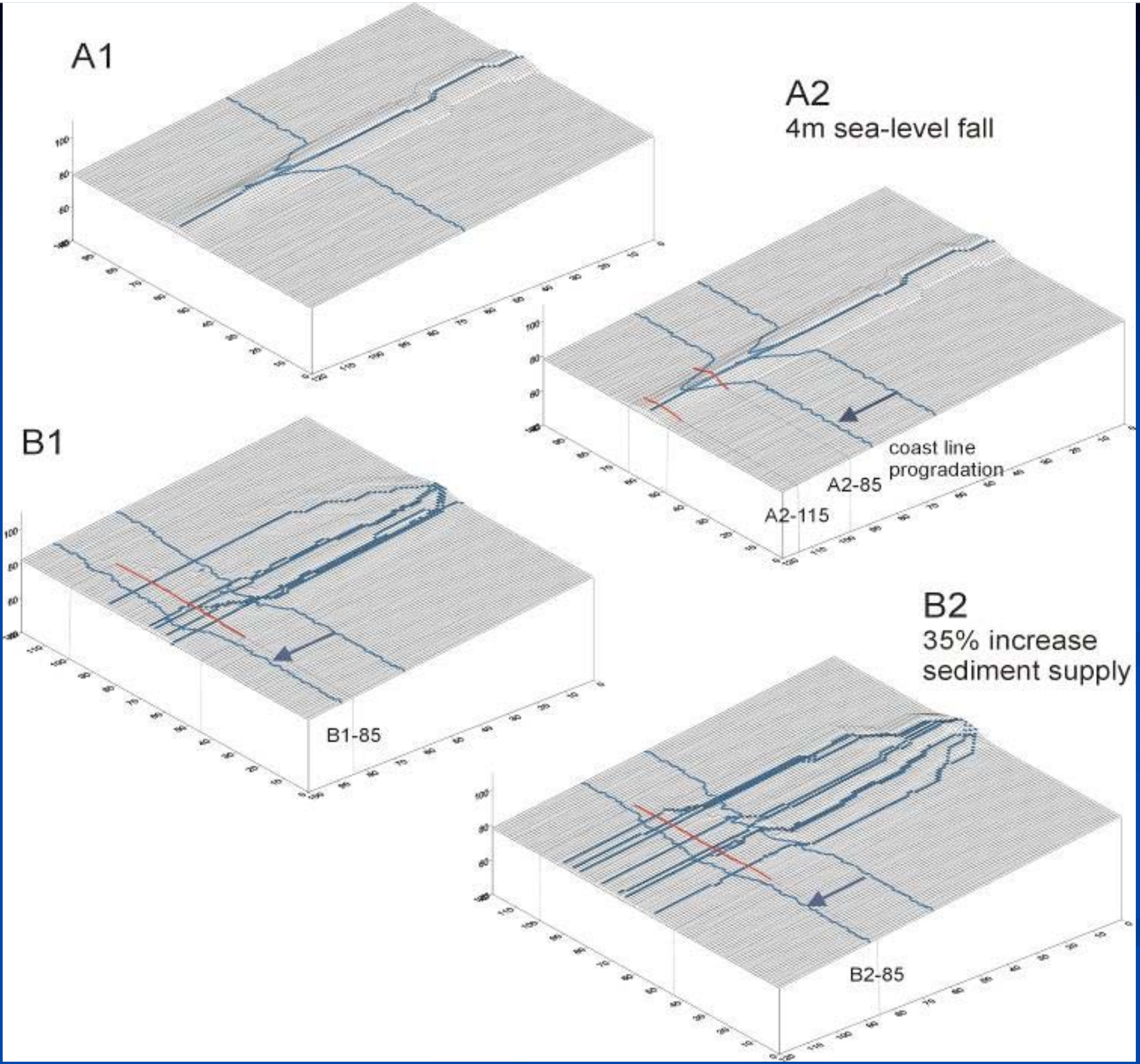
- X-sections
- Time or Horizon slices
- Pseudo-cores
- Time-line plots

