U.S. NAVAL RESEARCH LABORATORY

ICCE 2018 | 36TH INTERNATIONAL CONFERENCE ON COASTAL ENGINEERING 2018
Baltimore, Maryland | July 30 – August 3, 2018

O. H. Hinsdale Wave Research Laboratory
Oregon State University • College Of Engineering

Oregon State University

University of Delaware

Center for Applied Coastal Research

NSF

Observations of Horizontal ~~& Vertical~~ Sediment Fluxes on a Sandbar in the Suspended & Sheet Flow Layers

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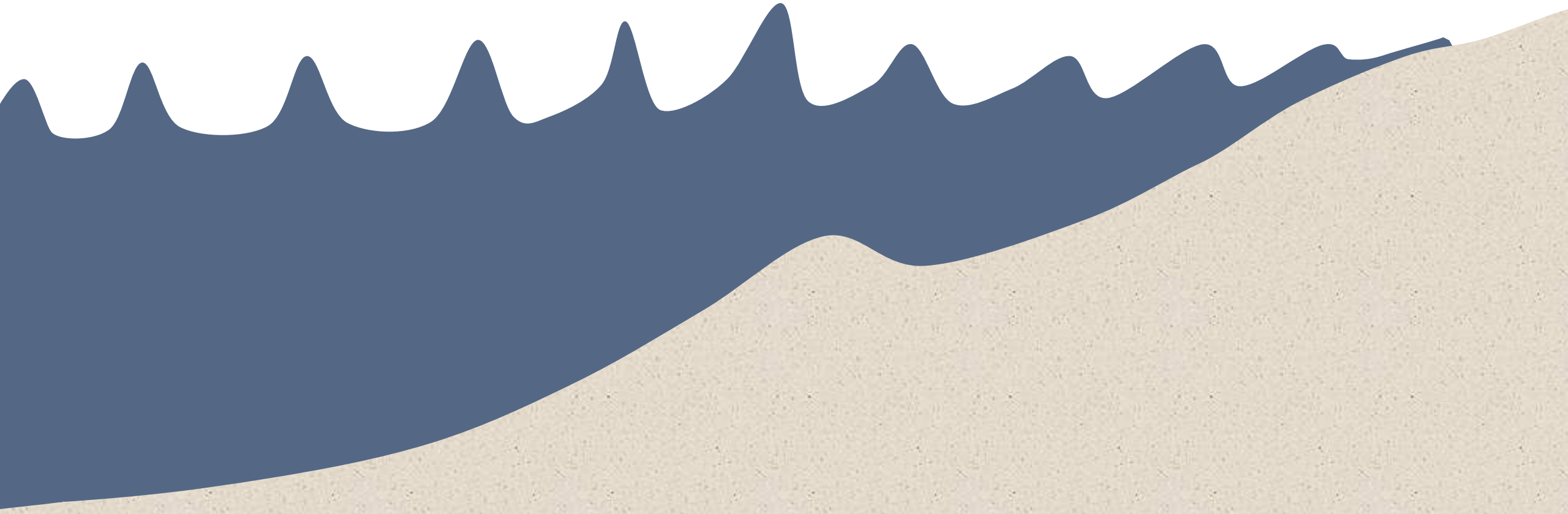
The National Academies of SCIENCES ENGINEERING MEDICINE

31 July 2018

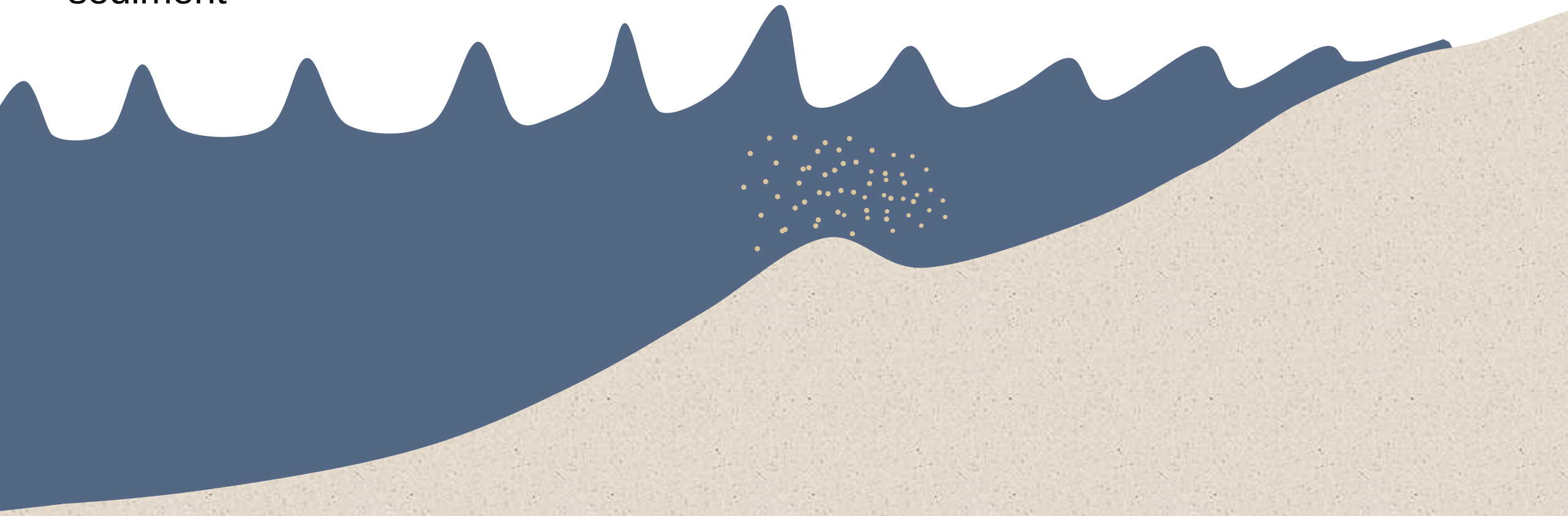
Onshore Sandbar Migration

Skewed → **Mixed** → **Asymmetric**



Onshore Sandbar Migration

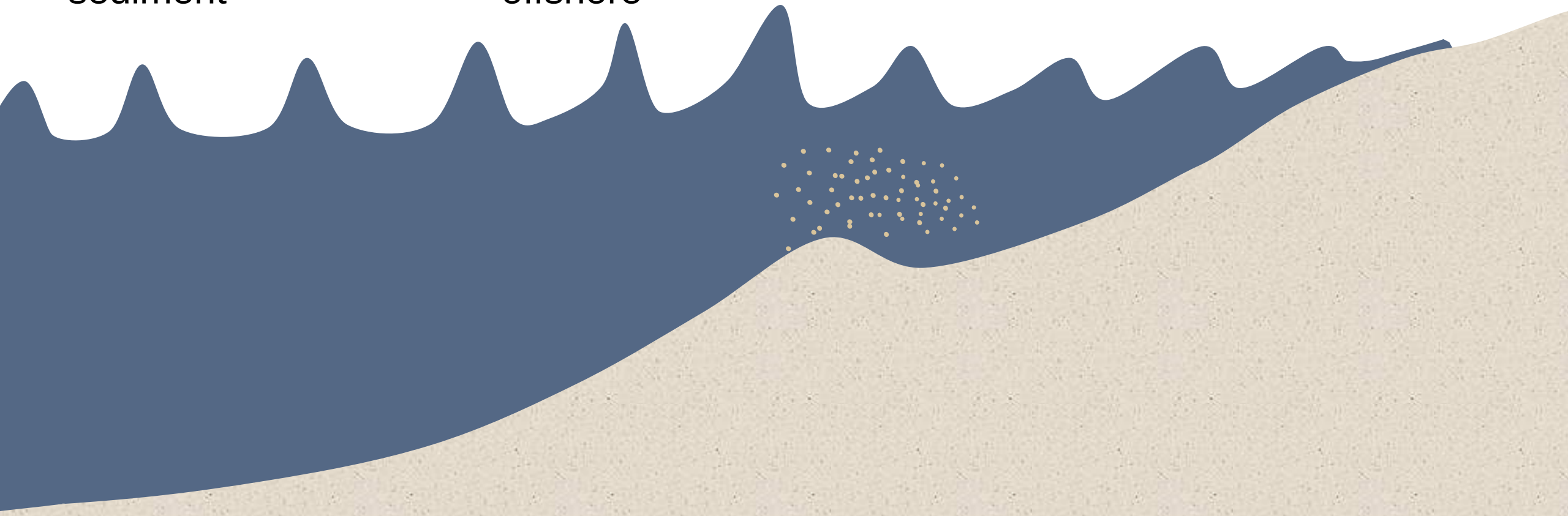
1. Waves pass over sandbar, and suspend sediment



