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Decoupling Allogenic Forcing from Autogenic Processes: Experimental Stratigraphy

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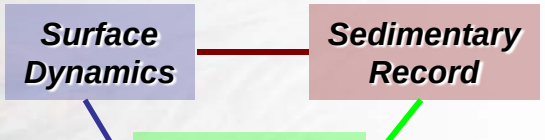
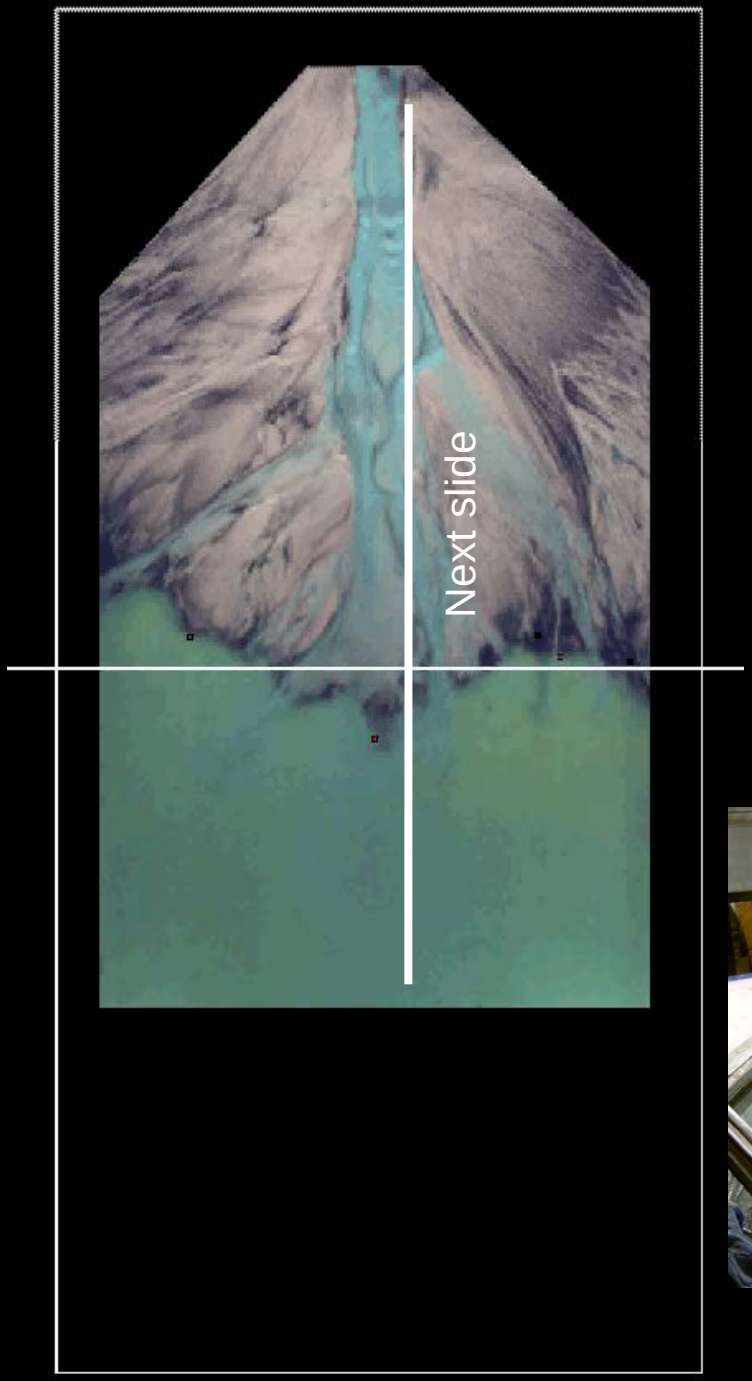
Fossilized Dynamics

- The morphodynamics of the sediment-fluid interface are influenced by both depositional mechanics and environmental forcing. Subsurface architecture records the fossilized dynamics of this moving boundary



Pleistocene channelized deposits of Mississippi Delta (~ 1km depth in subsurface)

Schollnberger (1998)



EXperimental EarthScape (XES) Subsiding Basin: 2002 Run

- St. Anthony Falls Lab., University of Minnesota
- Dimension: 6 m (long) x 3 m (wide) x 1. 5 m (deep)
- **Stratigraphic controls:**
  1. Sediment & Water supply: Constant
  2. Subsidence: Constant, fore-hinge
  3. Sea level: Sinusoidal cycles

(Kim, Paola et al. 2006 JGR; 2006 JSR)

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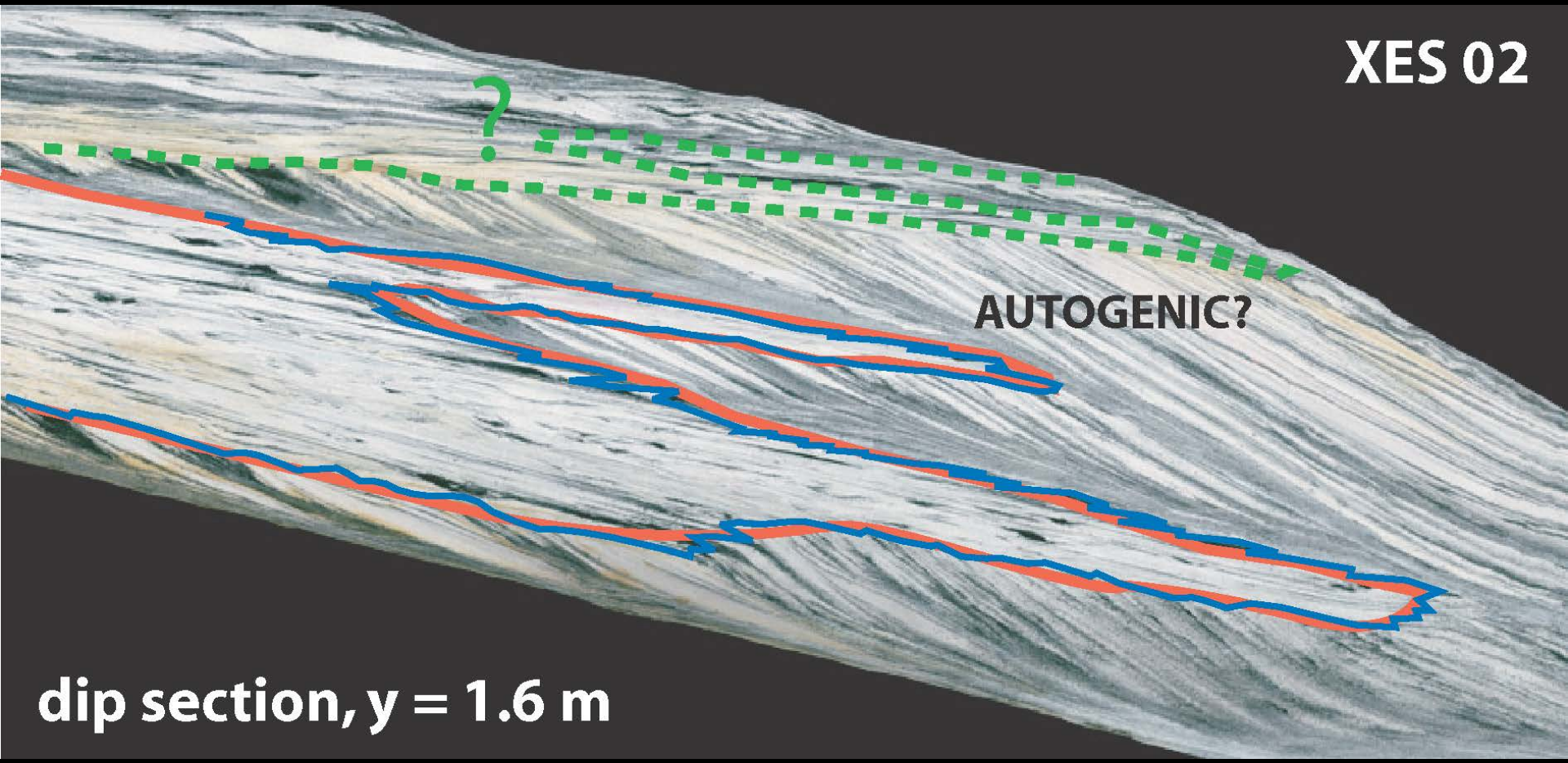
Experimental Stratigraphy

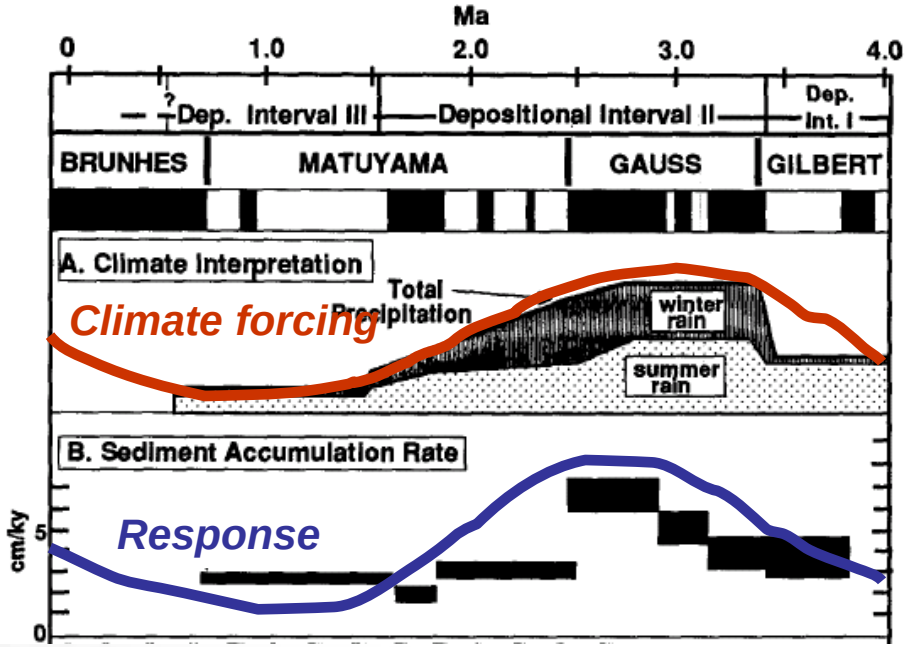
Controls of stratigraphic architecture: Base-level and Tectonic variation

