Overcoming Grand Challenges by Collaboration between Experimentalists and Modelers

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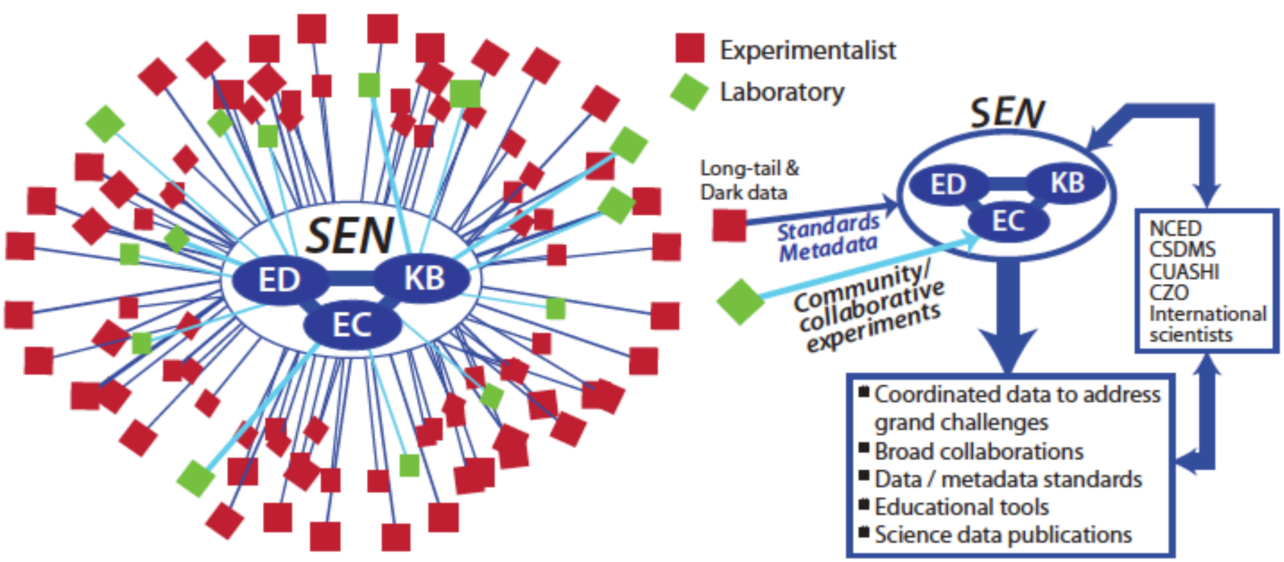
UW

UCLA

USGS
science for a changing world

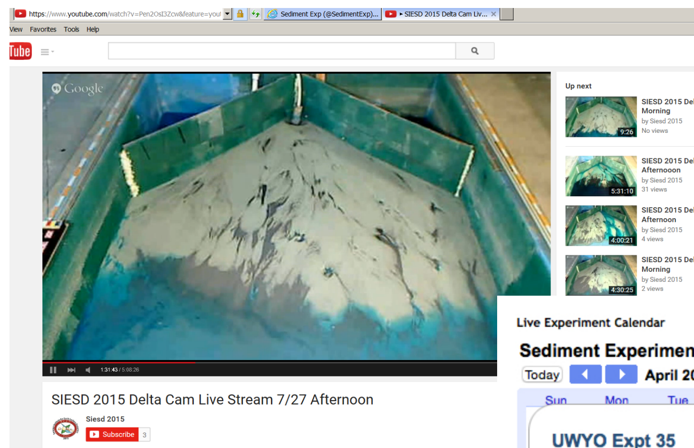
What is SEN?

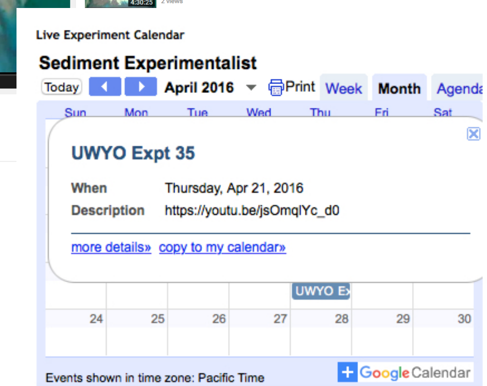
- ***Sediment Experimentalist Network***
- NSF EarthCube Research Coordination Network (RCN)
  - To support a data-enabled community for experimental Earth-surface process research
- **EC**: Experimental Collaboratories;
- **ED**: Education & Data Standards;
- **KB**: Knowledge Base;



SEN-EC (Experimental Collaboratories)

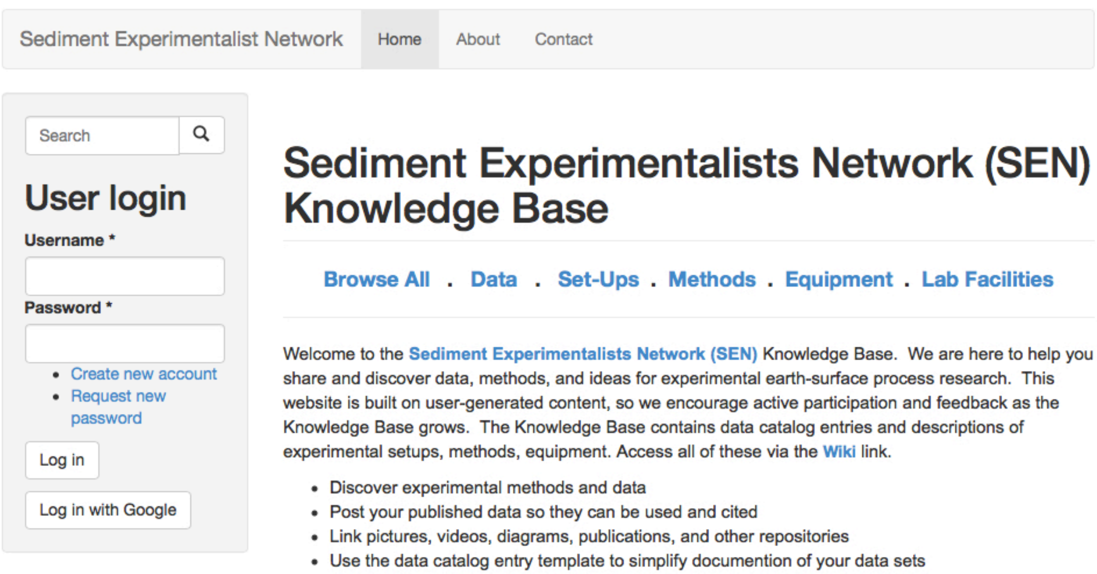
- ***Experimental Collaboratories***
  - Facilitate collaboration between experimental labs
    - Develop collaborative infrastructure
    - Broadcast experiments
    - Distribute experimental data
    - Address community grand challenges
- ***Broadcasting Experiments***
- ***Live Experiment Calendar***

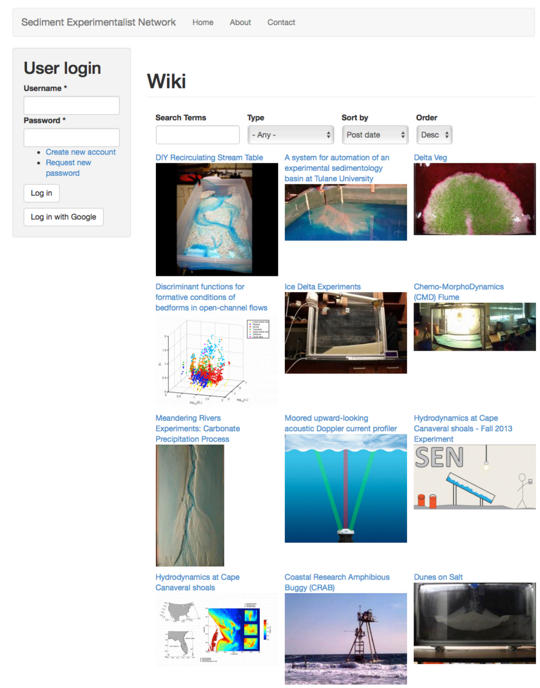




SEN-KB (Knowledge Base)

- ***Knowledge Base***
  - Develop online resources for experimental data management
    - SEN-Wiki **(sedexp.net)**
      - 45 Data; 26 Setups; 18 Methods; 21 Equipment; 6 Labs
    - Forum for user-based information exchange
    - Metadata, methods and facilities library





SEN-ED (Education & Data Standards)

- Develop & disseminate recommendations for data practices and standards
- ***Geomorphology paper in Binghamton Symposium***
  - Data management, sharing, and reuse in experimental geomorphology: Challenge, strategies, and scientific opportunities
- Workshop
  - 2014 SEN Workshop at Utrecht University
  - 2013 SEN Workshop at Nagasaki University
  - 2012 SEN Workshop at UT-Austin
- AGU Town Hall
  - 2012-2014: Publishing and sharing Earth Surface Process Data
- Summer Institute on Earth-surface Dynamics

- Two most significant challenges
  - Data discoverability
  - Data accessibility