Onshore Sandbar Migration

1. Waves pass over sandbar, and suspend sediment

2. More sediment is transported onshore than offshore

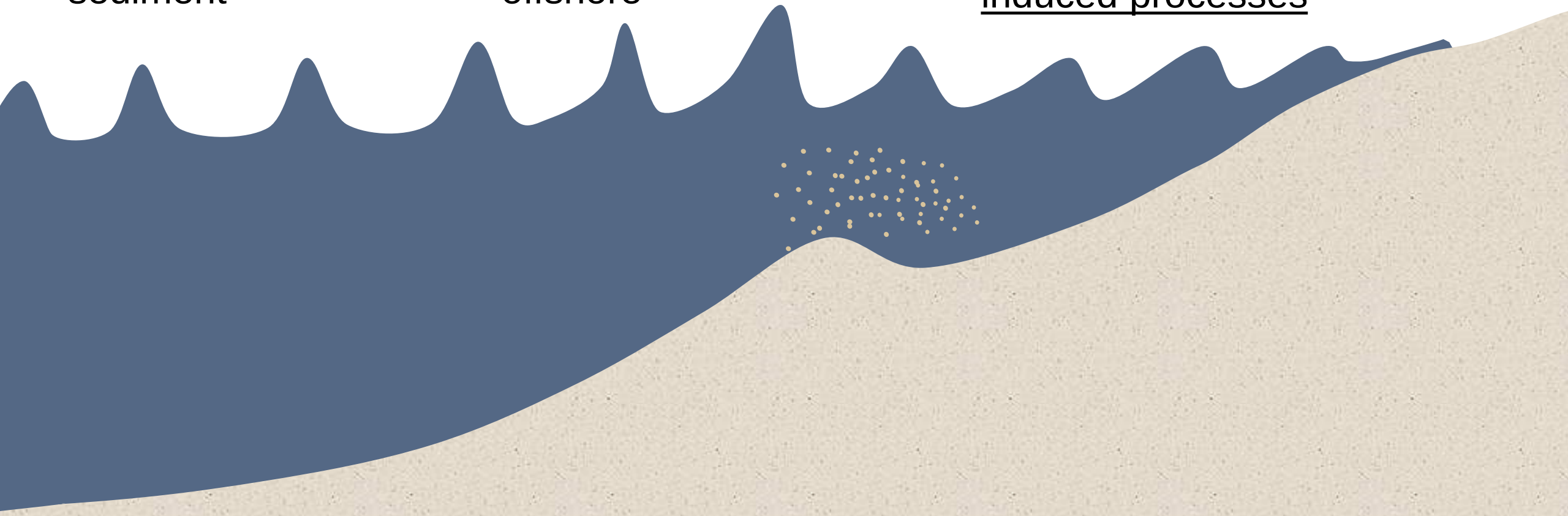


Onshore Sandbar Migration

1. Waves pass over sandbar, and suspend sediment

2. More sediment is transported onshore than offshore

3. And the sandbar migrates onshore, driven by wave-induced processes



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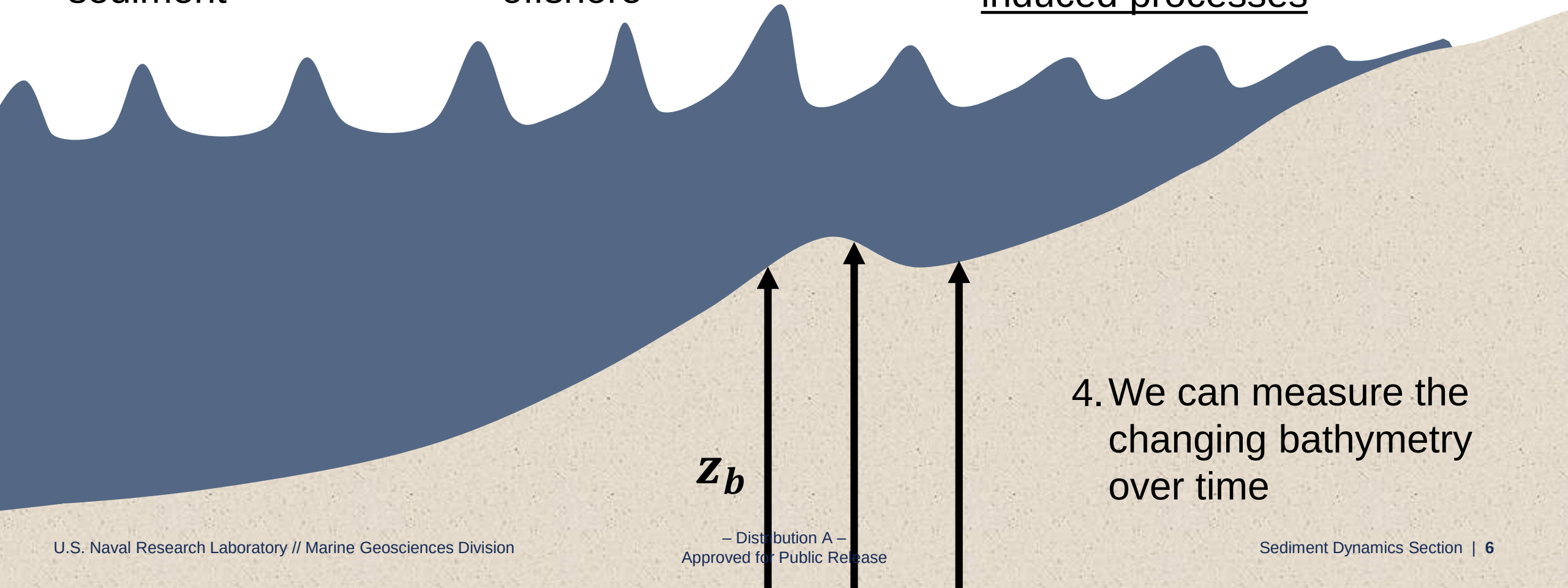