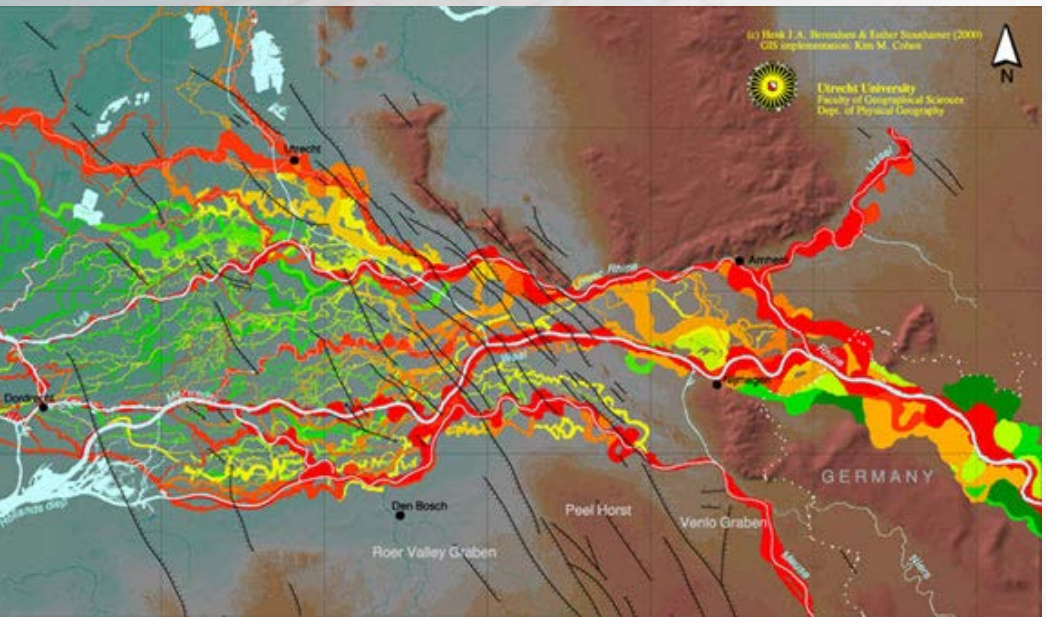


Cyclic and Acyclic Nature of the Processes

External forcing:
Climate, Tectonic, Sea-level variation…

Climatic influences on continental deposition during late-stage filling of an extensional basin, southeastern Arizona (Smith 1994)





Autogenic processes:
Delta-lobe switching, Channel avulsion… Internal, local “noise”

Rhine-Meuse delta: Palaeogeographic maps at 500 yr time intervals. All the channel belts that were formed during the Holocene from 7000 yr BP to the present. (Berendsen and Stouthamer 2001)

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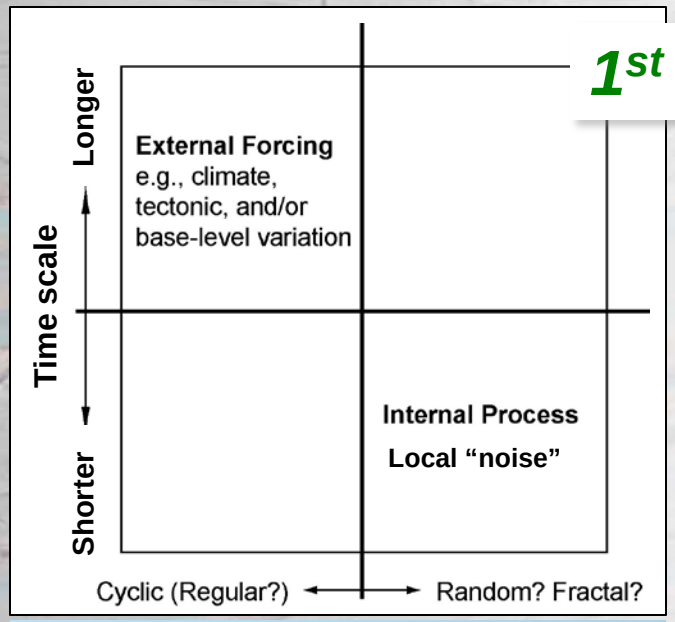
Stratigraphic Products attributed to
Allogenic forcing: **Cyclic** depositional sequences by **Long-Term changes,**
Autogenic Processes: **Acyclic** deposits by **Short-Term fluctuations**.

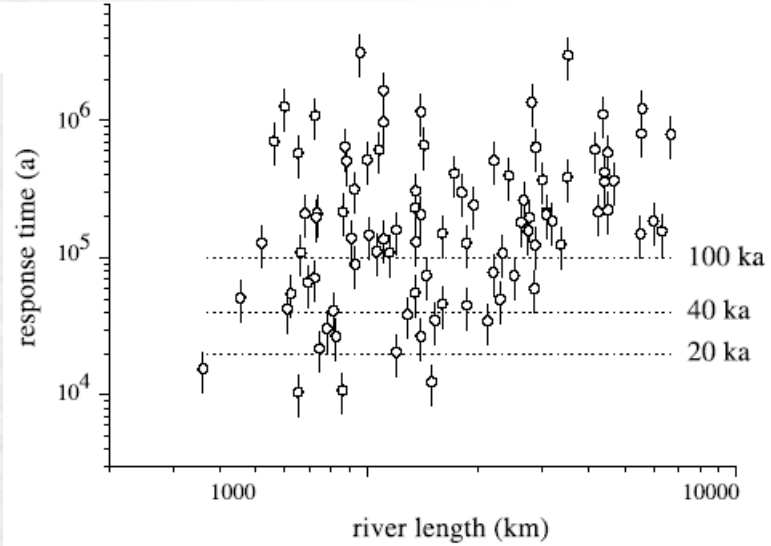


1st Key to decouple: Basin Response Time

Time scale for sedimentary systems to response to environmental changes (Paola et al. 1992)

$$T_{eq} = \frac{L^2}{\nu}$$

L: Basin length scale
ν: Diffusivity governing sediment transport



(Castelltort and van den Driessche,

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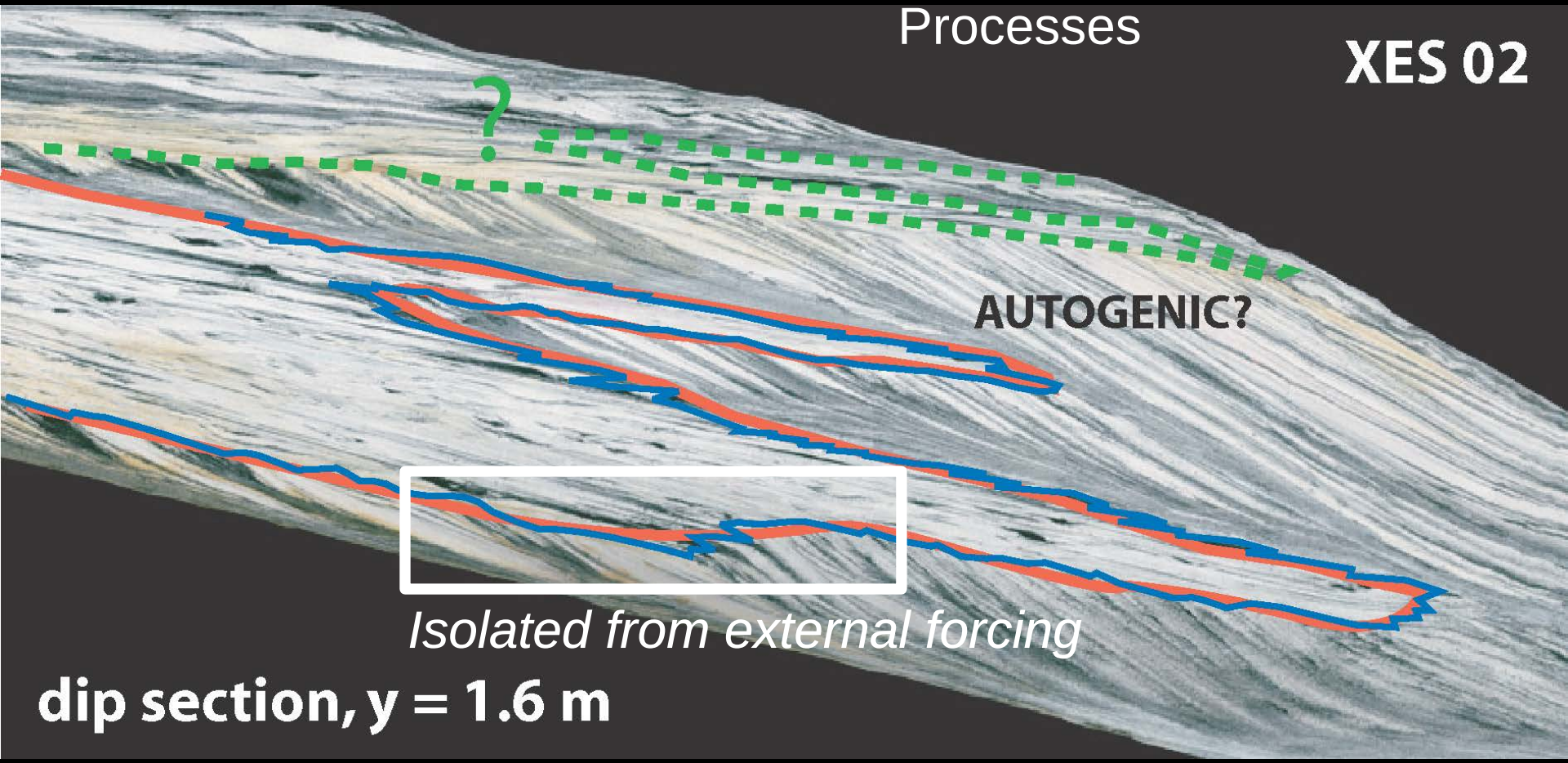
Experimental Stratigraphy