2012 SEN Workshop at the University of Texas

Calling All Experimentalists

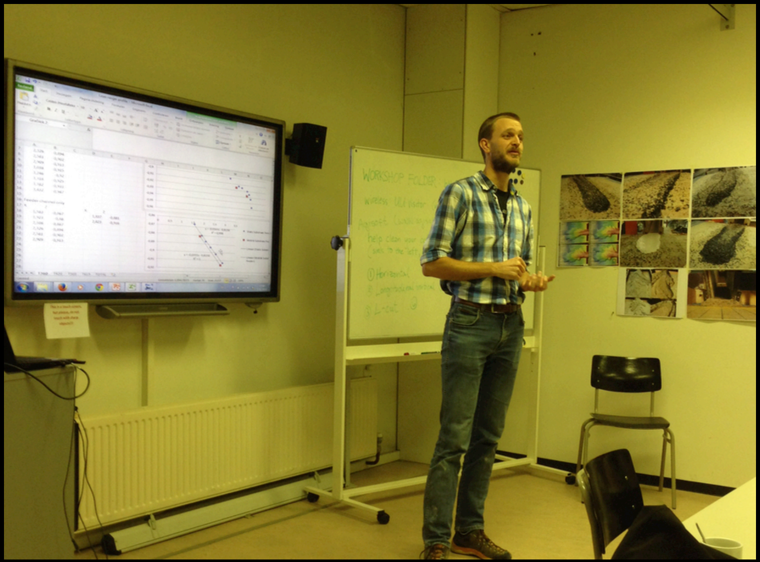
2013 SEN Workshop at Nagasaki University, Japan

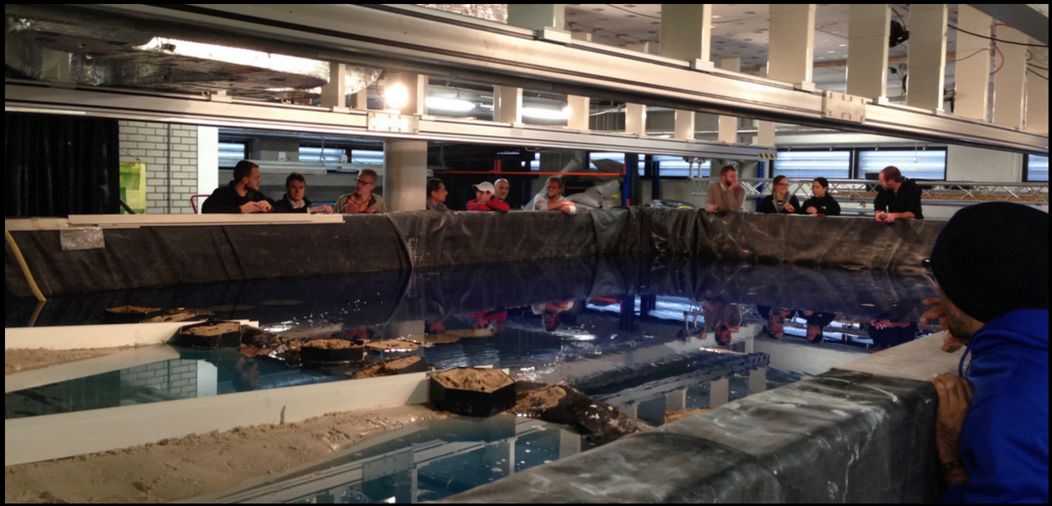
Stratodynamics

Tetsuji Muto
Hajime Naruse

2014 SEN Workshop at Utrecht University, Netherlands

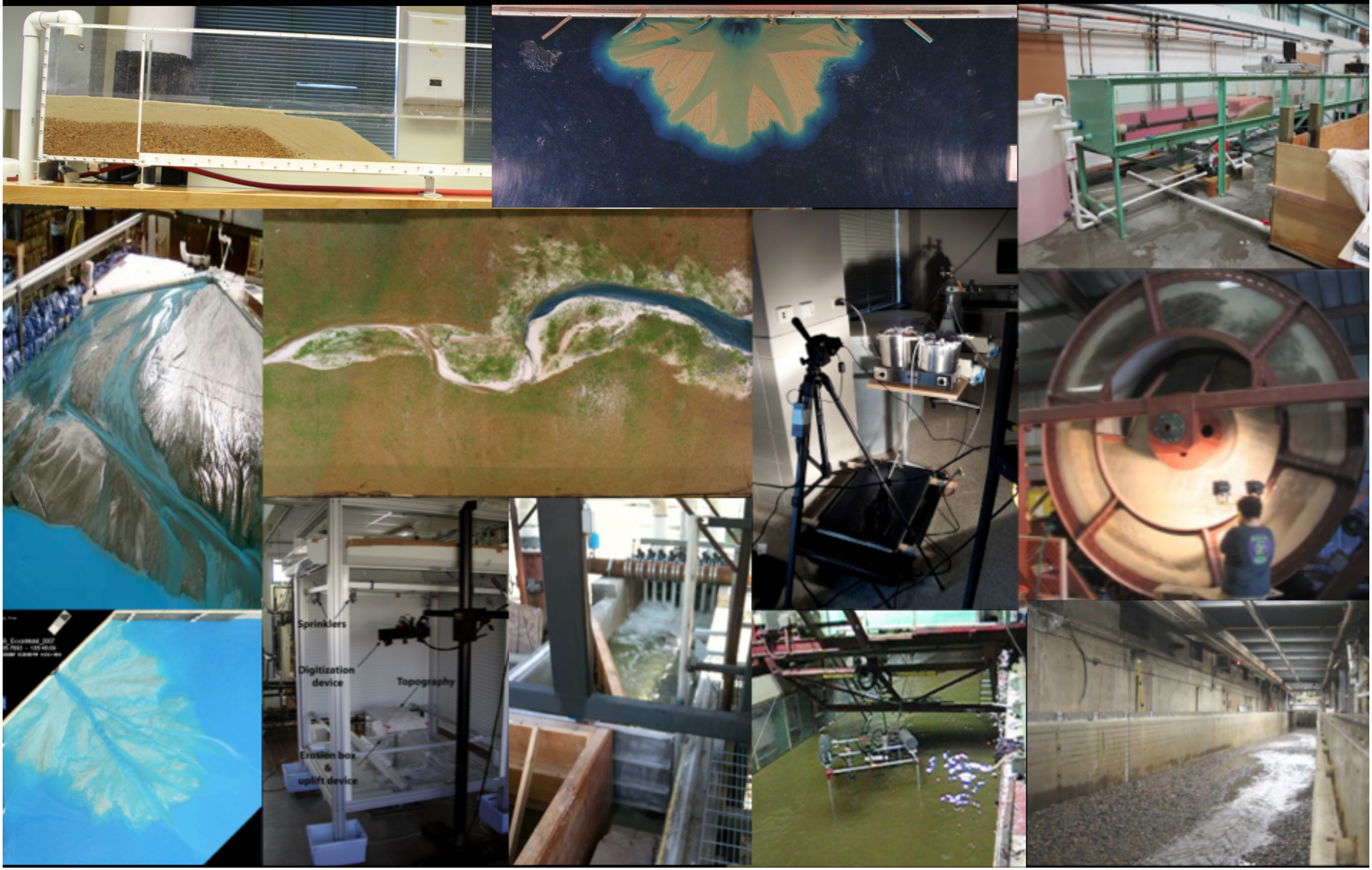
SEN Going Dutch: Exploring the Life Cycle of Sedimentary Experiments.





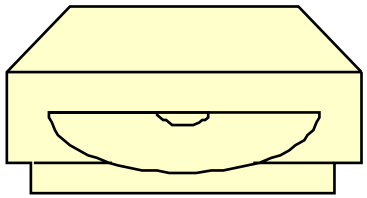
Joris Eggenhuisen

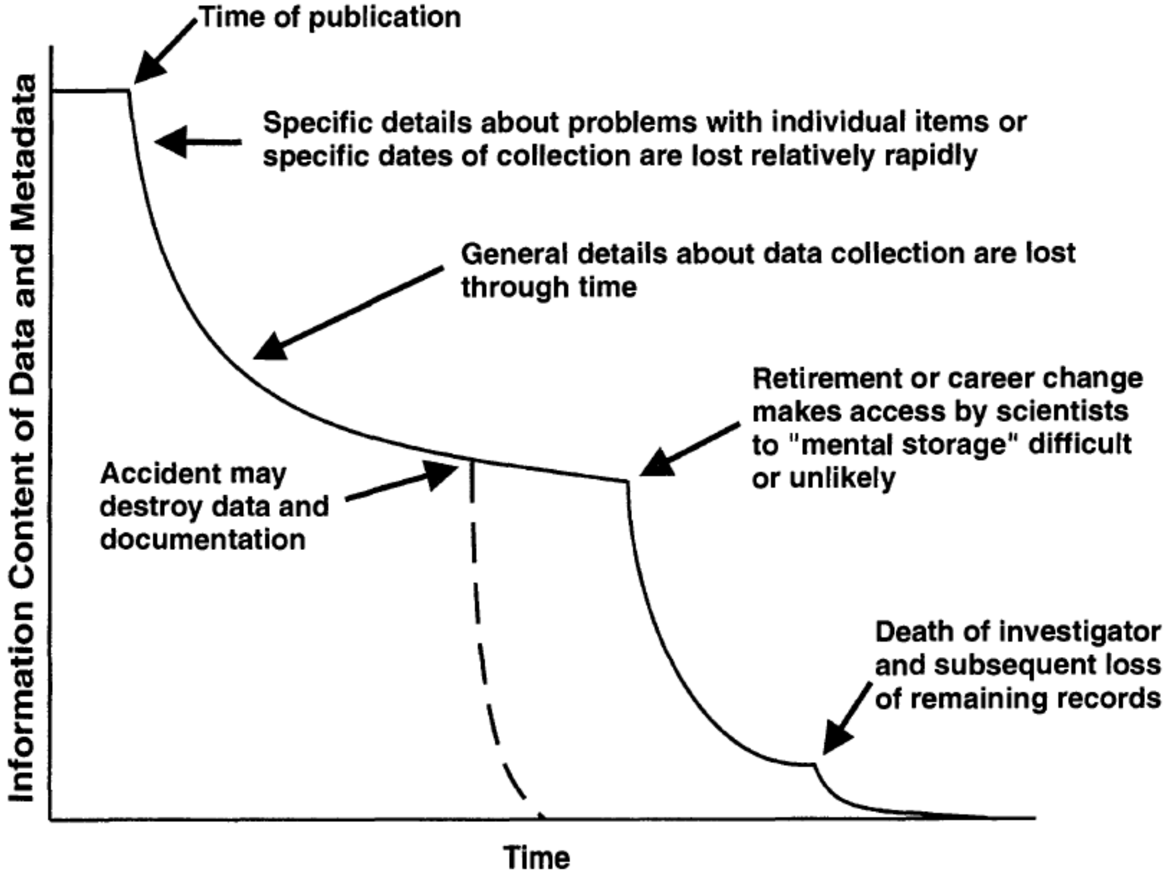
Why do we need a Sediment Experimentalist Network?