4. We can measure the changing bathymetry over time

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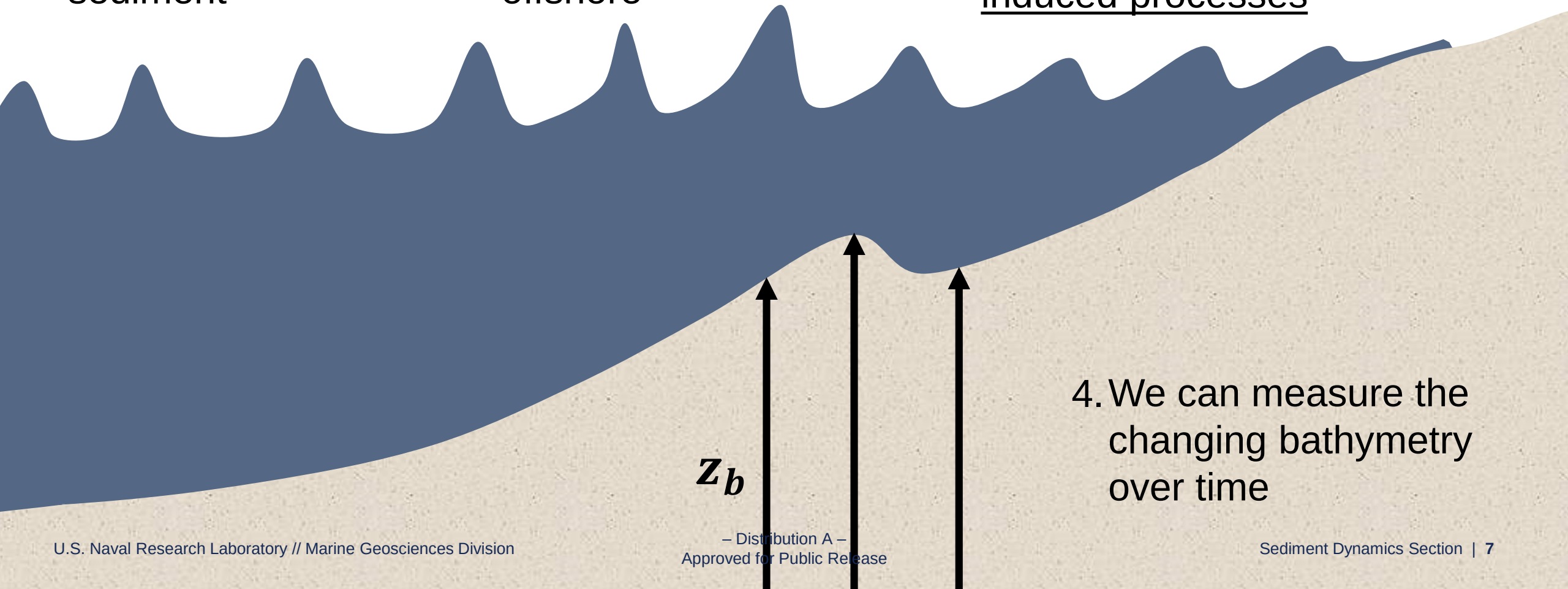

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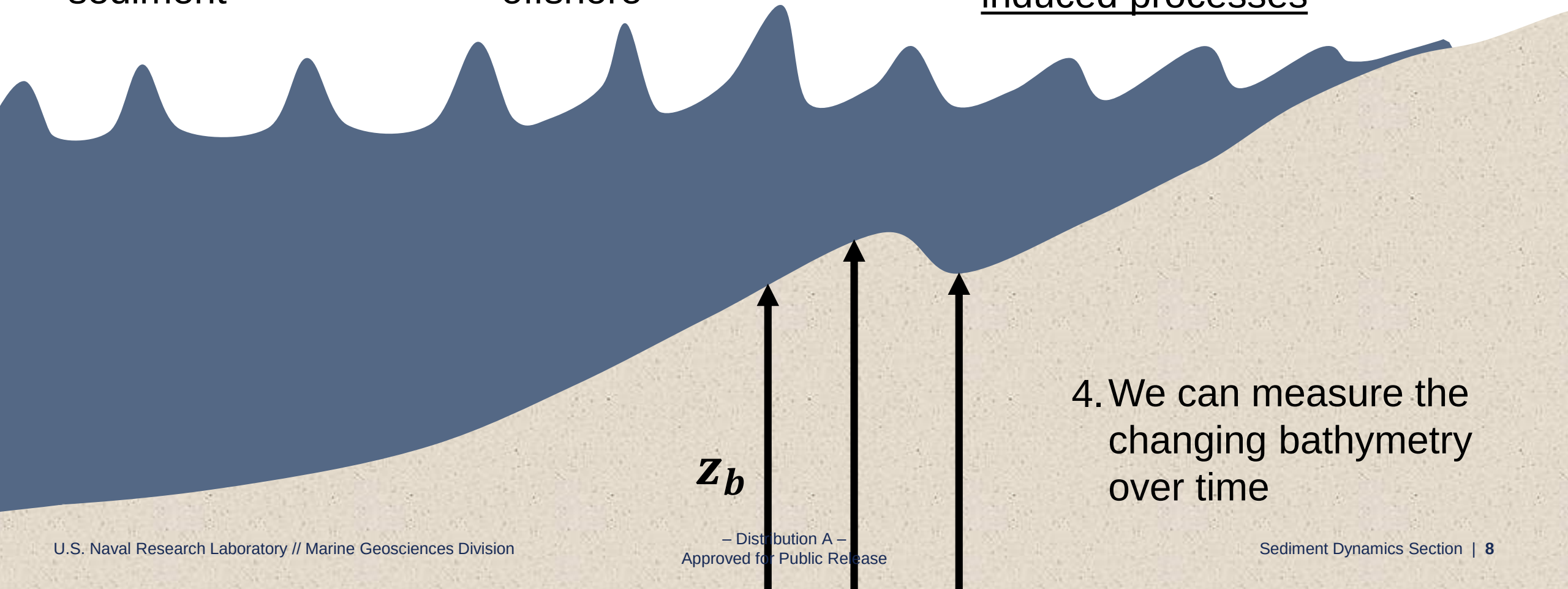

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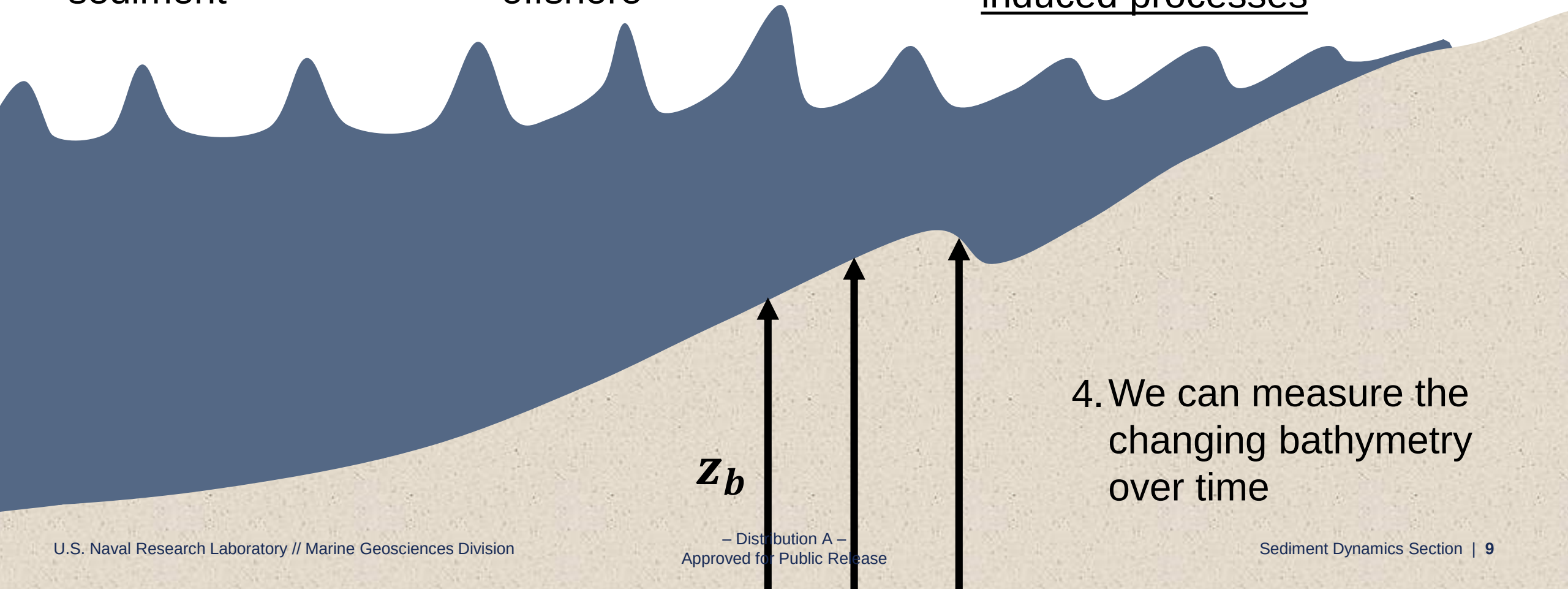