Controls of stratigraphic architecture: ~~Base level and Tectonic~~ variation

➔ Autogenic Processes



XES 2002 and 2005 Experiments

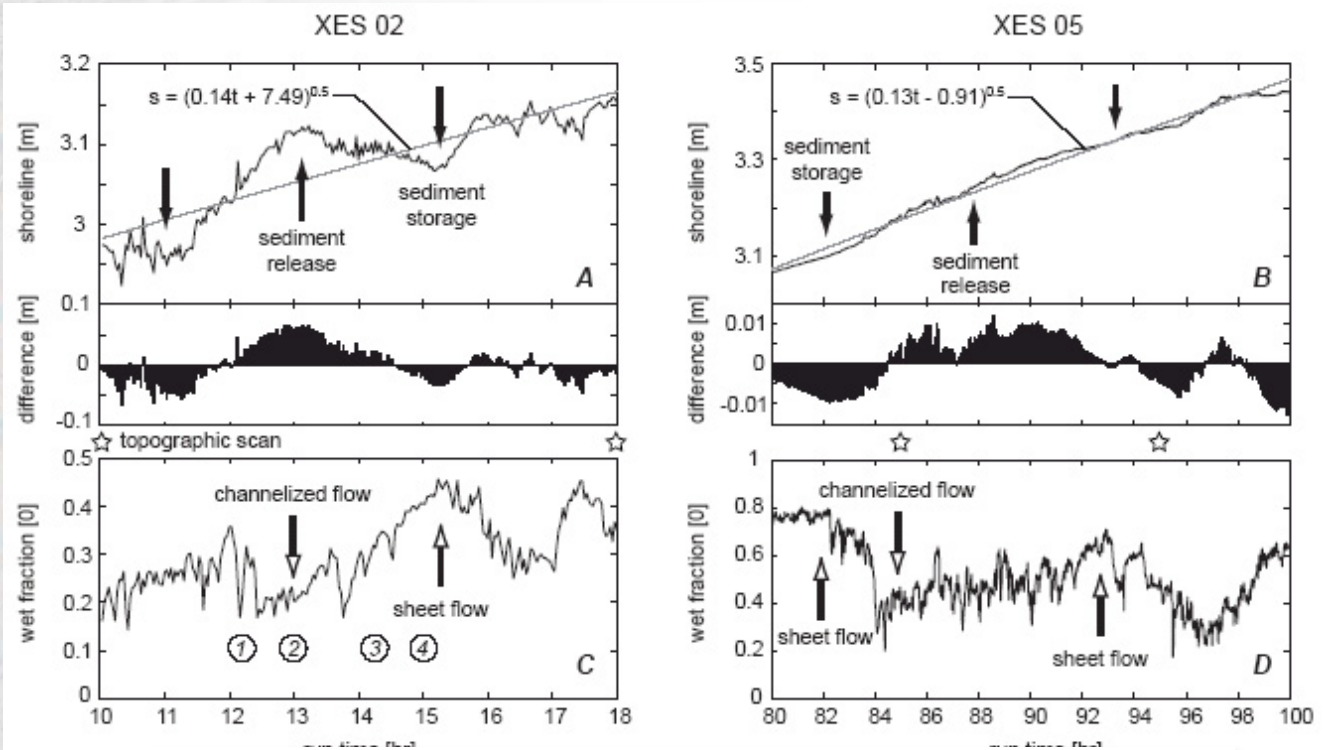
Laterally Averaged
Shoreline Fluctuation at time scale less than T_{eq}

Period between sheet- and channelized flow, T_A:

- ~ 5 hrs in XES 2002

  $< T_{eq}$ = 60 hrs
- ~ 13 hrs in XES 2005

  $< T_{eq}$ = 390 hrs



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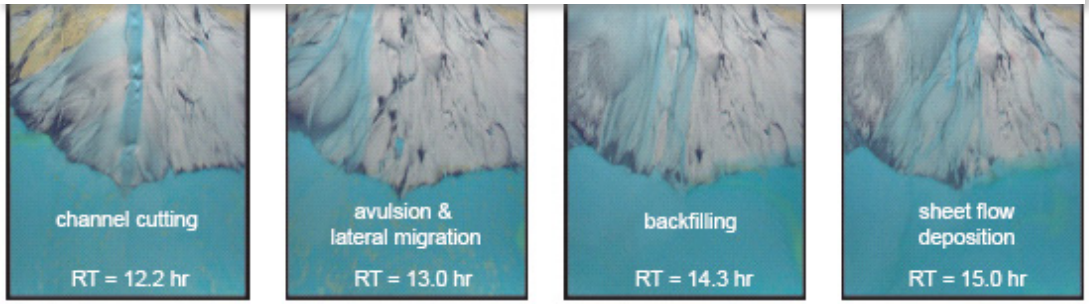
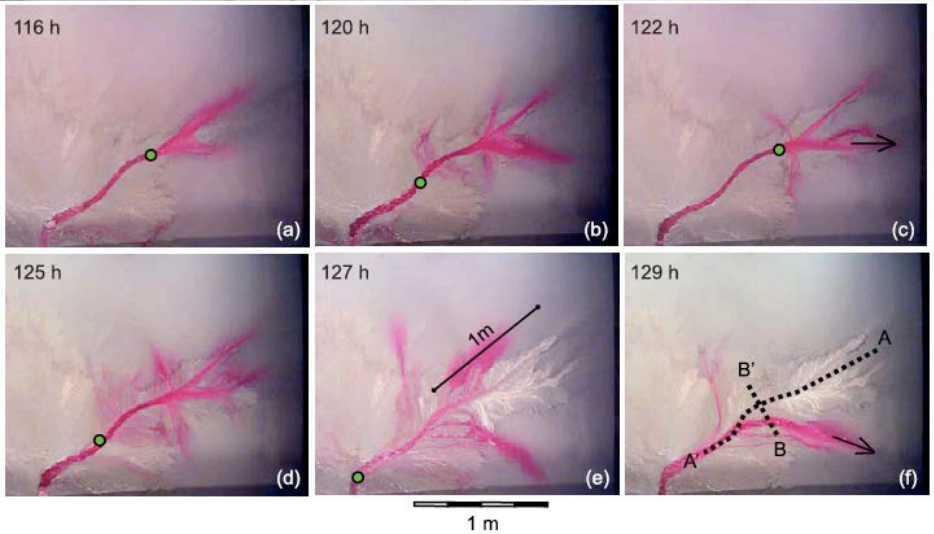
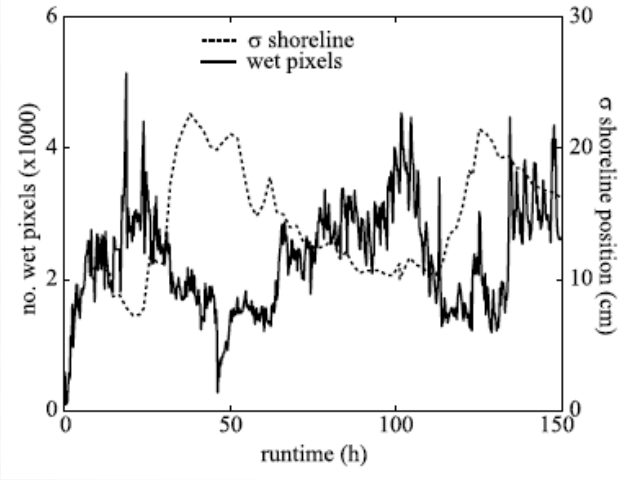
2nd Key to decouple: Autogenic Time & Event scales

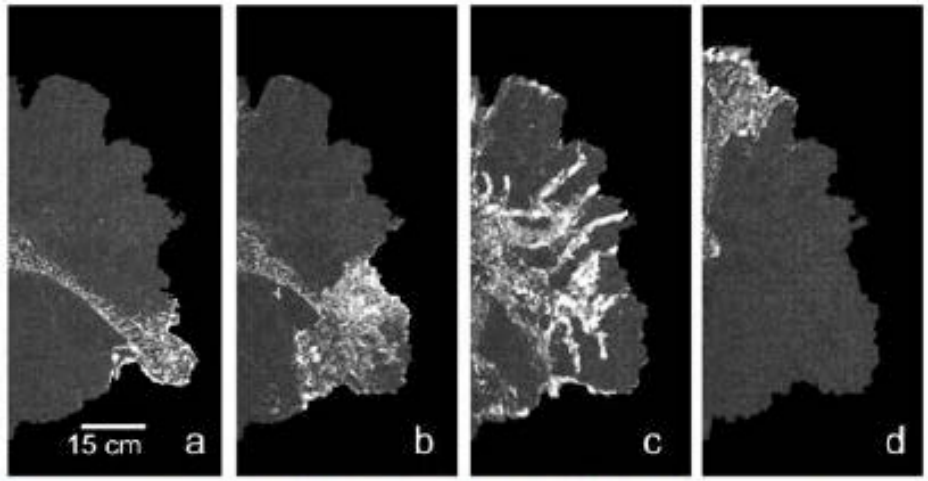


(Kim and Jerolmack

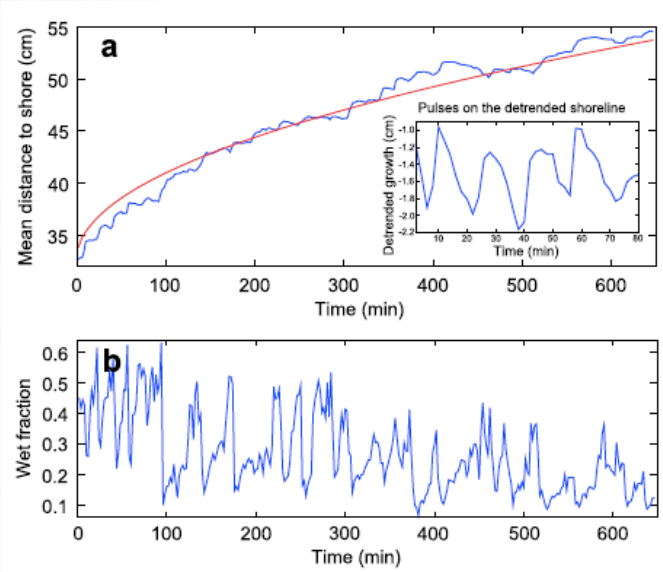




Cohesive sediment mixture (Hoyal and Sheets 2009)