Data Challenges for Earth Surface Science

- *Dark Data*





Michener et al., 1997

Data Challenges for Earth Surface Science

- ***Dark Data***
- ***Big Data***

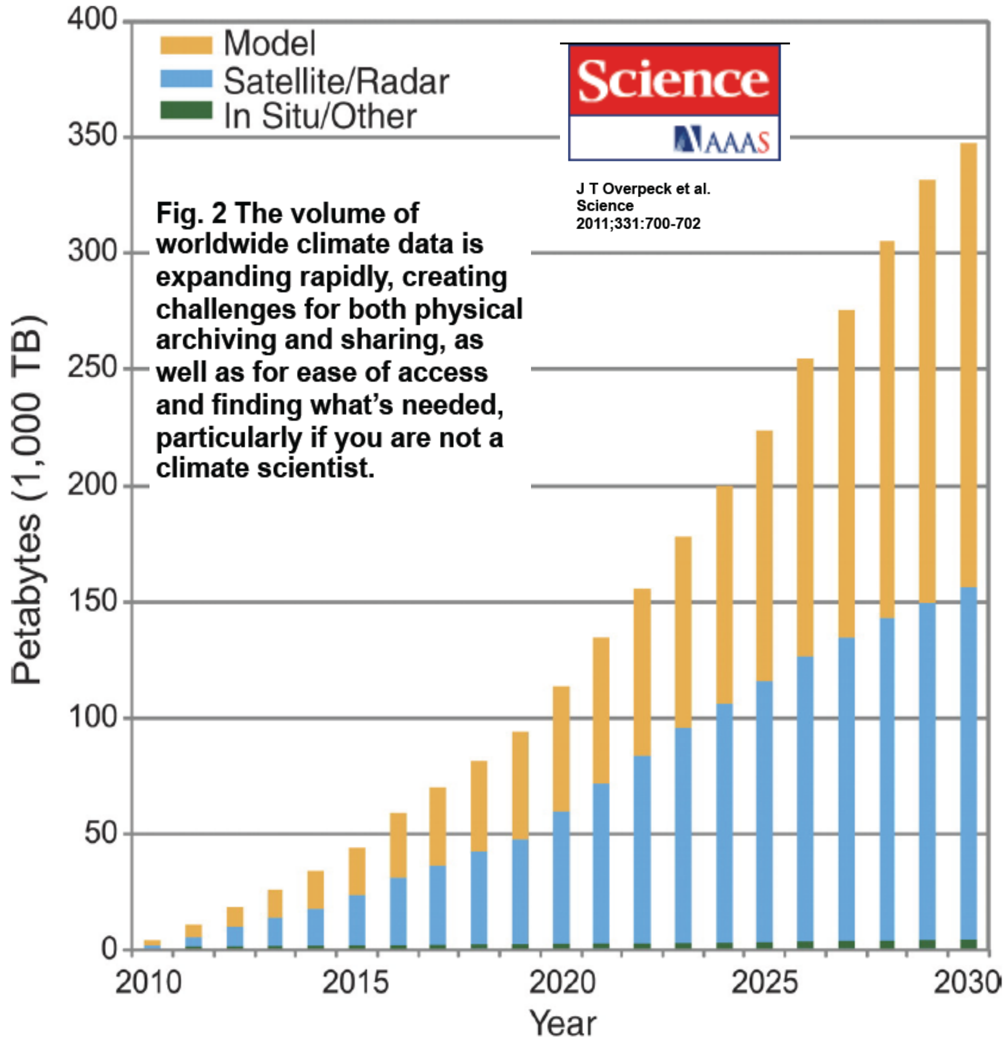


Fig. 2 The volume of worldwide climate data is expanding rapidly, creating challenges for both physical archiving and sharing, as well as for ease of access and finding what's needed, particularly if you are not a climate scientist.

IGSN Workshop, 34 IGC
Brisbane, August 5, 2012

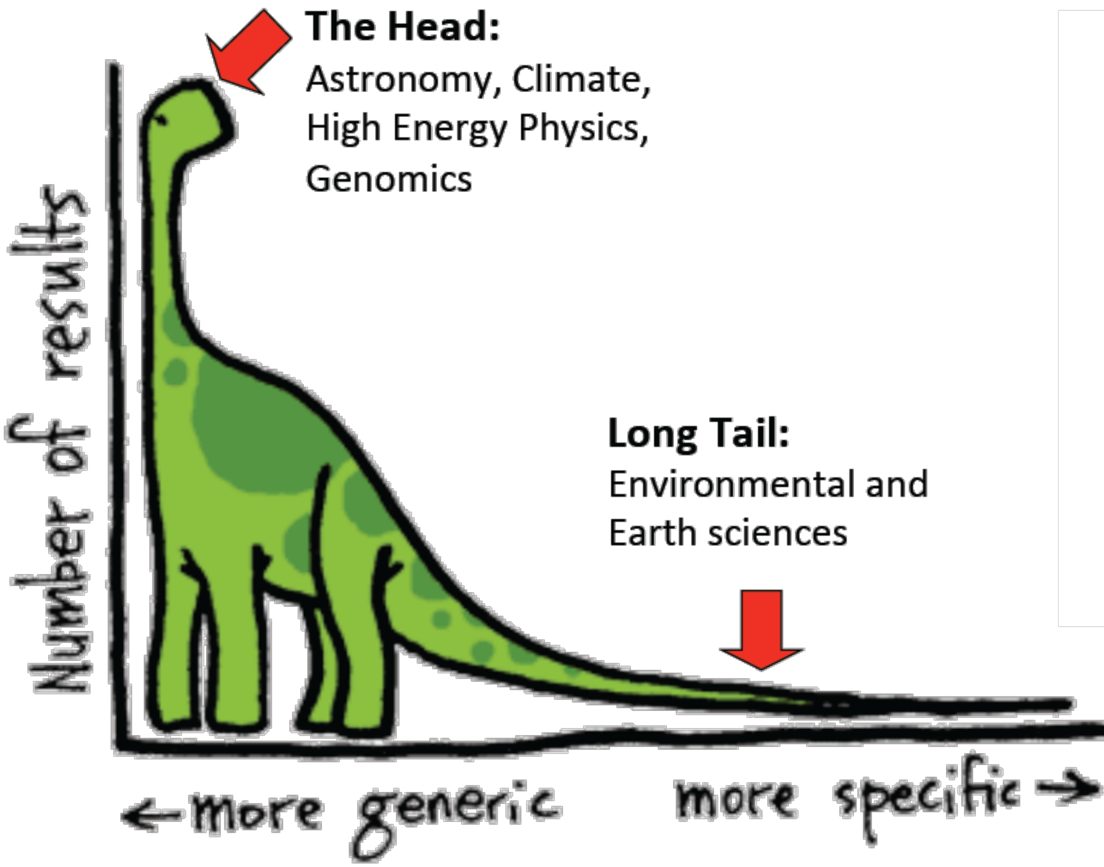
L. Wyborn

Data Challenges for Earth Surface Science

- *Dark Data*
- *Big Data*
- *Diverse Data*

Long Tail Characteristics

- More specialised
- Low volume
- On C drives
- Hard to find
- Heterogeneous
- Collected by many people
- Citizen science
- Etc
- Etc



http://juliegood.wordpress.com/tag/long-tail/

IGSN Workshop, 34 IGC
Brisbane, August 5, 2012

Data Challenges for Earth Surface Science

- ***Dark Data***
- ***Big Data***
- ***Diverse Data***
- ***Separable Data***
  - *Funding agencies are asking for data management plans*
  - *Journals are asking for links to archived full datasets*

Jorge cham

Data Challenges for Earth Surface Science

- ***Clinic2.1: SEN:*** ***Take only measurements. Leave only data***
- ***Wednesday at 1:30 PM C120A/B***

- **Best practices for data collection and management**
  - Lifecycle of data
  - Metadata
  - Data preservation, discovery, and reuse
  - Workflow
  - Cyberinfrastructure, web-based data repositories
  - The SEN Knowledge Base, and more