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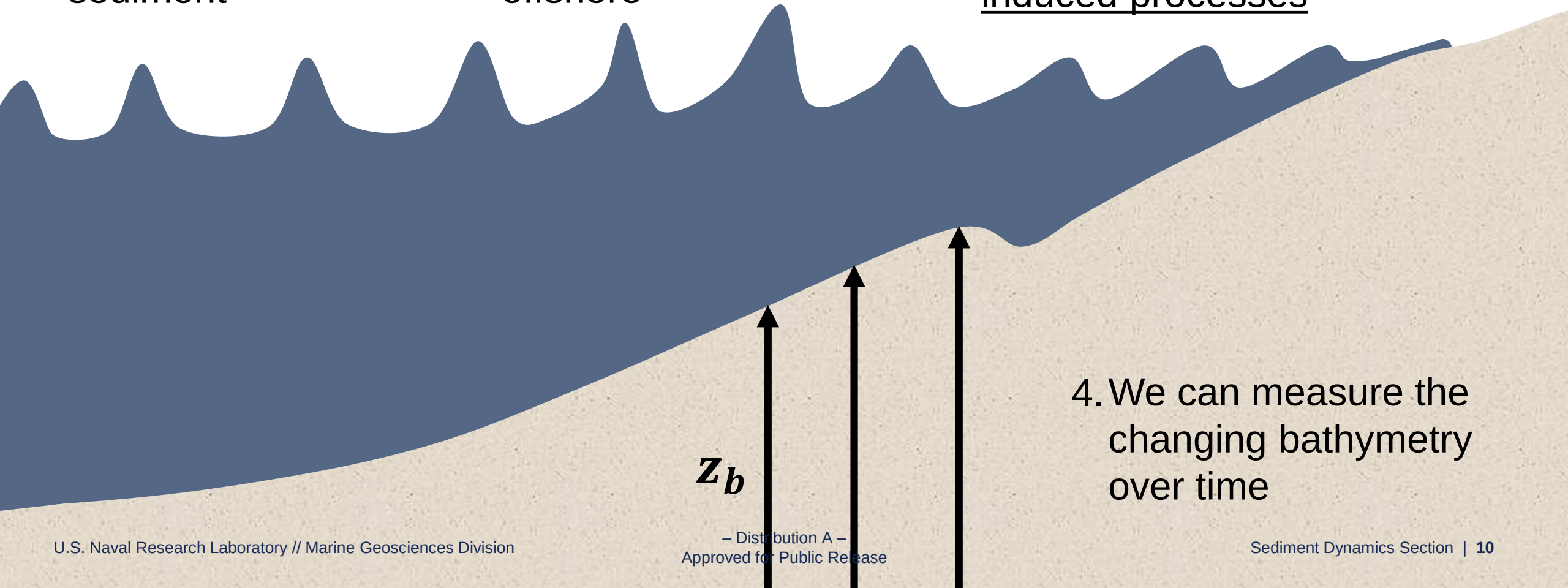

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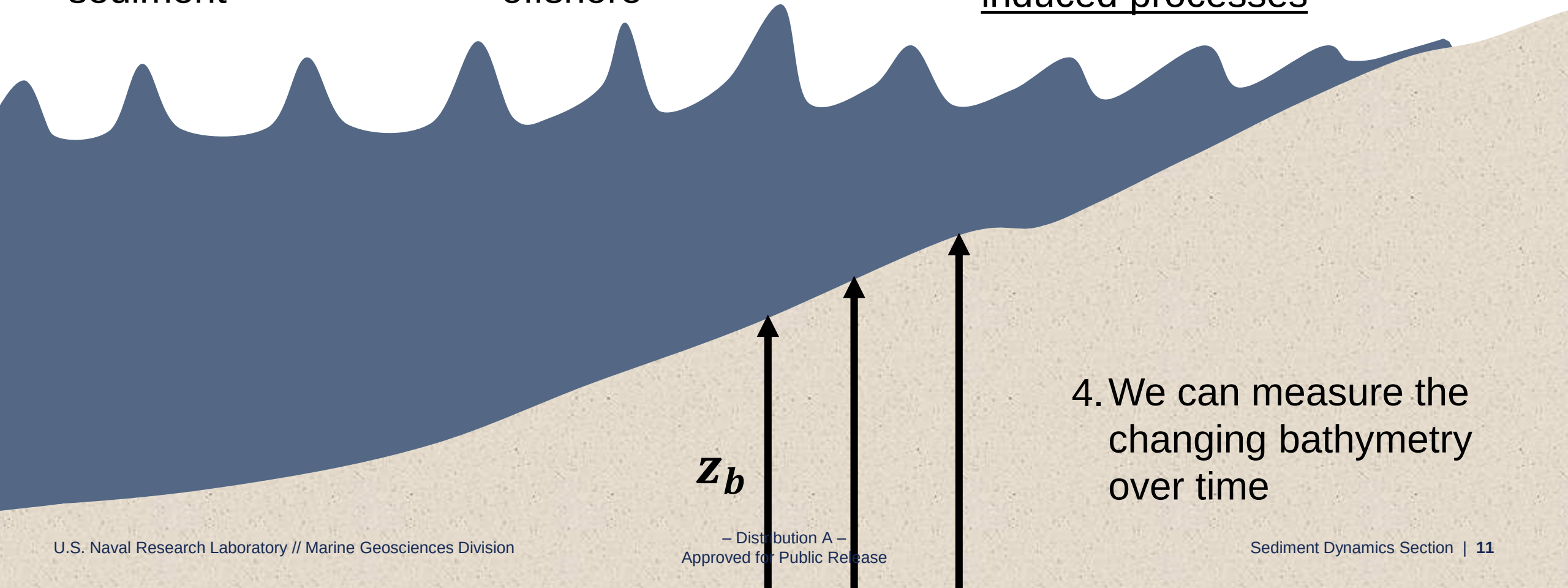