20% granite chips (D = 2 mm) + 80% acrylic sand (D = 0.3 mm)
(Reitz et al. 2010)



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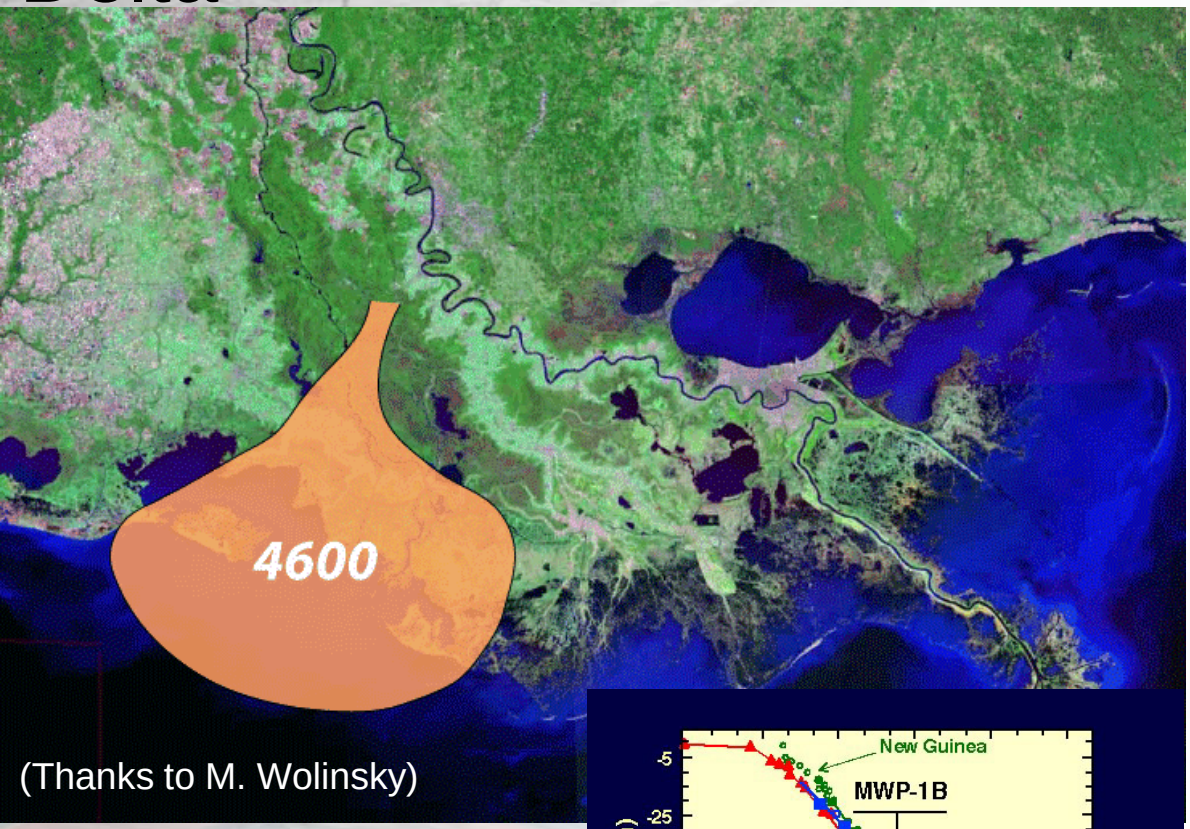
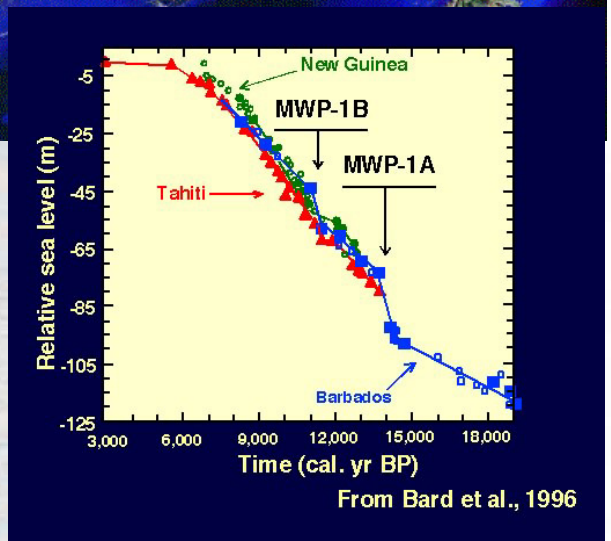
Natural Delta Building in the Mississippi Delta



(Thanks to M. Wolinsky)



Characteristic Autogenic Time Scale, T_A (Reitz et al. 2010)**:**

$$T_A \approx \frac{hBL(t)}{Q_s}$$

h: Flow depth
L: Basin length scale
B: Averaged channel-belt width
Q_s: Sediment load

Predicted T_A ~ 1500 years (h = 25 m, B = 1.5 km, L = 400 km, $Q_s = 10^7$ m^3/yr, Reitz et al. 2010)

Sea-Level Rise from 19,000 years BP until 3,000 years BP according to the Bard Curve (Bard et al., 1990).

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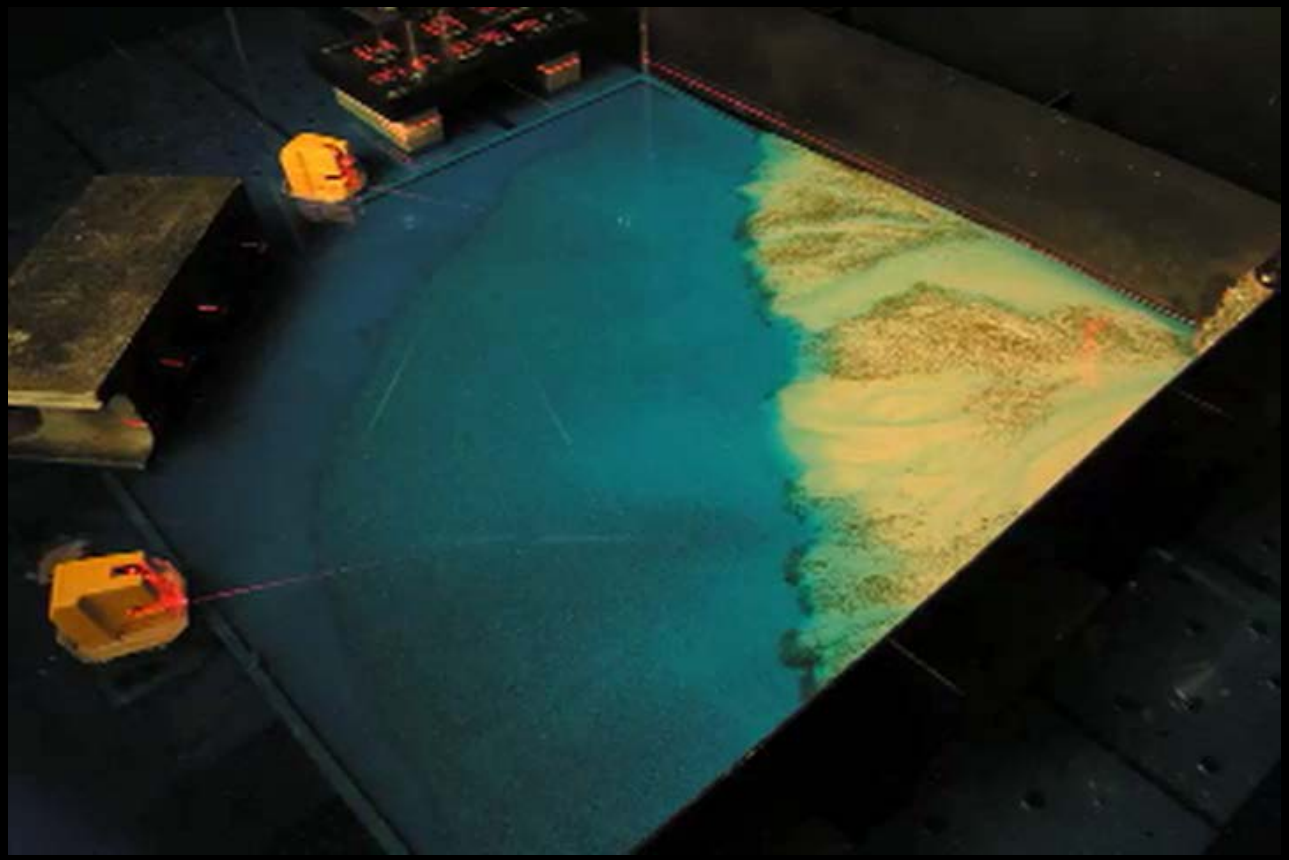
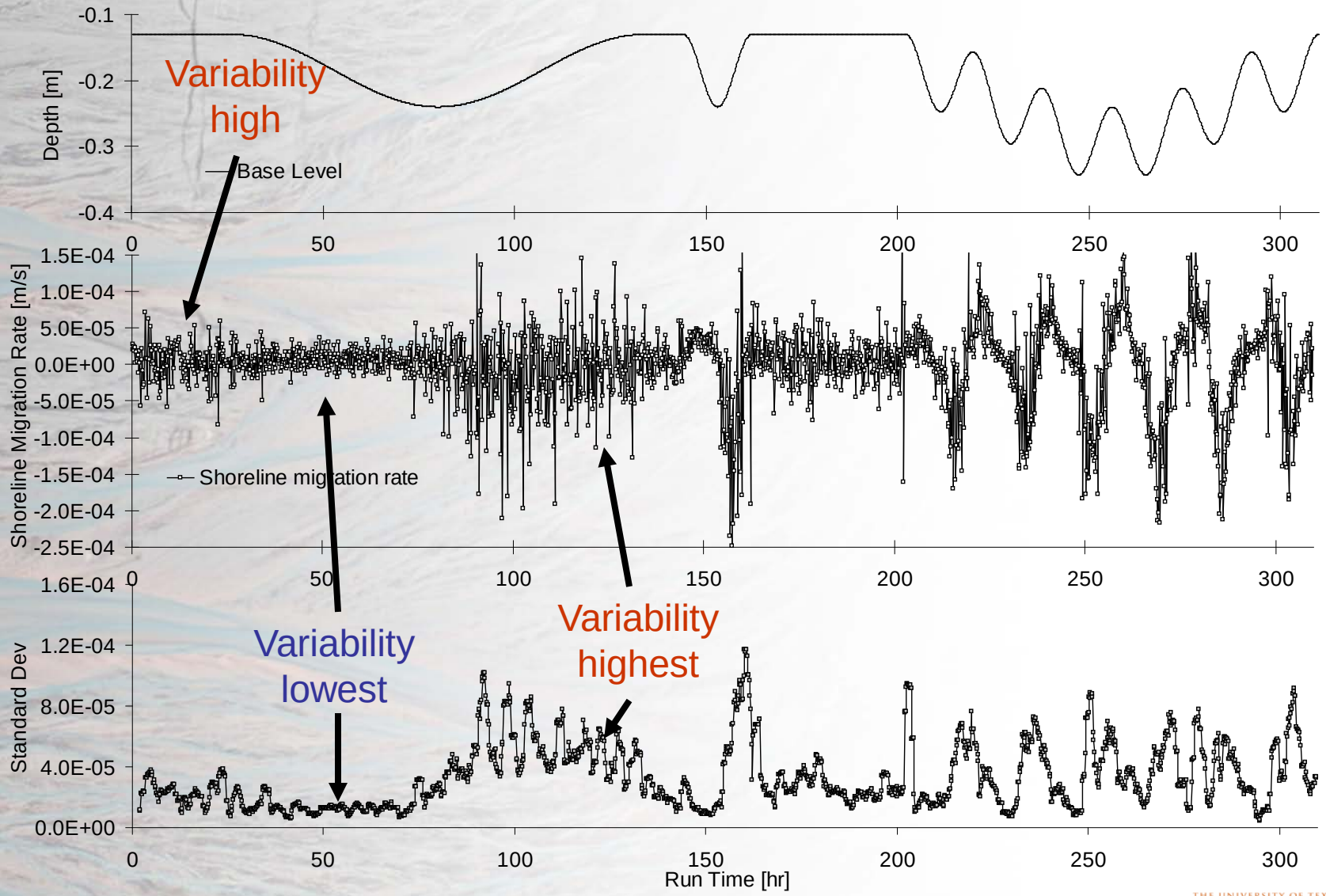
Complex Response of AP to Sea-level Changes