Challenges in Experimental Surface Science

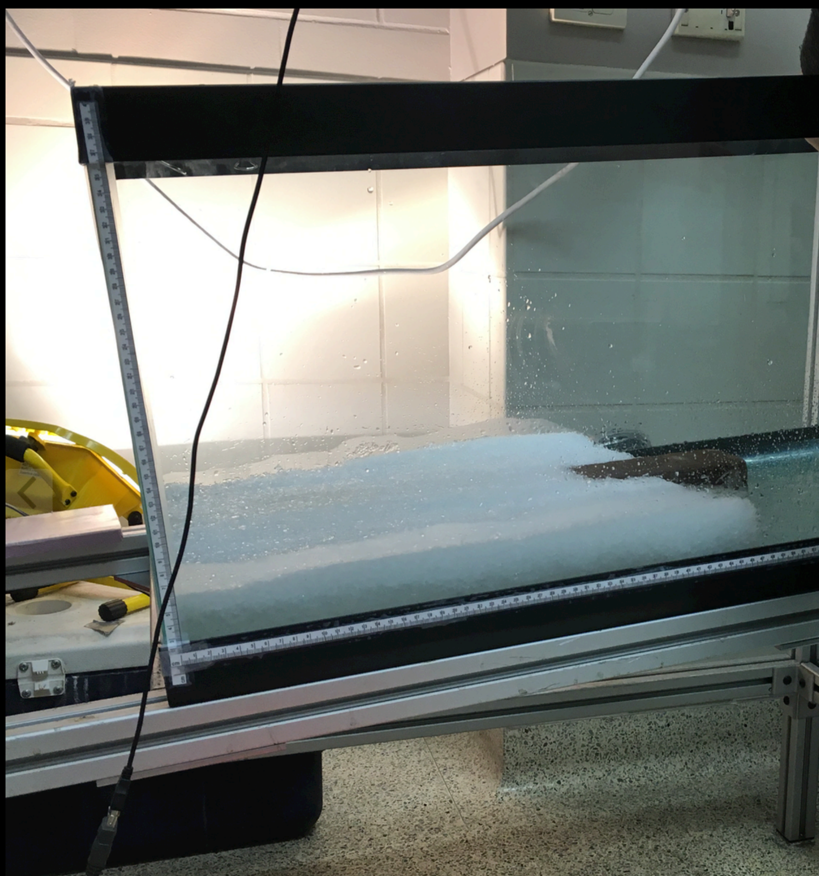
- ***Earthscape 2100*** *(Gary Parker at the 2013 Nagasaki SEN Workshop)*
- ***2016 CSDMS:*** *Advances in simulating* ***the imprint of climate change on the land and seascapes****, including the processes that influence them*

- ***Challenges in experimental surface science require data synthesis and experimentalist-modeler collaborations:***
  - *Repeatability*
  - ***Scalability***
  - ***Autogenic vs. Allogenic Processes***

Earthscape Imprint of Climate Change

Arctic: A delta prograding an ice-cover lake

Jan 2016, No name basin (0.9 m x 0.5 m)



Ye Jin Lim (MS student in UT)

Earthscape Imprint of Climate Change

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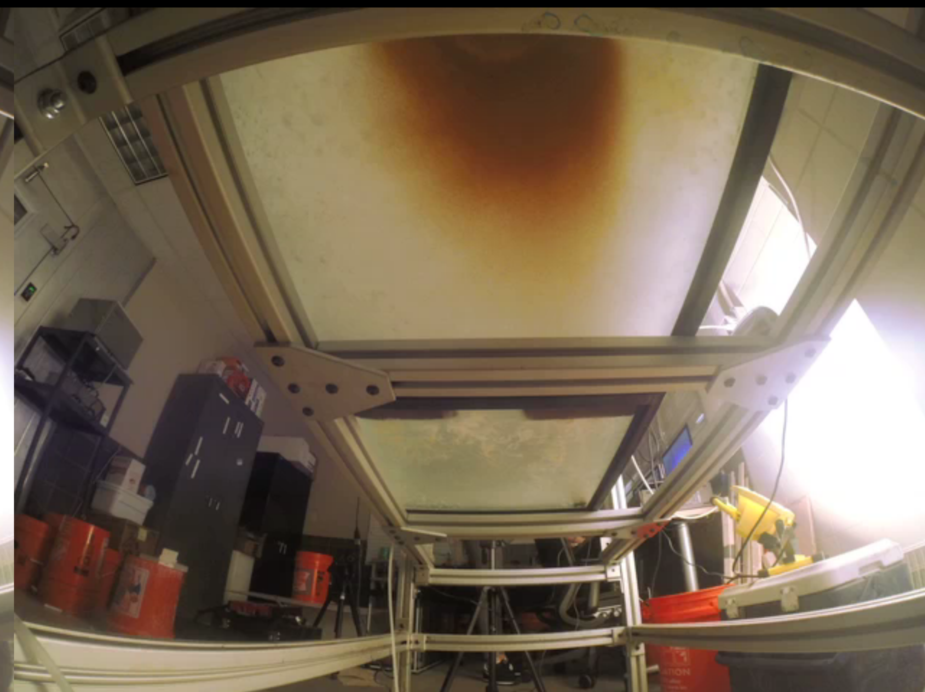

No ice-cover

Ice-cover

Earthscape Imprint of Climate Change

Arctic: A delta prograding an ice-cover lake

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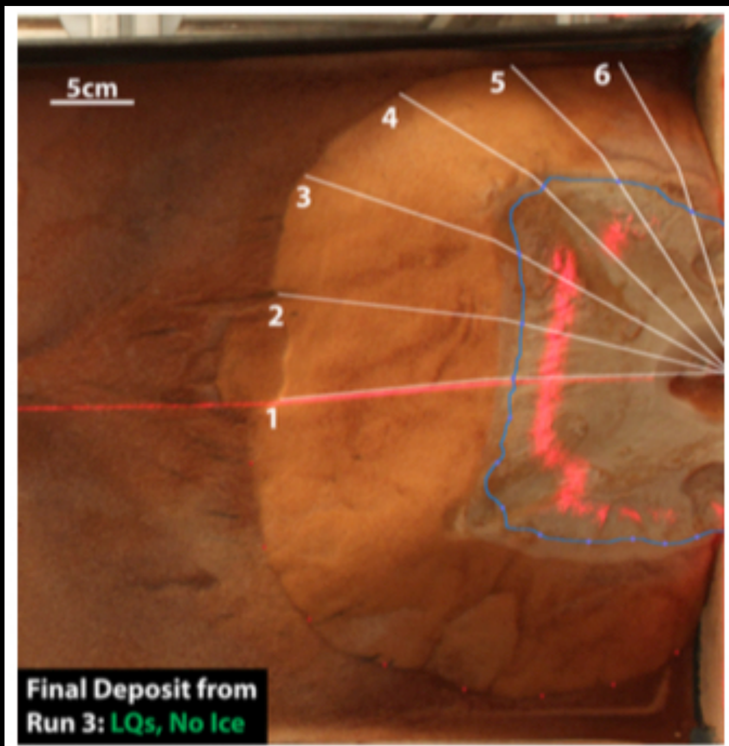
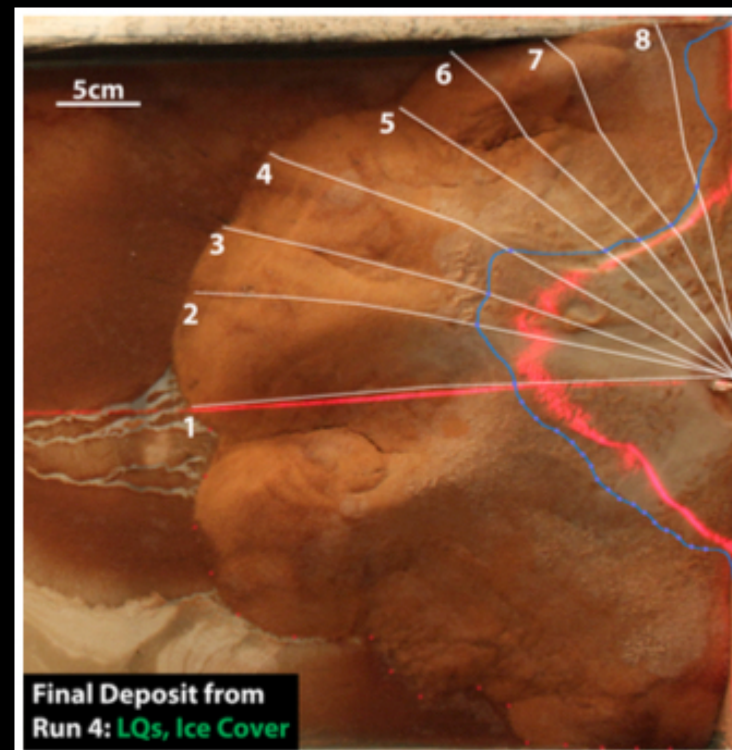