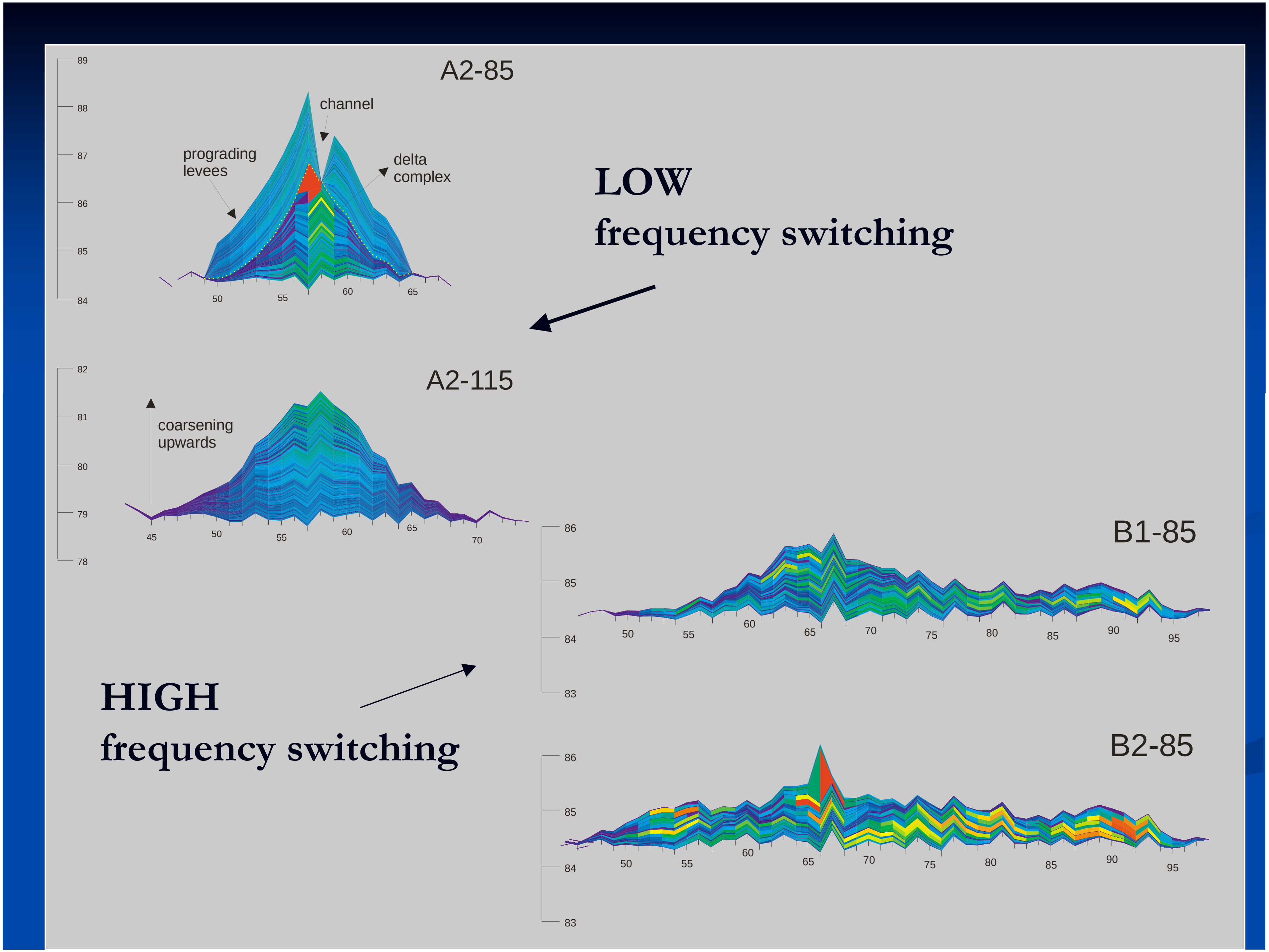


Floodplain sedimentation (AquaTellUs)






A1
A2
4m sea-level fall
coast line
progradation
A2-85
A2-115
B1
B1-85
B2
35% increase
sediment supply
B2-85



A2-85
channel
prograding levees
delta complex
LOW
frequency switching
A2-115
coarsening upwards
B1-85
B2-85
HIGH
frequency switching

‘Outstanding’ Problems

- Need for quality input data
- Quantitative understanding of different processes in **three-dimensions**
- Most 3D models sofar are not well tested, can they mimick thresholds and self-organization?
- Event-based vs time-averaged methodology

Review Papers

- Overeem, I., Syvitski, J.P.M., Hutton, E.W.H., (2005). Three-dimensional numerical modeling of deltas. In: Giosan, Bathacharaya (eds) SEPM Spec. Issue, 83. 'River Deltas: concepts, models and examples'. p.13-30.

- Fagherazzi, S., Overeem I., 2007. Models of deltaic and inner continental shelf evolution. Earth and Planetary Science Reviews.