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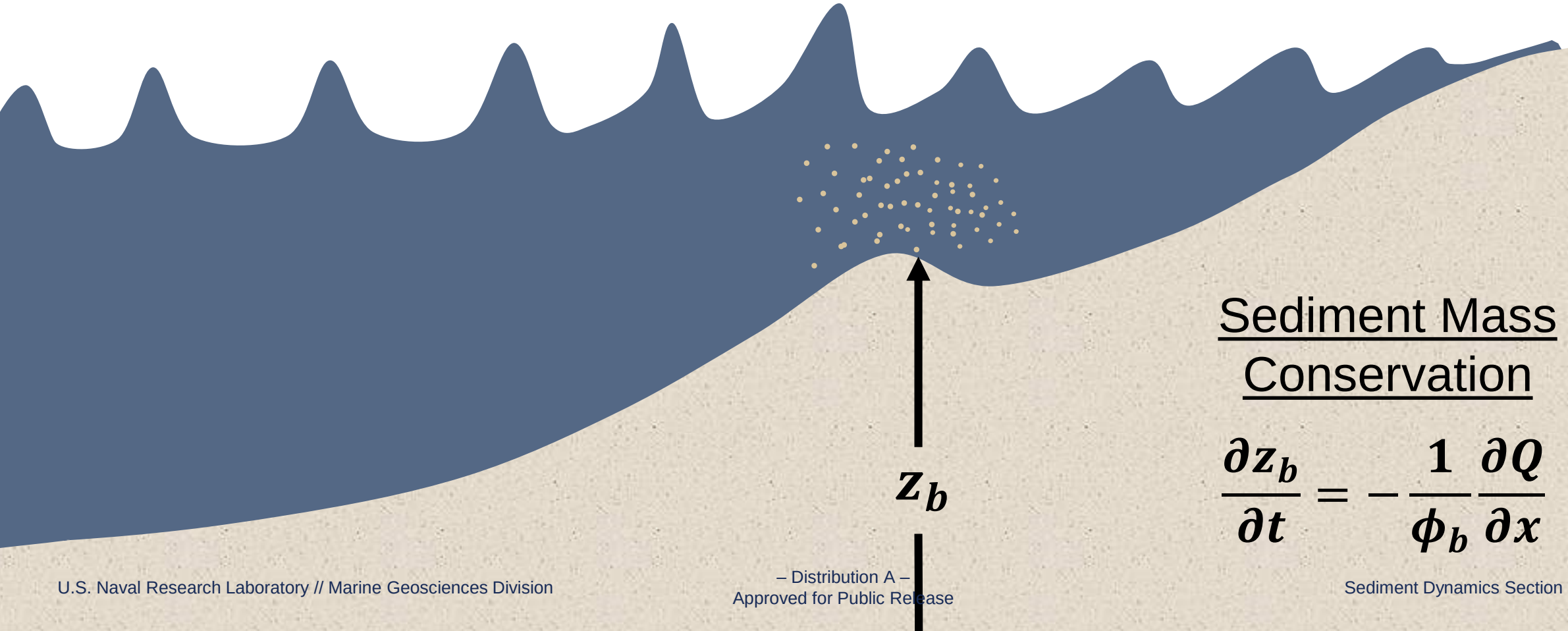
Onshore Sandbar Migration

Simplified Operational Modeling Approach

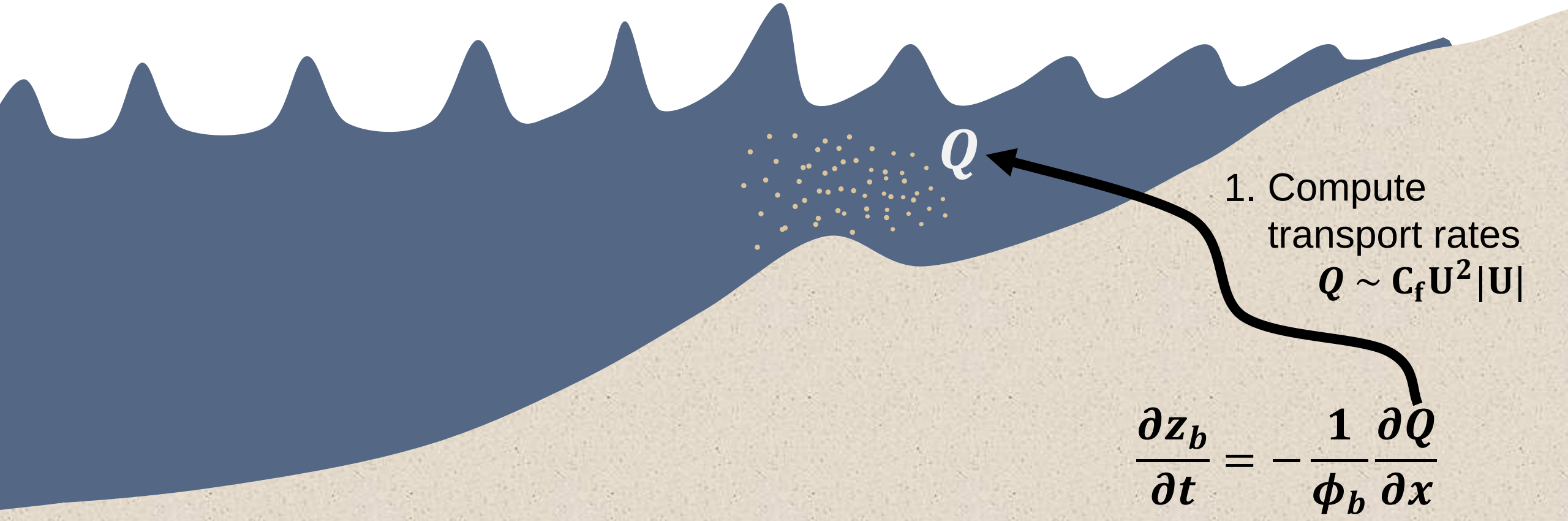


Sediment Mass Conservation

$$\frac{\partial z_b}{\partial t} = -\frac{1}{\phi_b}\frac{\partial Q}{\partial x}$$