No ice-cover



Ice-cover

Observation of core processes through Experiment

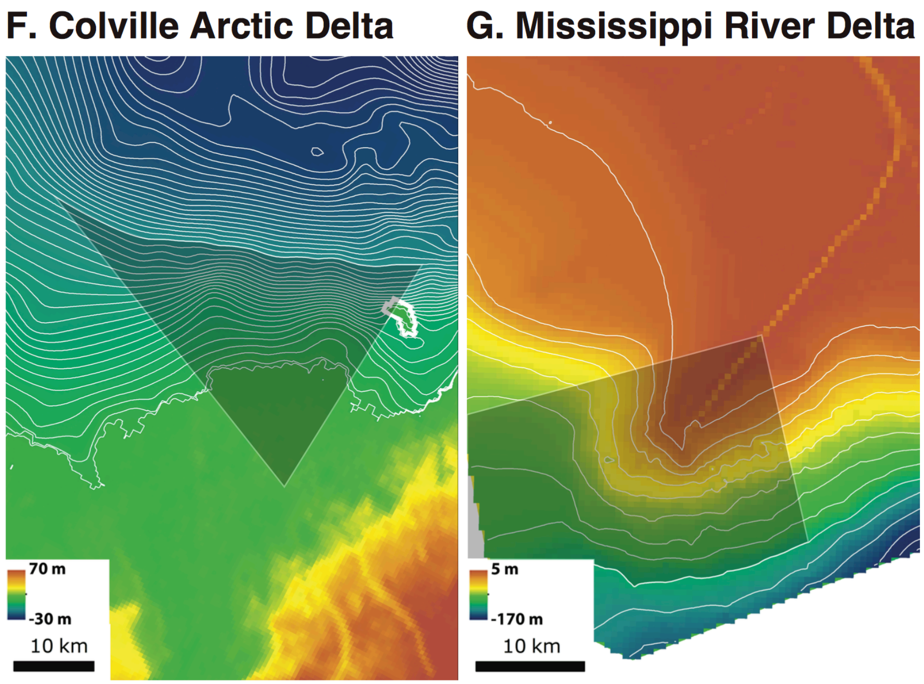
High-resolution data to support ideas

Arctic: A delta prograding an ice-cover lake

- *The processes that created under-ice subaqueous channels and associated rough topography are demonstrated.*
- *Ice-delta interaction produces the climate imprint on sea-scape!*

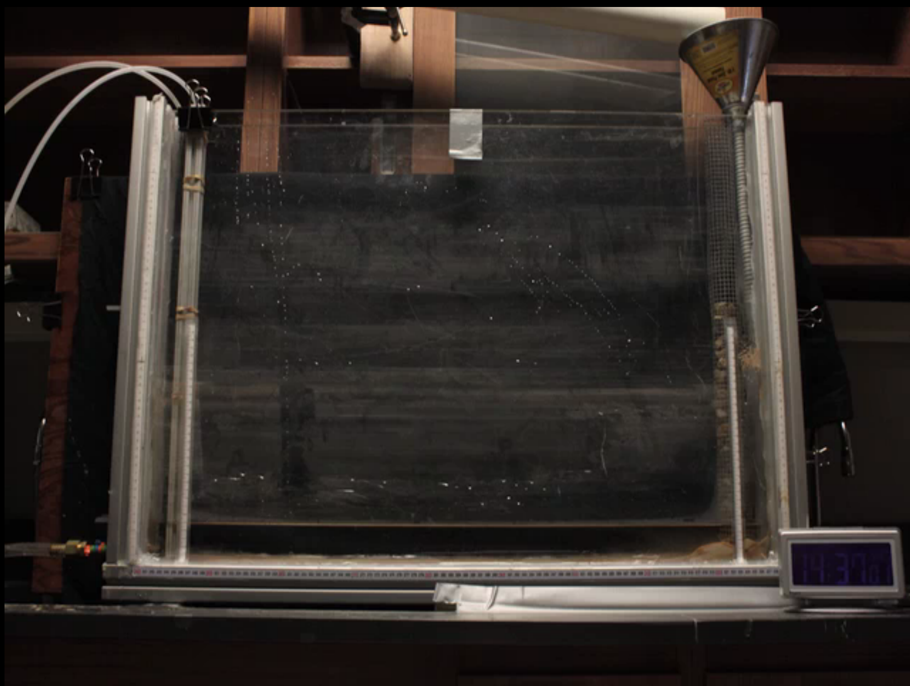
- ***Simple***
- ***Space and time scales inaccessible in the field***

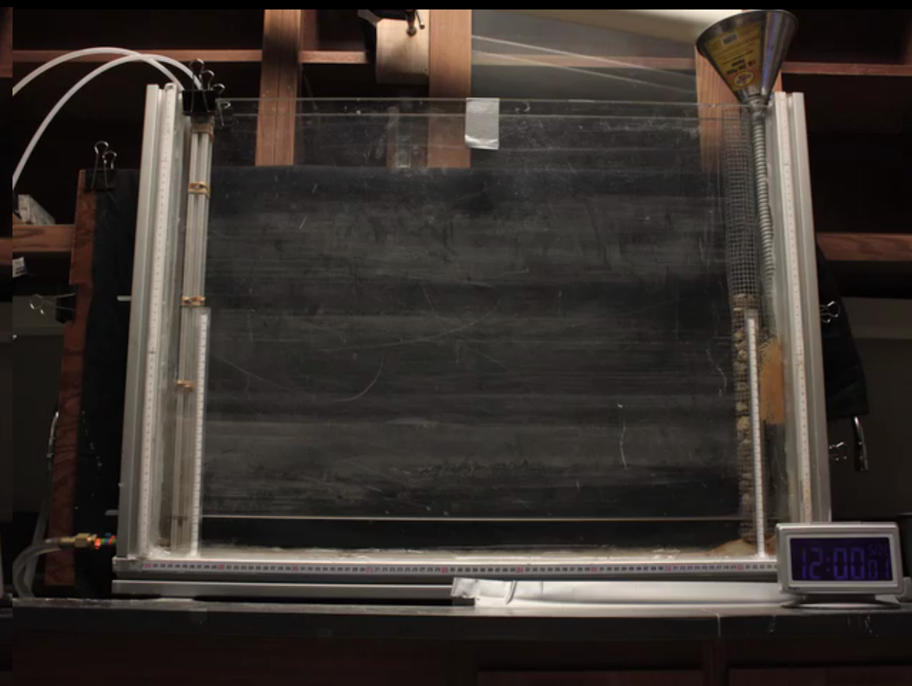
- ***HOWEVER,***
  - ***Scale?***
  - ***Natural example?***



Autogenic vs. Allogenic Processes

Experimental Results





R4: 0.052 mm/s RSLR

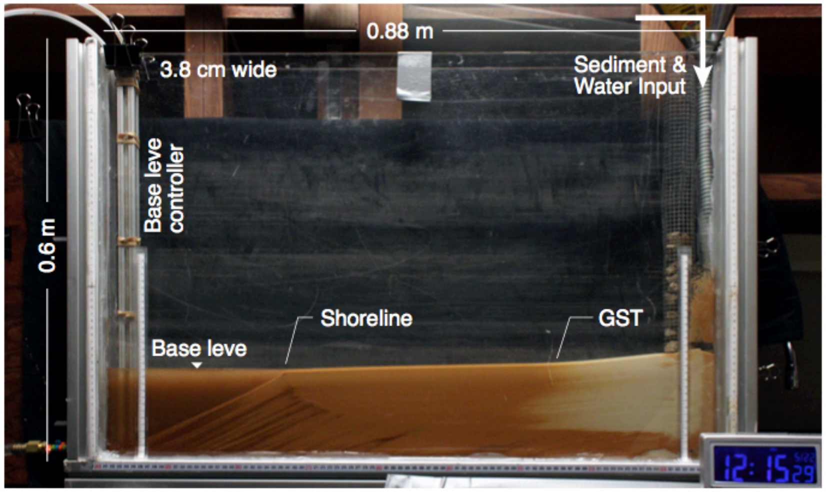
R5: 0.116 mm/s RSLR

Migration Reversal!

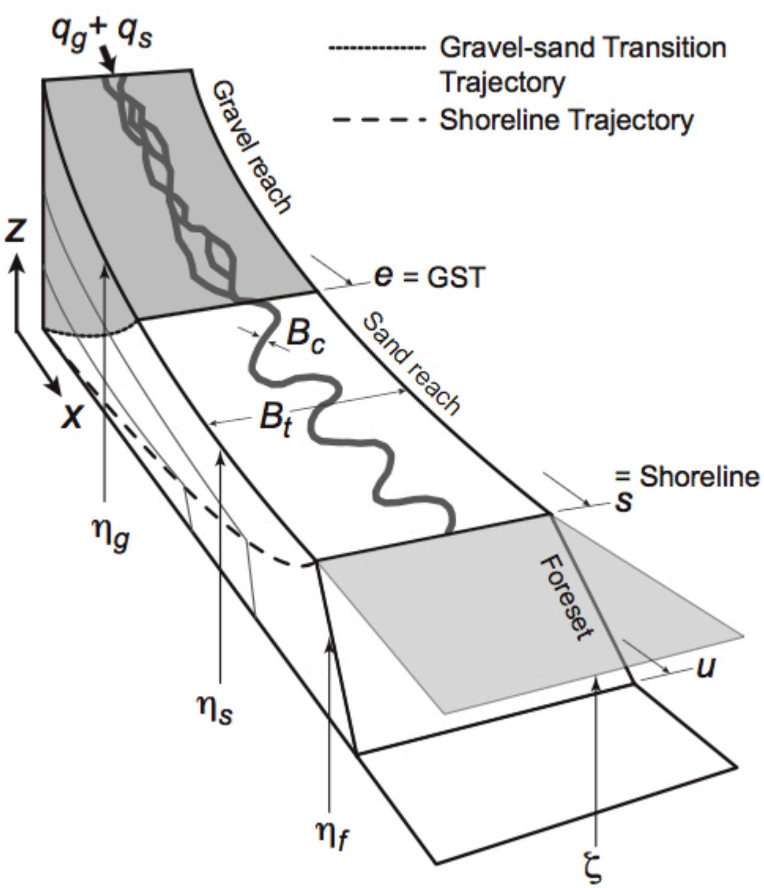
Carolina Baumanis (Undergrad student in UT)