Dancing Channel (DC) Experiment conducted by Powell, Kim, and Muto (Aug. 2010)
Bimodal: 50% Fine sand (D = 0.1 mm) + 50% Coarse sand (D = 1 mm)
Sea level: Constant rise

Complex response: ***Change in variability***



XES 2002 shoreline data: The autogenic signal in the shoreline migration rate varies by a factor of **3** (Kim et al. 2006)

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New York Times:

In Weather Chaos, a Case for Global Warming

August 14, 2010

PAKISTAN The worst flooding in at least 80 years has killed ~1,384 people.

RUSSIA Wildfires stoked by the country's worst heat wave on record have burned 1.9 million acres.

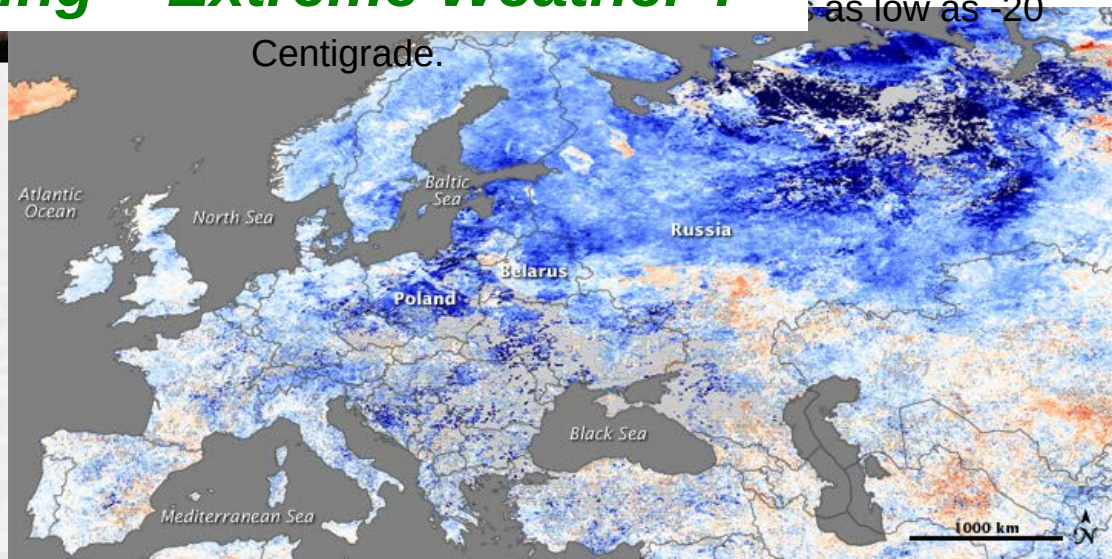
NASA Earth Observatory: A wave of frigid air spilled down over Europe and Russia from the [illegible] a deadly cold [illegible] as low as -20 Centigrade.

Global Warming ~ Extreme Weather ?

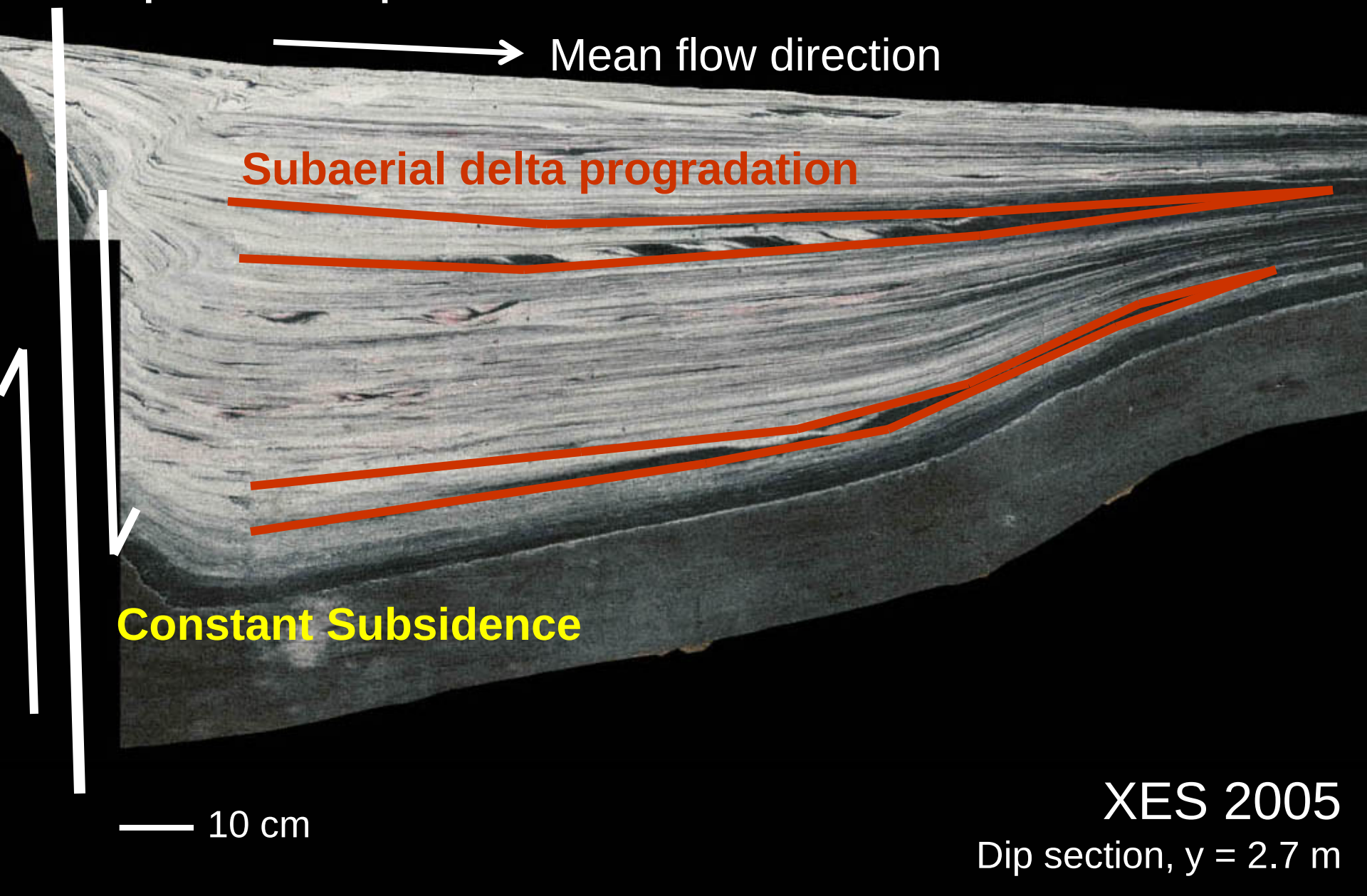
FOX News:

Extreme Weather: Why Has Mother Nature Gone Bonkers?