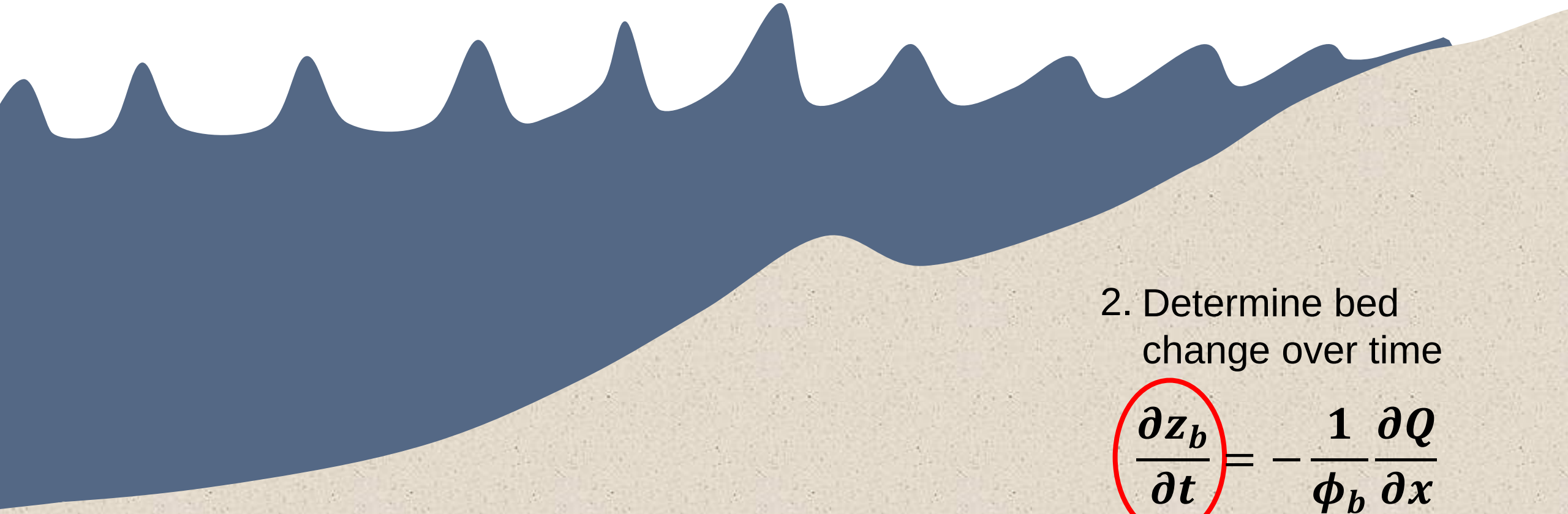
Onshore Sandbar Migration

Simplified Operational Modeling Approach



Onshore Sandbar Migration

Simplified Operational Modeling Approach

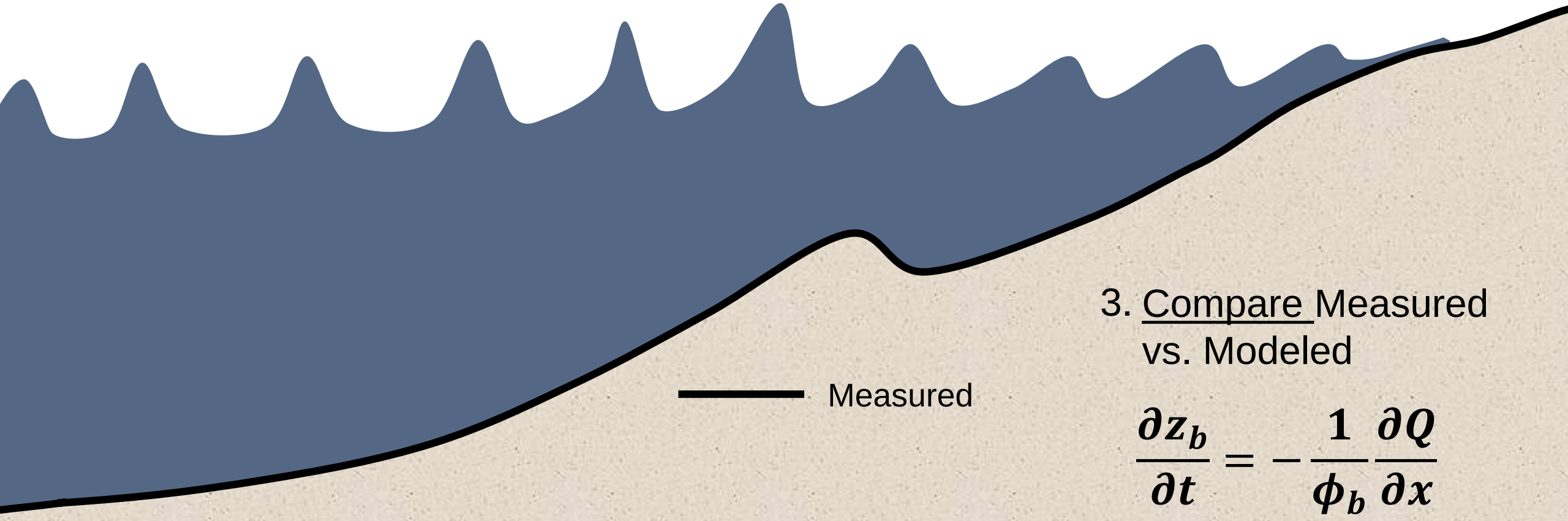


2. Determine bed change over time

$$\frac{\partial z_b}{\partial t} = -\frac{1}{\phi_b}\frac{\partial Q}{\partial x}$$

Onshore Sandbar Migration

Simplified Operational Modeling Approach



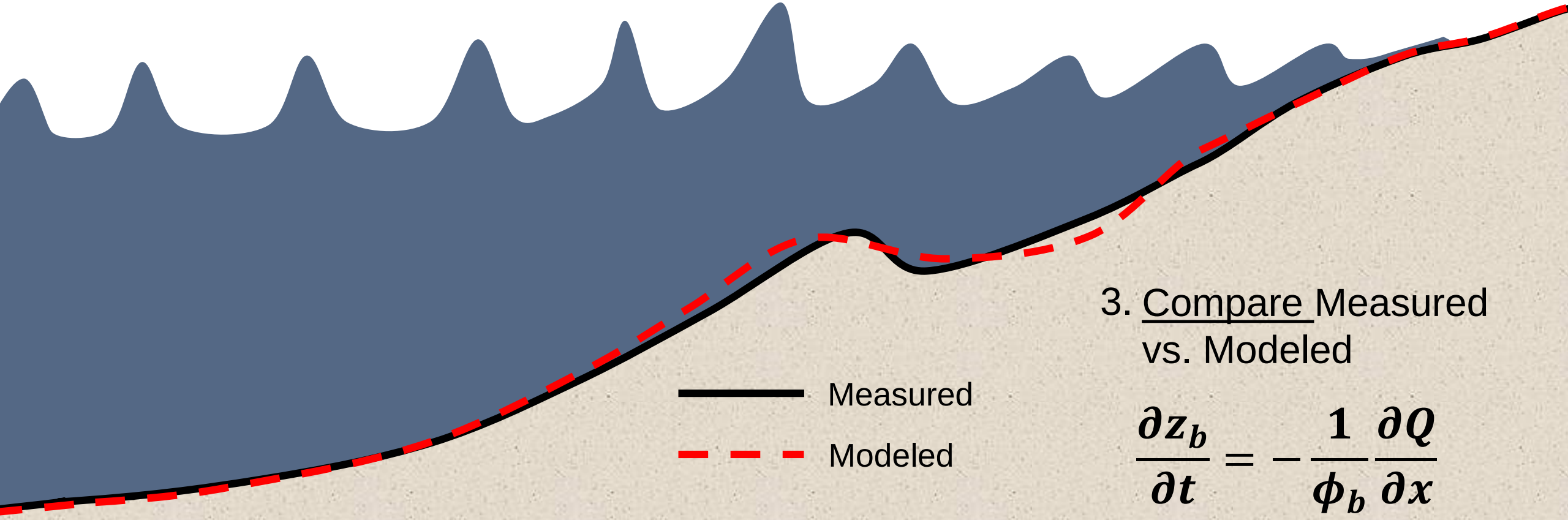
Measured

3. Compare Measured vs. Modeled

$$\frac{\partial z_b}{\partial t} = -\frac{1}{\phi_b}\frac{\partial Q}{\partial x}$$

Onshore Sandbar Migration

Simplified Operational Modeling Approach



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Onshore Sandbar Migration

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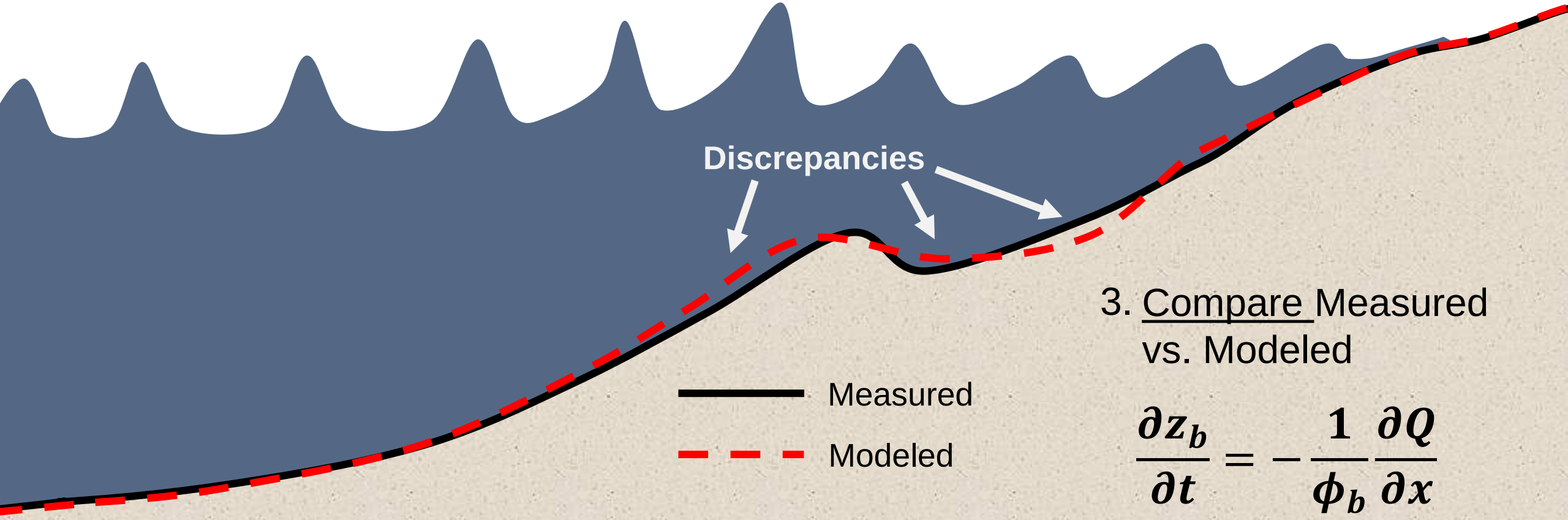