Physical Flume Experiment

- Verifying the mathematical model with sediment experiments
- Flume dimensions: 0.88 x 0.6 x 0.04 m
- Six Runs with RSLRs = 0, 0.072, 0.013, 0.052, 0.116, and 0.325 mm/s
- Sediment mixture:
  - **Quartz sand** (33%; D = 0.1 mm; **2650 kg/m³**)
  - **Walnut sediment** (66%; D = 0.1 mm; **1300 kg/m³**)
- Q_s = 3.34 g/s; Q_w = 11.39 ml/s
- Initial base level: 5 cm



Mathematical Model



Sediment mass-balance equation for the gravel and sand river reaches:

$$\frac{\partial \eta_{g,s}}{\partial t} + \sigma = -\frac{I_f(1+\Lambda_{sg,ms})\Omega_{g,s}}{(1-\lambda_{pg,ps})\Phi_{g,s}}\frac{\partial q_{g,s}}{\partial x}$$

Moving Boundary 1: Gravel-Sand Transition (GST)

$$\dot{e} = \left[\frac{\partial \eta_g}{\partial t}\Big|_e - \frac{\partial \eta_s}{\partial t}\Big|_e\right] \Big/ \left[S_g\big|_e - S_s\big|_e\right]$$

$S_g|_e$ = gravel-bed slope at GST & $S_s|_e$ = sand-bed slope at GST

Moving Boundary 2: Shoreline

$$\dot{s} = \frac{1}{(S_f - S_s|_s)}\left\{\frac{I_f(1+\Lambda_{ms})\Omega_s}{(1-\lambda_{ps})(u-s)\Phi_s} q_s[s(t),t] - \frac{\partial \eta_s}{\partial x}\Big|_s\right\}$$

Shoreline shock condition: No sediment transport beyond x = u

Moving Boundary 3: Delta toe

$$\dot{u} = \frac{1}{(S_f - S_b|_u)}\left\{\frac{\partial \eta_s}{\partial t}\Big|_s + (S_f - S_s|_s)\dot{s}\right\}$$

A linear foreset geometry; Non-erodible linear sloped basement

Backwater Formulation

$$\frac{\partial H_{g,s}}{\partial x} = \frac{S_{g,s} - C_{fg,fs}Fr^2_{g,s}}{1 - Fr^2_{g,s}}$$

C_f = friction coefficient; Fr = Froude number; H = flow depth.

Sediment Transport Relations

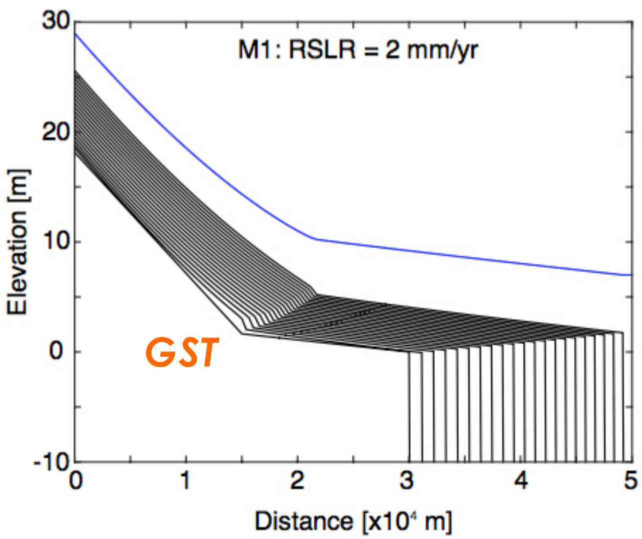
$$q_g = \sqrt{RgD_g}D_g 11.2(\tau_g^*)^{1.5}\left(1 - \frac{0.03}{\tau_g^*}\right)^{4.5}$$

Parker [1979] for the gravel transport

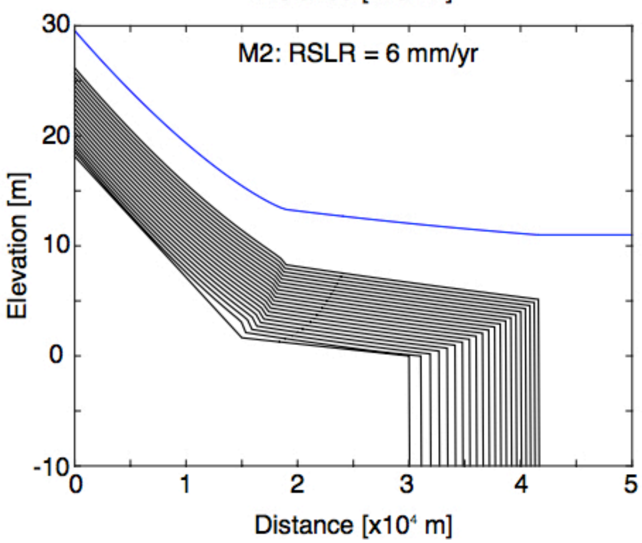
$$q_s = \sqrt{RgD_s}D_s \frac{0.05}{C_{fs}}(\tau_s^*)^{2.5}$$

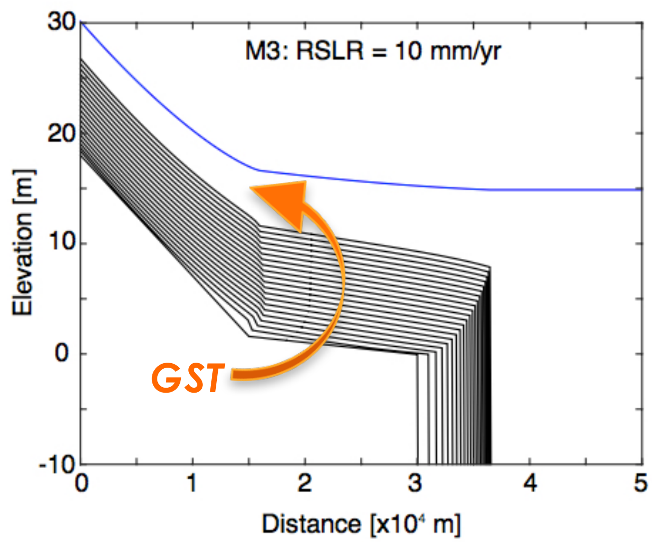
Engelund-Hansen [1972] for the sand transport

Modeling Results: Three RSLR Rates



- Q_{bf} [m³/s] Bankfull water discharge = 1000
- Q_g [m³/s] Feed rate of gravel = 0.1
- Q_s [m³/s] Feed rate of sand = 0.2
- Initial s = 30 km; Initial GST = 15 km
- RSLR (Relative Sea Level Rise) = 2, 6, and 10 mm/yr