January 06, 2010



Complex Response of AP to Tectonics



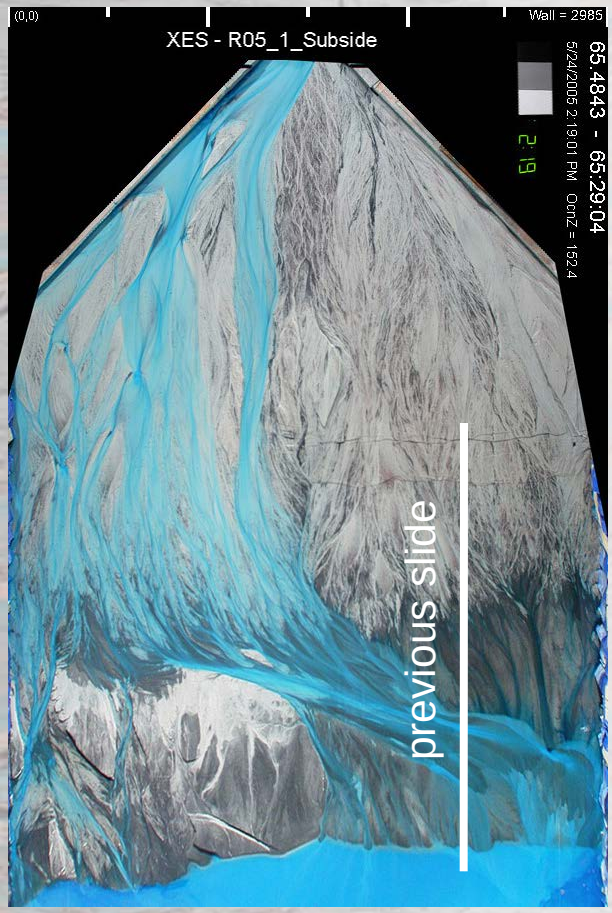
XES 2005

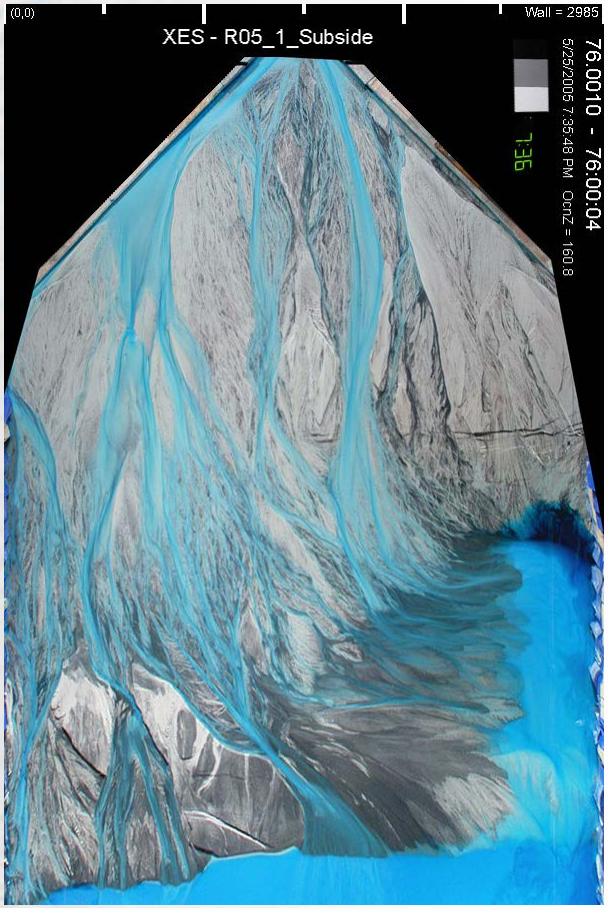
Dip section, y = 2.7 m

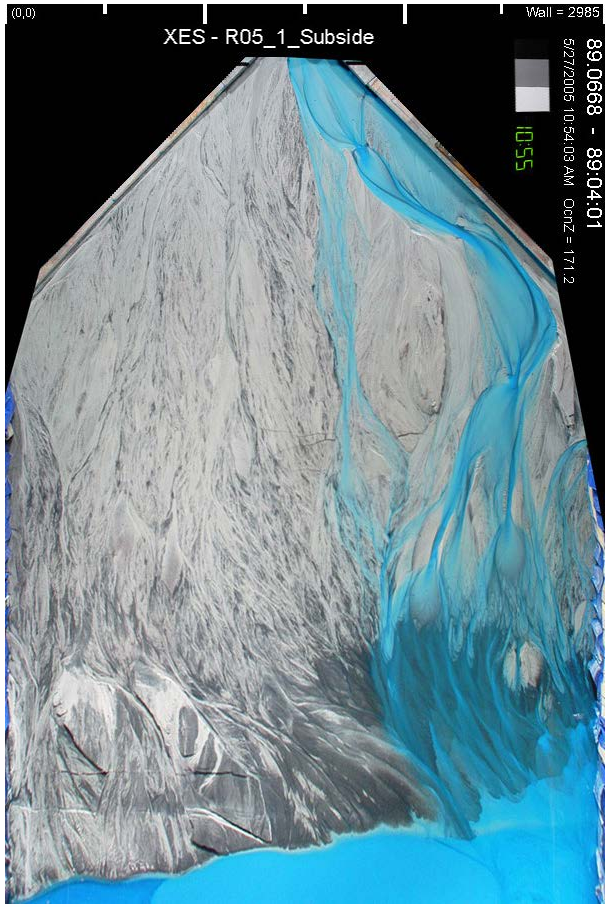
Reorganization of the Fluvial System

Lake phase

Erosion-fill phase



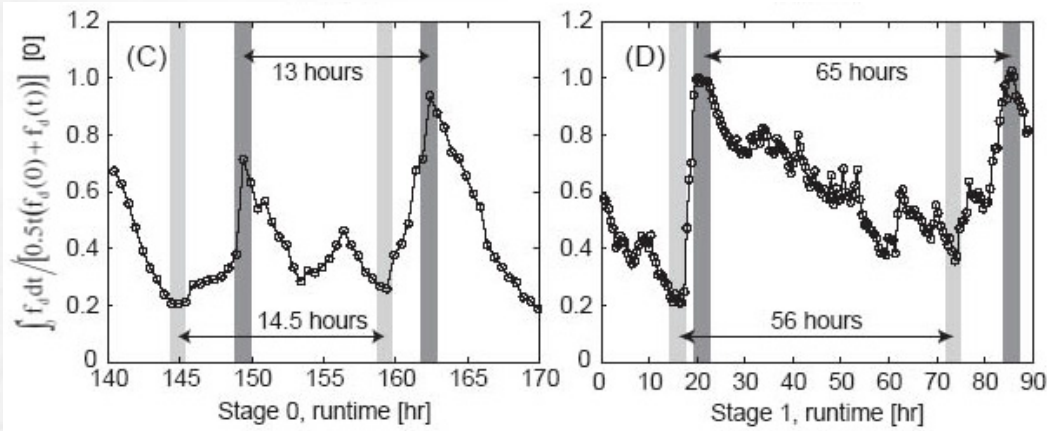


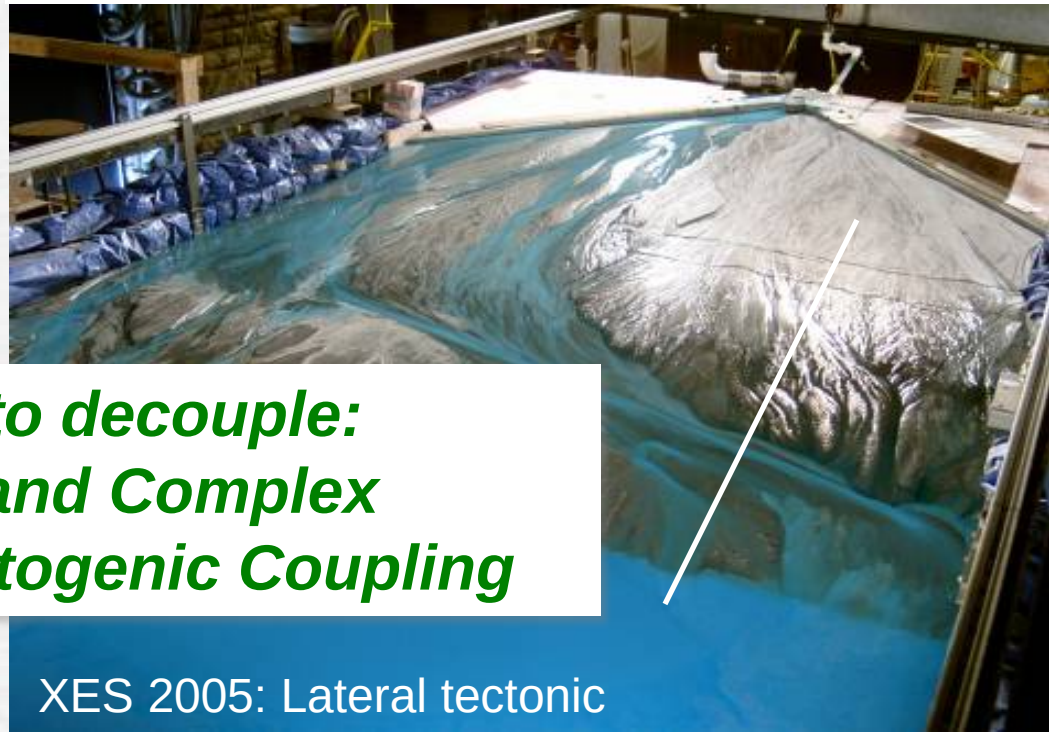


(Kim et al. 2010)

Complex Response: ***Long-term autogenic processes***

- **Increase** in the time period of the fluvial autogenic variation by active tectonics
  - Stage 0: No tectonics
    - 13~15 hours
  - **Stage 1: Lateral Tilting**
    - ***56~65 hours***