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Onshore Sandbar Migration

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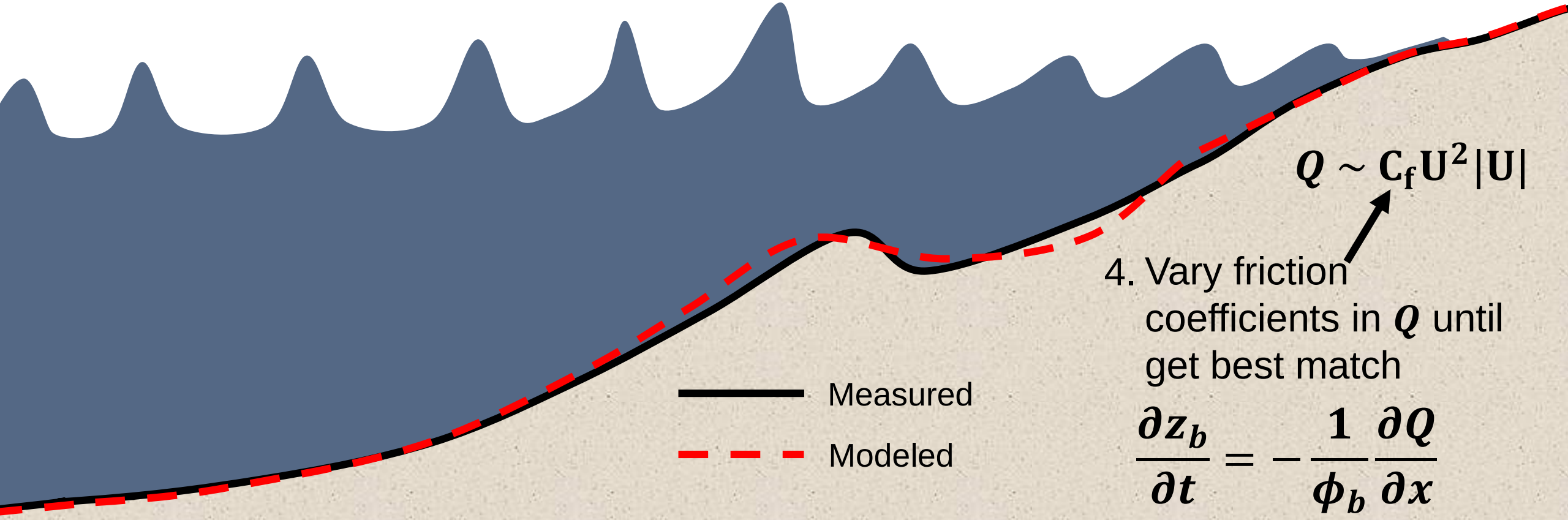


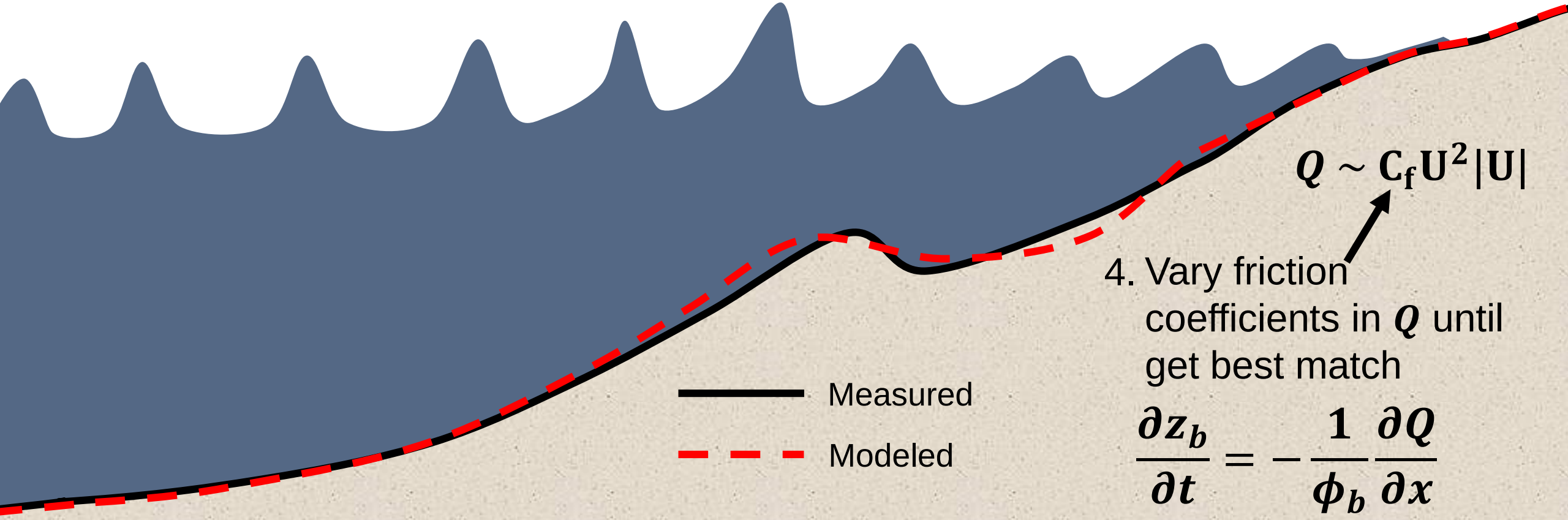
$$Q \sim C_f U^2 |U|$$

4. Vary friction coefficients in Q until get best match

$$\frac{\partial z_b}{\partial t} = -\frac{1}{\phi_b}\frac{\partial Q}{\partial x}$$

Onshore Sandbar Migration

Coastal morphology models → Match changing bathymetry → But **NOT** underlying physical processes causing the changes