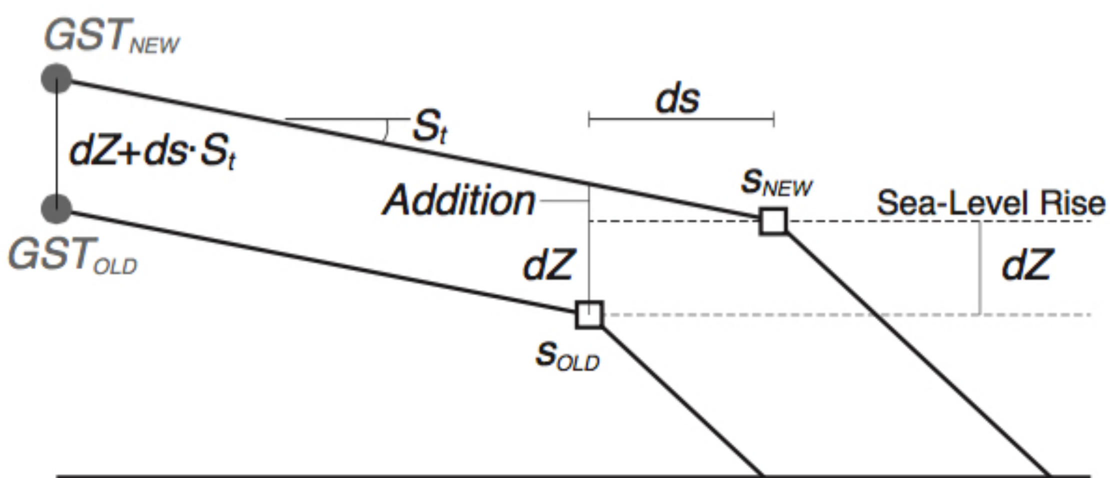


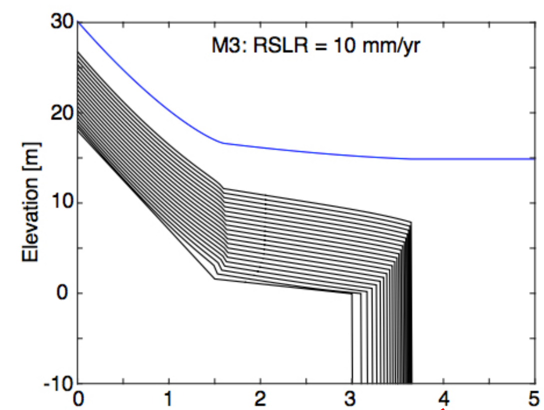
Shoreline progradation

GST Retreat! Fining Upward

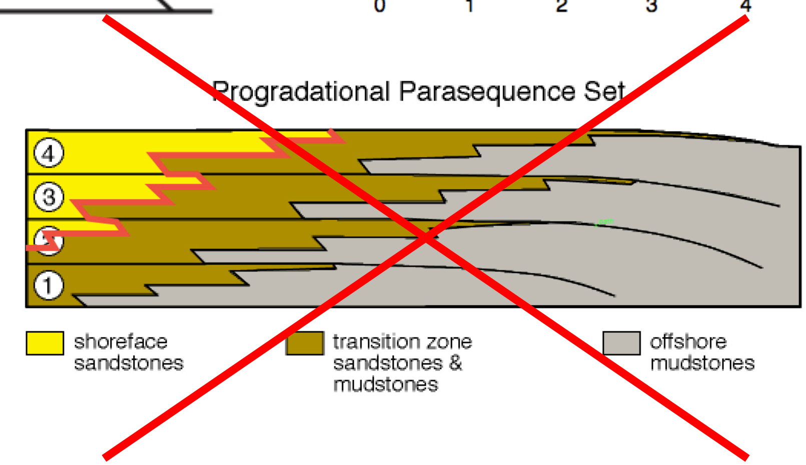
Migration Reversal in M3

- The GST and shoreline migrated opposing directions

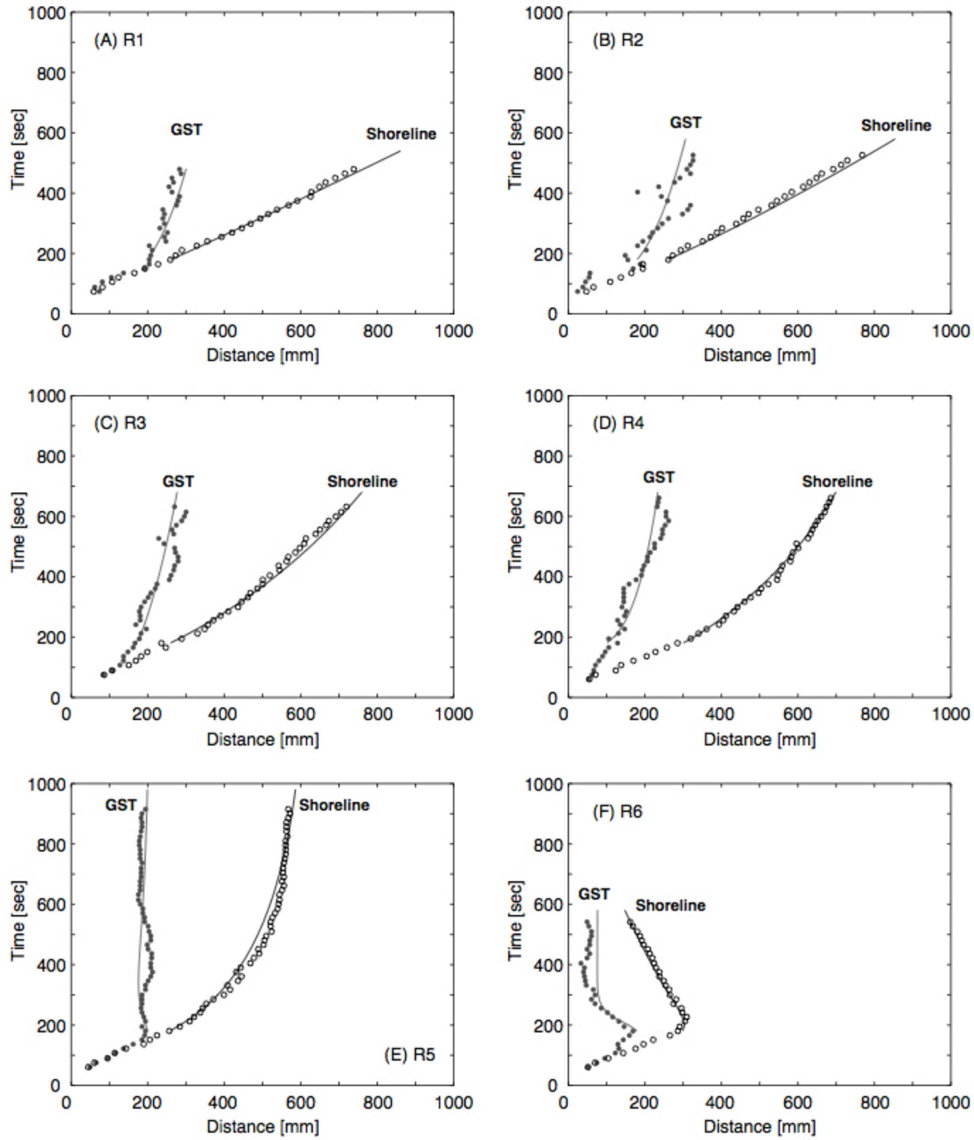




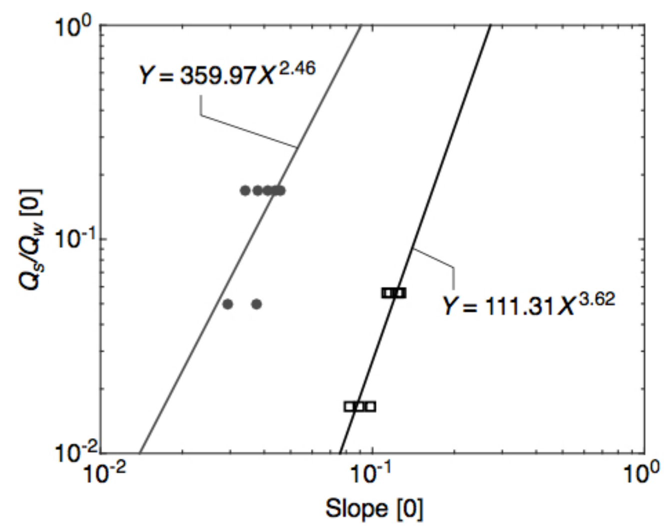
- The GST experienced faster RS
- **Additional rate ~ $ds \cdot S_t$ = (shorel slope)**
- **GST migrates in an opposing d shoreline**



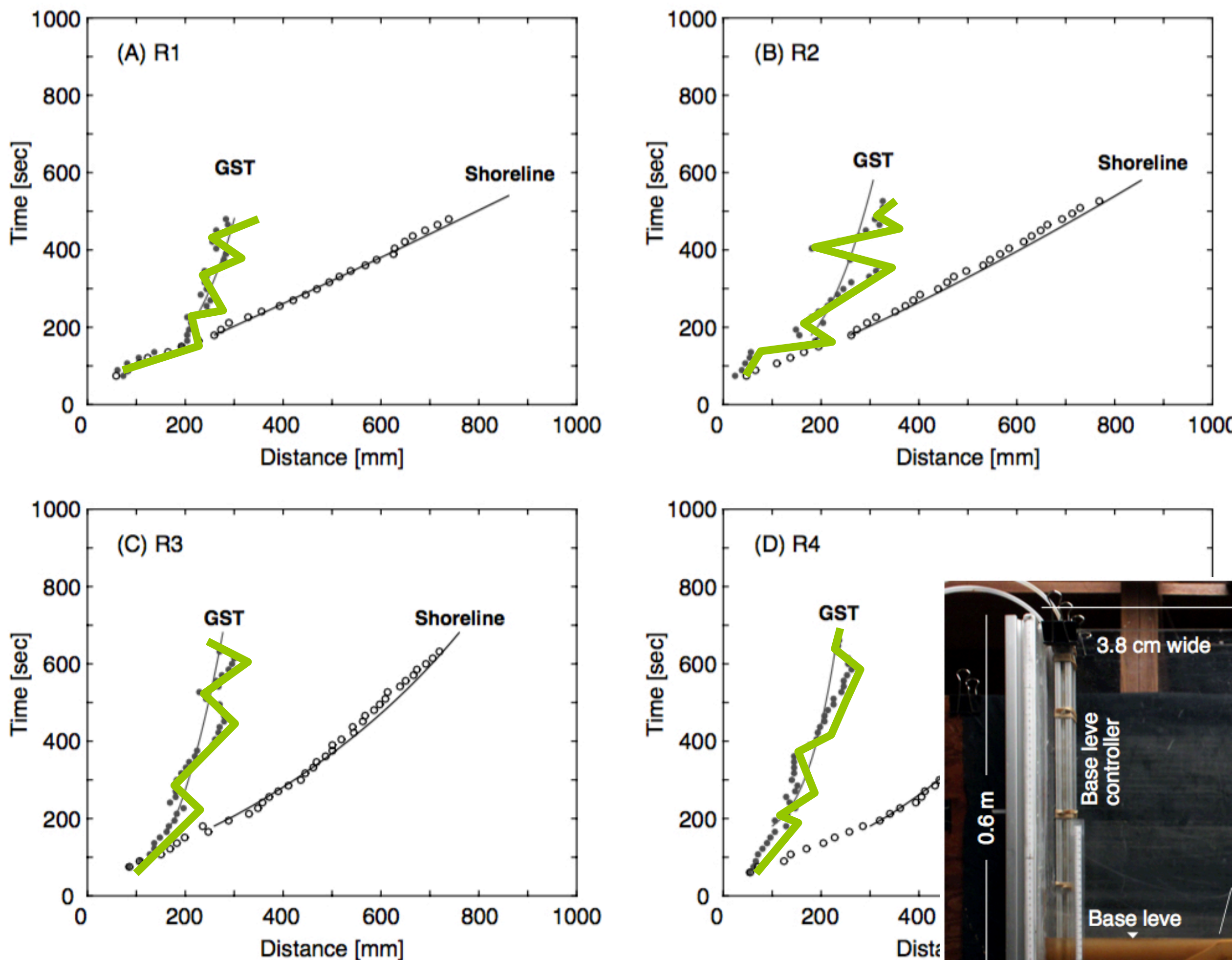
Comparison with Model

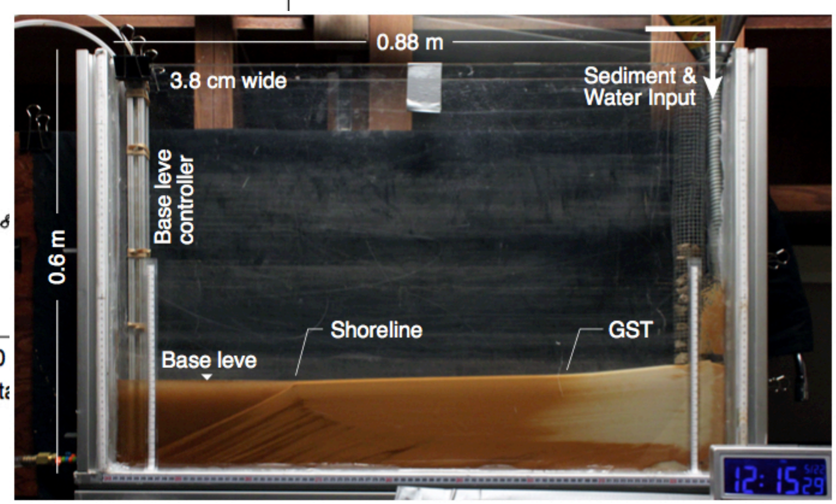


- Change the **sediment transport relations** to **empirical relations** from the current runs