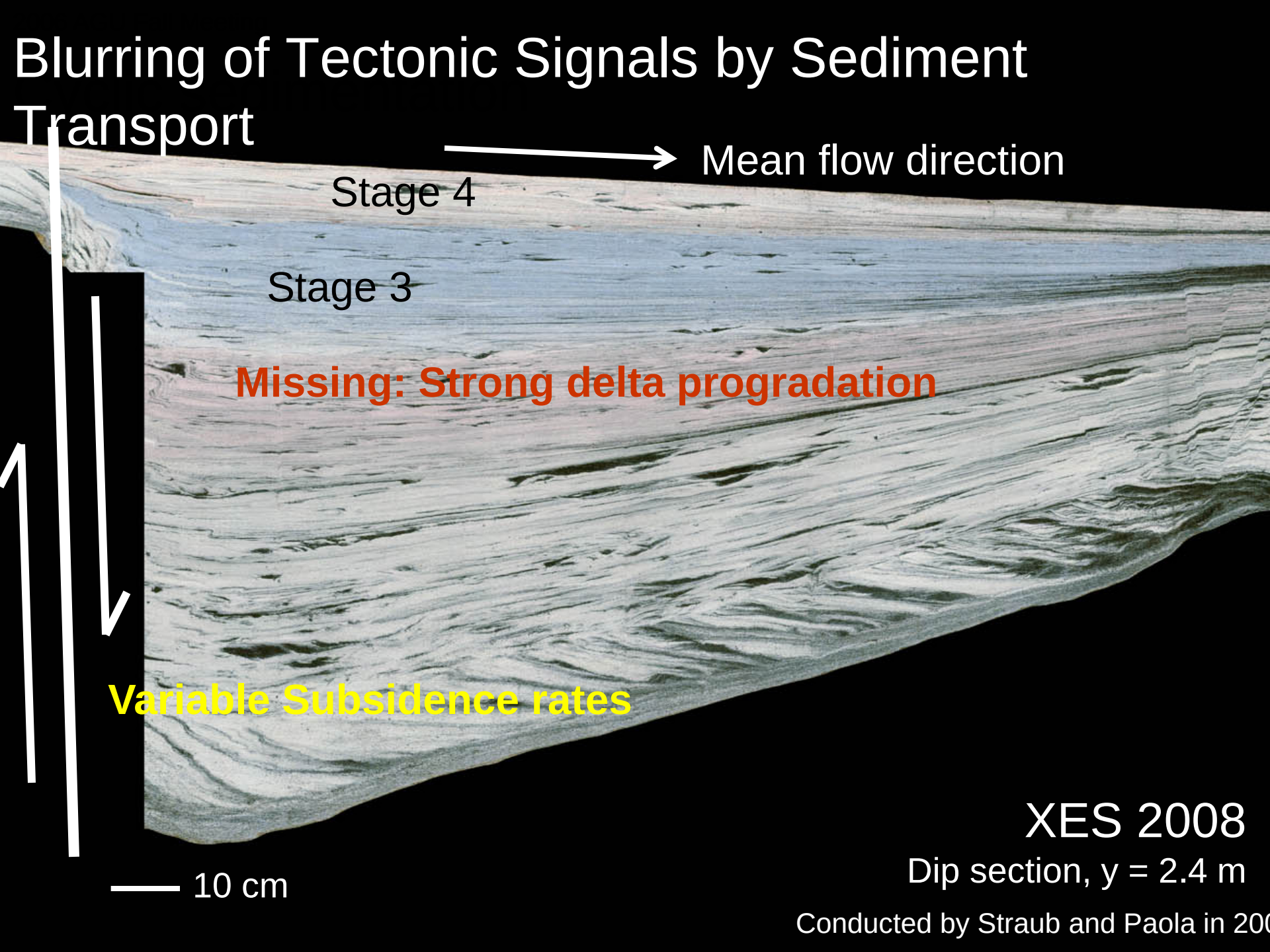


3rd Key to decouple: Understand Complex Allogenic-Autogenic Coupling

(Kim and Paola 2007)

XES 2005: Lateral tectonic

Blurring of Tectonic Signals by Sediment Transport



Blurring of Tectonic Signals by Sediment Transport

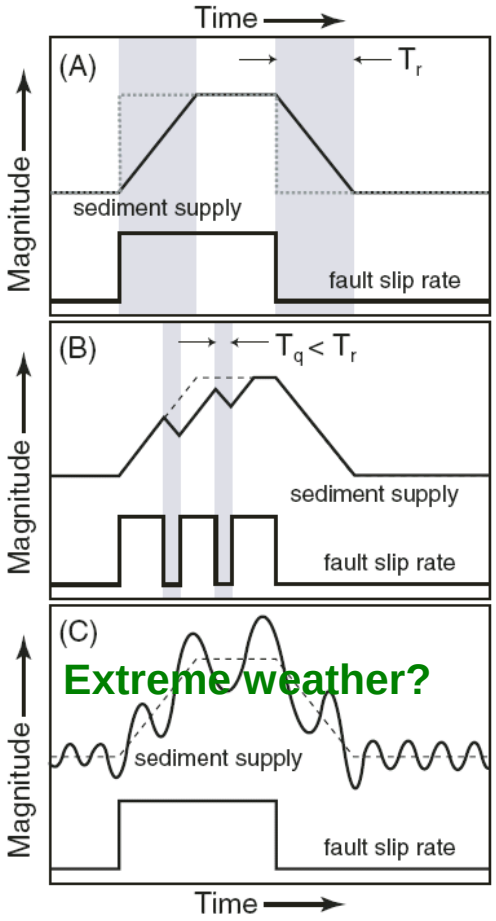
	q_s	h	B_w/B_t	T_C	S_x	$\Delta\sigma/L_y$	T_t	T_r	Run Time
	[m2/hr]	[m]	[0]	[hr]	[0]	[hr]	[hr]	[0]	[hr]
XES 99	0.012	0.01	0.45	1.28	0.05	0.002	9.6	0.3	
XES 05	0.00125	0.01	0.34	17	0.04	0.003	14.8	1.15	
XES 08 S1	0.00375	0.01	0.3	5.02	0.04	0.003	14.8	0.34	0-50
XES 08 S2	0.00214	0.01	0.3	7.52	0.05	0.003	14.8	0.51	50-100
XES 08 S3	0.0015	0.01	0.3	15.4	0.05	0.003	19	0.51	107-152
XES 08 S4a	0.0015	0.01	0.3	15.4	0.05	0	inf	0	152-168
XES 08 S4b	0.0015	0.01	0.3	15.4	0.04	0.007	5.4	2.84	168-174
XES 08 S4c	0.0015	0.01	0.3	15.4	0.04	0	inf	0	174-198

red layer

blue layer

yellow layer

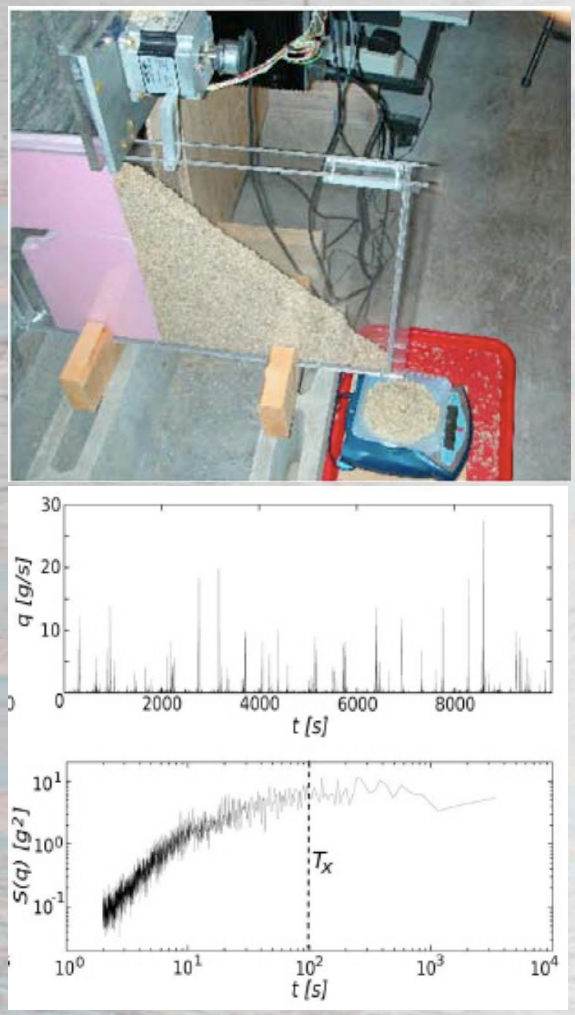
Parameters in XES 2008 (Straub et al. 2010)
Stage 3: 5% Red colored sand / Stage 4: 5% Yellow colored sand



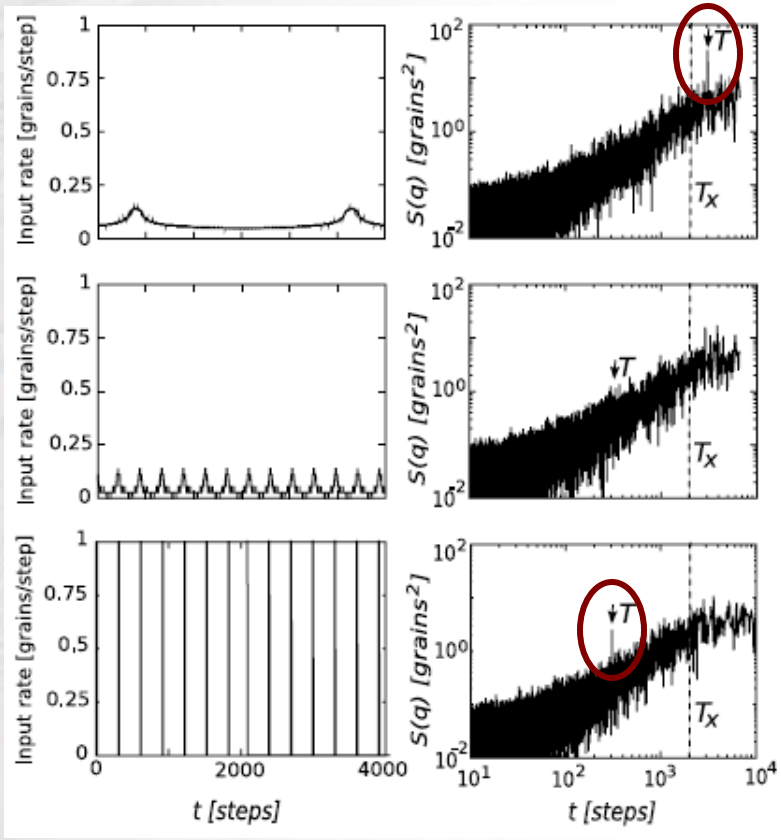
Attenuate high frequency environmental signals (Kim and Paola 2007)

Which one do you think has changes in subsidence rate?

Blurring of Climate Signals by Sediment Transport



Rise-pile experiment:
T_x = saturation time scale
Jerolmack and Paola (2010)



Numerical rise-pile experiment:
Cyclic sediment input with the period T
$> T_x$ and $< T_x$; $M > M_{max} \sim L^2 S_c$
Jerolmack and Paola (2010)

Complex Stratal Response – ***How to decouple?***

http://pittsburghmom.com/blogs/pittsburghmom/archive/2009/01/05/is-barbie-driving-the-fire-truck-the-joys-of-toy-organization.aspx

Complex Stratal Response – ***Where to start?***

http://pittsburghmom.com/blogs/pittsburghmom/archive/2009/01/05/is-barbie-driving-the-fire-truck-the-joys-of-toy-organization.aspx

http://ptinterns.files.wordpress.com/2009/02/playdough5.jp

rstand Individuals,

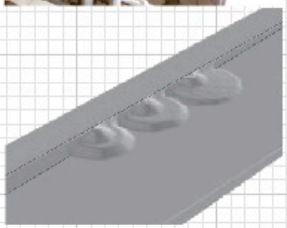
n Mix One by One!