Autogenic vs. Allogenic



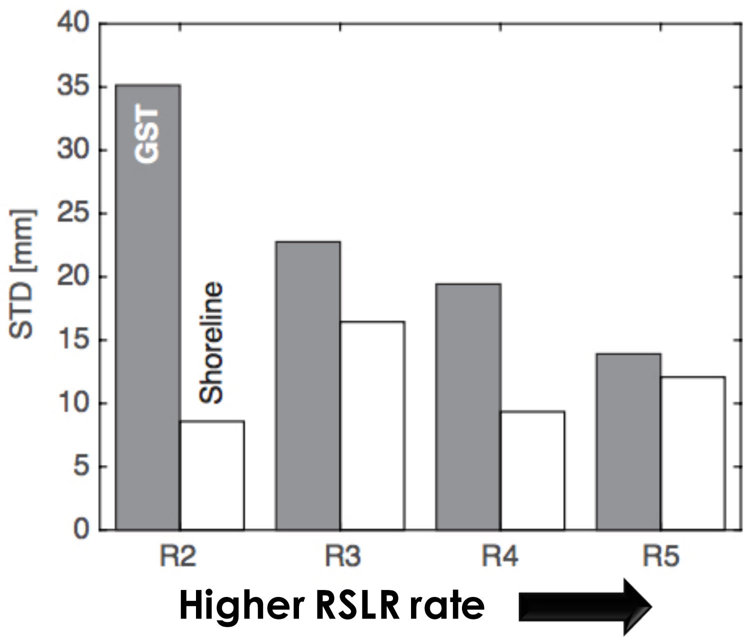


Shazam?

Autogenic fluctuations of the GST migration

Autogenic Product as a Signal

- Standard Deviation for GST decreases with RSLR rate



- **Fluctuations of the topset slope (Kim and Jerolmack, 2008)**
- **The zigzag shazam trajectories are from the cycles of autogenic processes**

What caused the changes in the magnitude of variation?

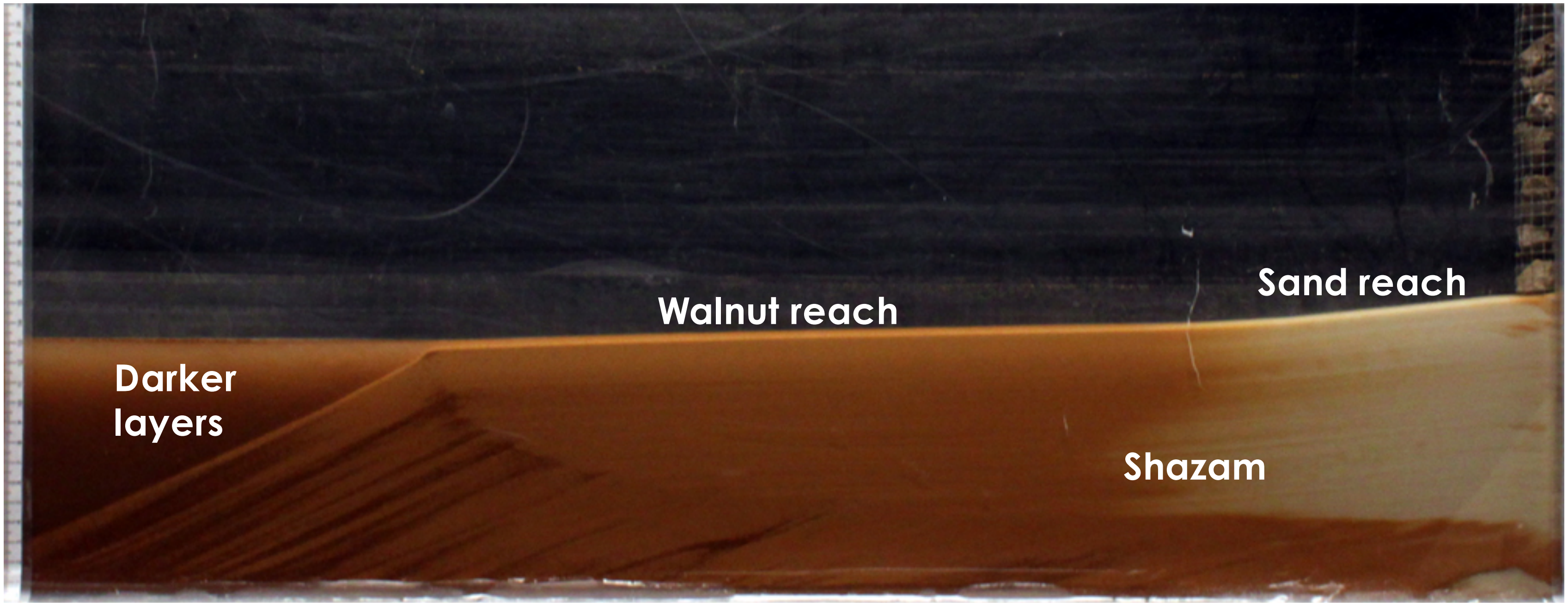
Moving Boundary 1: Gravel-Sand Transition (GST)

$$\dot{e} = \left[\frac{\partial \eta_g}{\partial t}\bigg|_e - \frac{\partial \eta_s}{\partial t}\bigg|_e\right] \Big/ \left[S_g|_e - S_s|_e\right]$$

$S_g|_e$ = gravel-bed slope at GST & $S_s|_e$ = sand-bed slope at GST

Changes in slopes and depositional rates

Stratigraphic Evolution: S2S



- Storage in the sand reach → increasing slope
- Less deposition of the sand reach at GST causes a retreat of GST
- More deposition of the walnut reach at GST = less transport to the foreset
- Only most fine sediment reaches the foreset, developing a darker layer
- Storage in the walnut reach → increasing slope (some sand can transport through) and initiating release, developing a lighter-colored layer
- Release in the walnut reach → decreasing slope, decreasing deposition at the GST
- Release in the sand reach → decreasing slope and advancing GST

Modeling Autogenic Processes

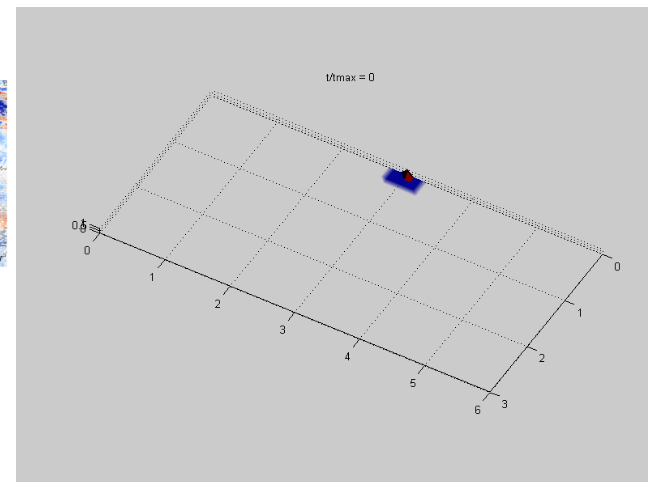
- ***Modeling internal dynamics and stratigraphic signatures***
- Noise? Autogenic stratal product can be a useful signal to understand environmental controls (sea-level, tectonics, and sediment supply) to the sedimentary basin.

Complex Allogenic - Autogenic Coupling

Global Warming and Extreme Weather

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.
FOX News: Extreme Weather: Why Has Mother Nature Gone Bonkers?January 06, 2010
NASA Earth Observatory: A wave of frigid air spilled down over Europe and Russia from the Arctic in mid-December, creating a deadly cold snap. Blue indicates temperatures as low as -20 Centigrade.

Climate = Allogenic / Weather = Autogenic



Example modeling results using the discontinuous ('sticky') sediment transport (Wolinsky, M., unpublished work).

Extreme Weather by Climate Change

Overcoming Grand Challenges by Collaboration between Experimentalists and Modelers

- Theoretical and numerical modeling based on first principles can help
  - to extrapolate insight from experiments to field scales,
  - to compare results from different lab facilities, and
  - to decouple autogenic processes and allogenic forcings in geomorphology and stratigraphy.
- The experimentalist-modeler collaborative effort will result in tremendous opportunities for overcoming grand challenges in our communities.

Thank You!