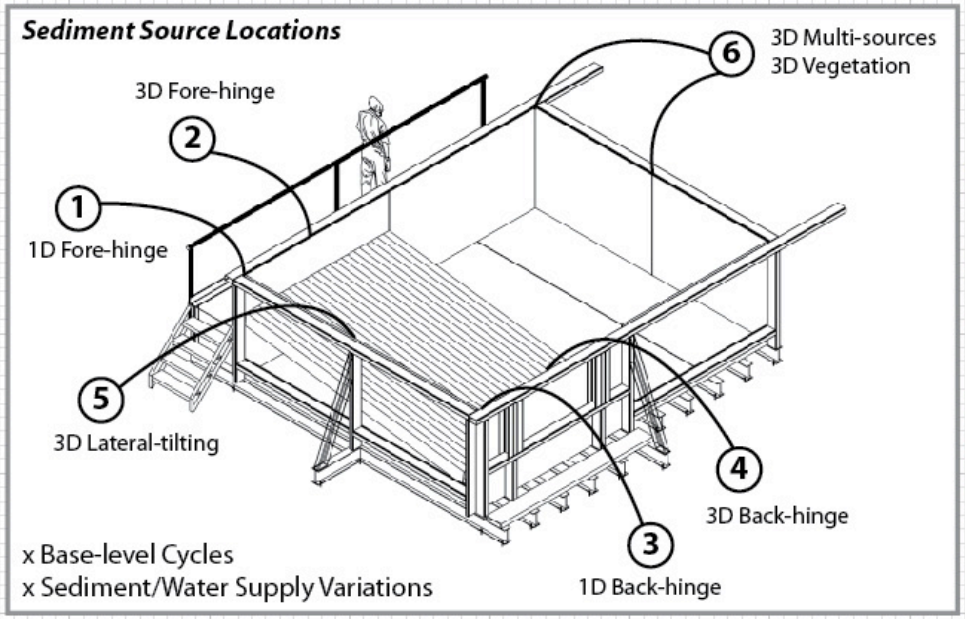
Complex Stratal Response – ***Where to start?***

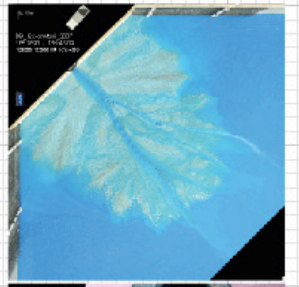
Understand Individuals, Then Mix One by One!

University of Texas Experimental Delta (UTED) Basin

- Morphodynamics Laboratory, J.J. Pickle Research Campus, UT at Austin







http://www.ig.utexas.edu/people/staff/delta/experiments.html

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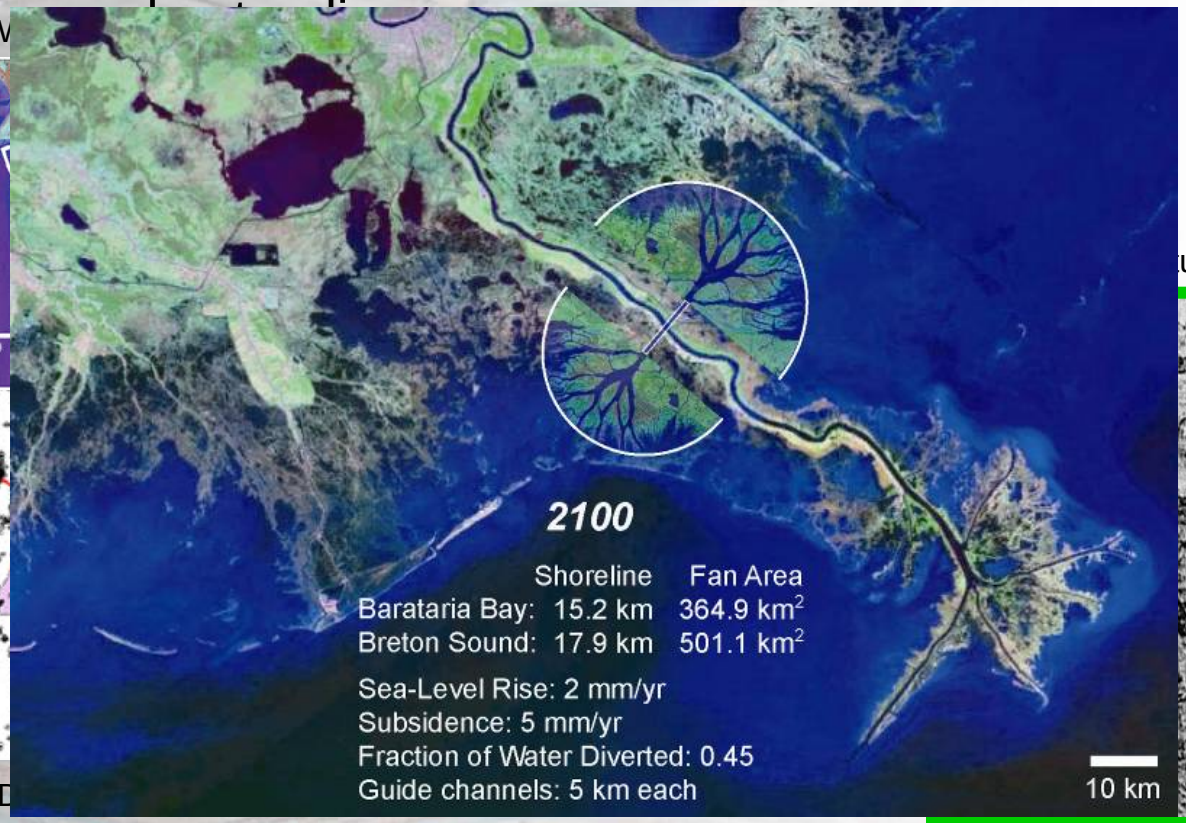
GeoPRISMS

Quantitative understanding of ***fossilized dynamics*** across time scales

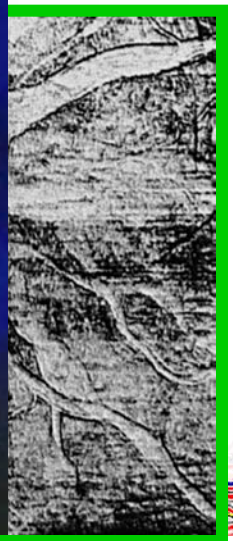
The following should be considered to accomplish our goal:

- Abundant ***well log & core data*** that provide ***robust age control*** across scales
- Emerging high-resolution information of modern ***surface topography*** data and ***subsurface records*** (i.e. digital topography + 3D seismic) across scales

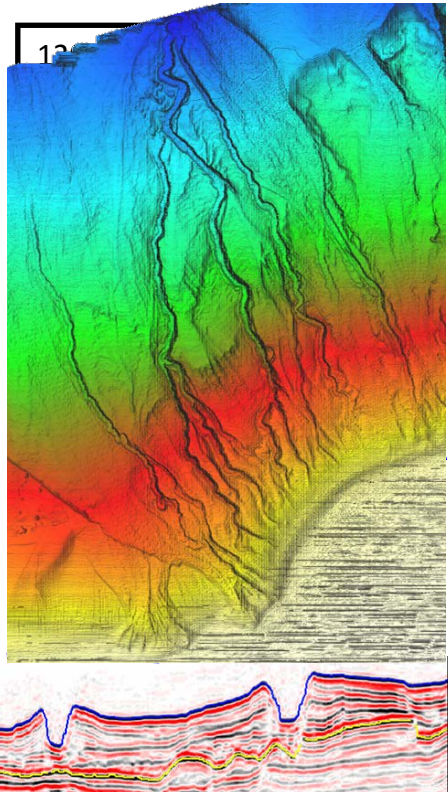
Predictive science: data collection & analysis establishing quantitative



umberger 1998



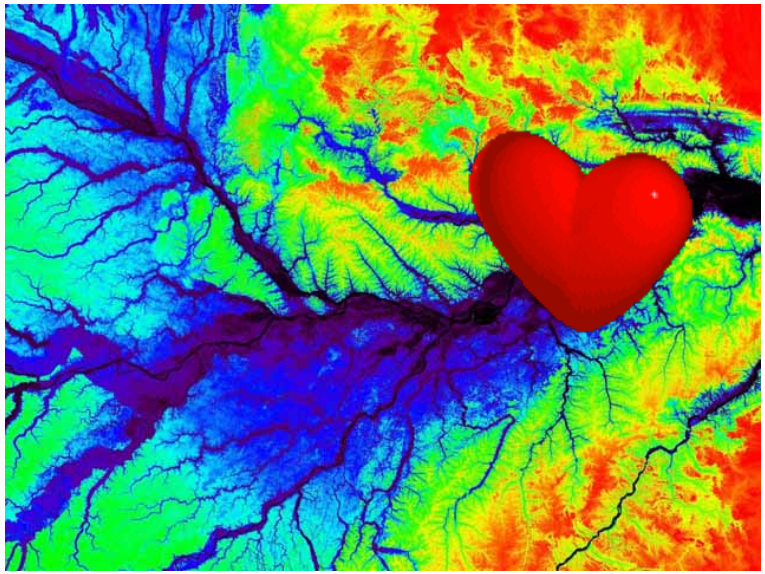
Brunei Shell Petroleum Co.



Conclusions

Decoupling Allogenic Signatures from Complex Autogenic Responses in Stratigraphy

1. Basin response time scale
   - $T > T_{eq}$ Full response
   - $T < T_{eq}$ Suppressed/delayed response
2. Autogenic time and event scales
3. Complex interactions of Autogenic processes with Allogenic forcing
   - Elongated autogenic time scale
   - Overlap regime between autogenic and allogenic processes becomes broader



Topographic map of Amazon River Basin, Ohio State University news release, October 5, 2005

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