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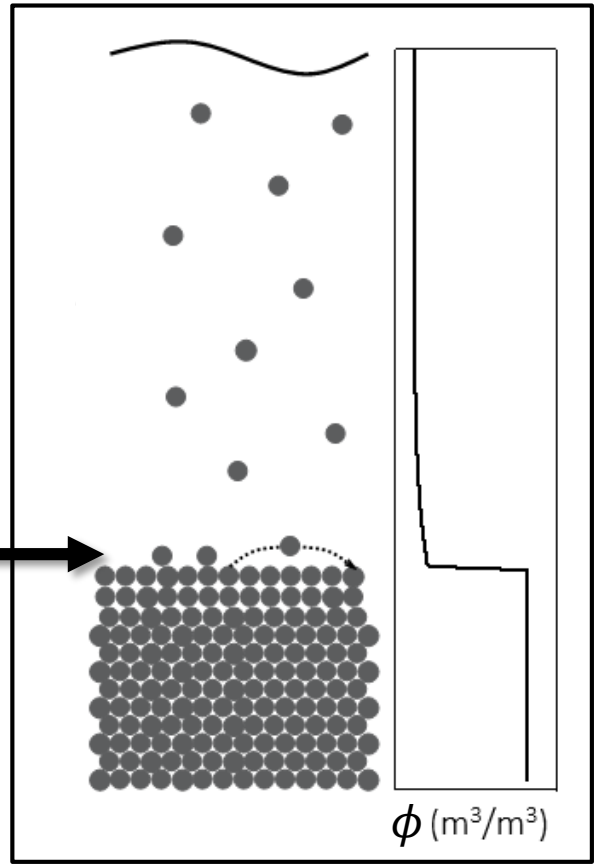
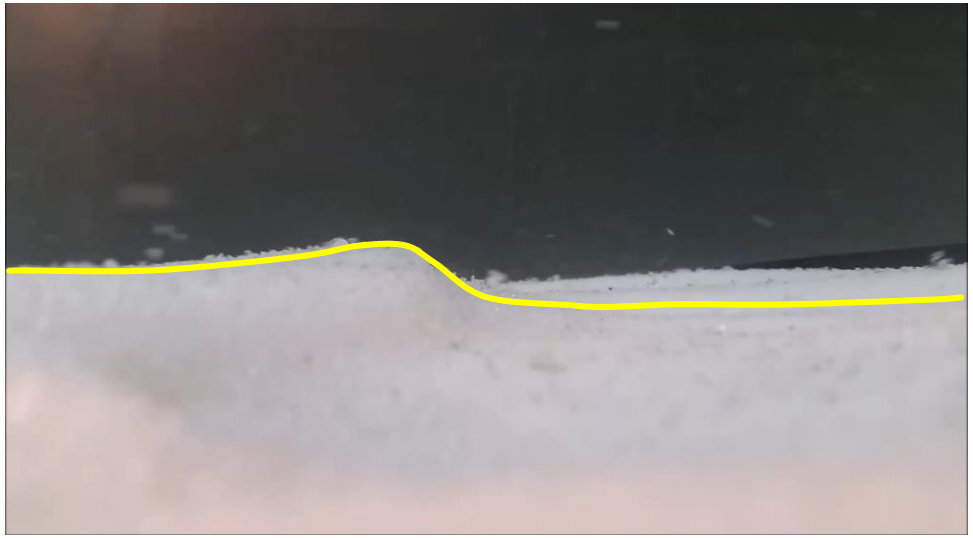
Modes of Sediment Transport

Total = **Suspended Load** + Bed Load

Saltating Grains Sheet Flow



NOT to scale

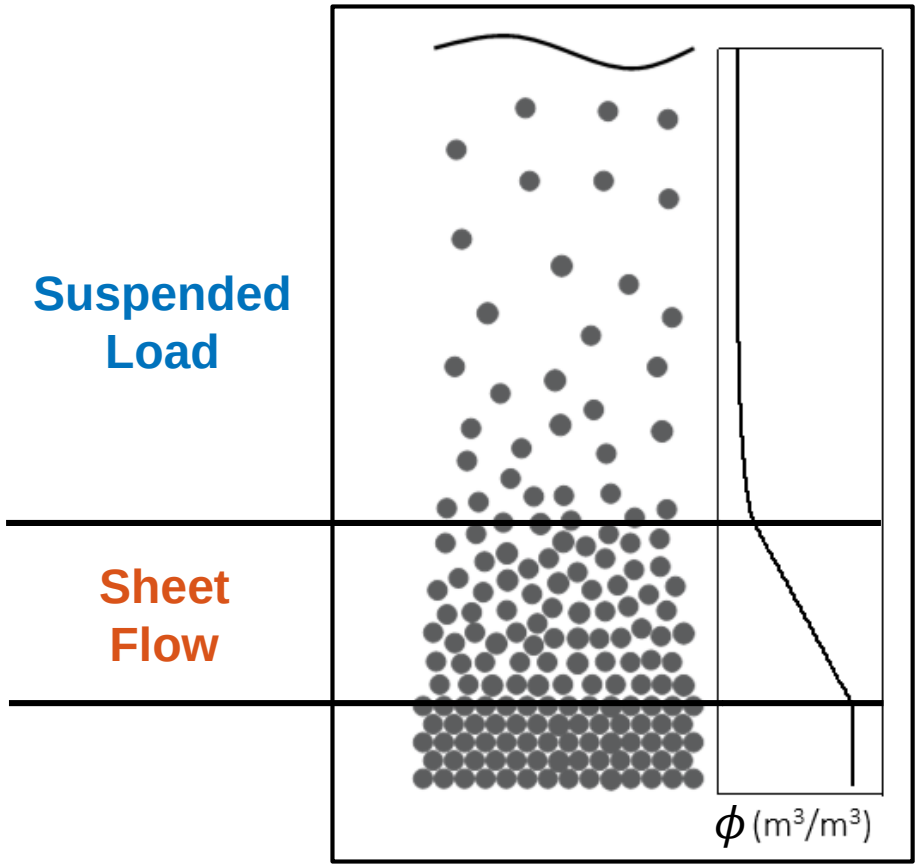


Example of bed load in a flume

Modes of Sediment Transport

Total = **Suspended Load** + Bed Load

- Saltating Grains
- **Sheet Flow**



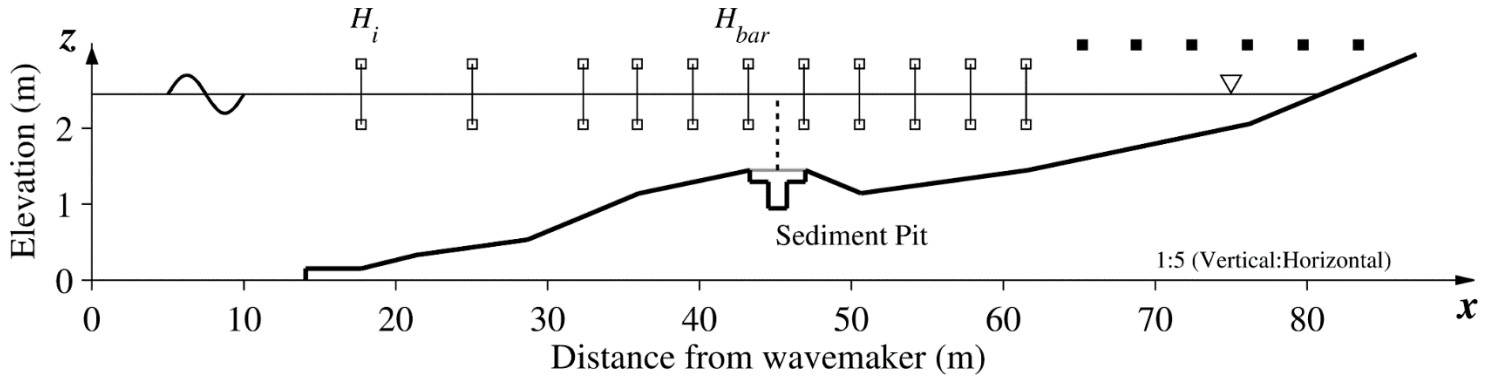
NOT to scale

Example of sheet flow on a sandbar

Laboratory Experiment

SandBAR SEDiment Transport Experiment

Hybrid, fixed profile (near-field scale) with sediment pit on sandbar crest



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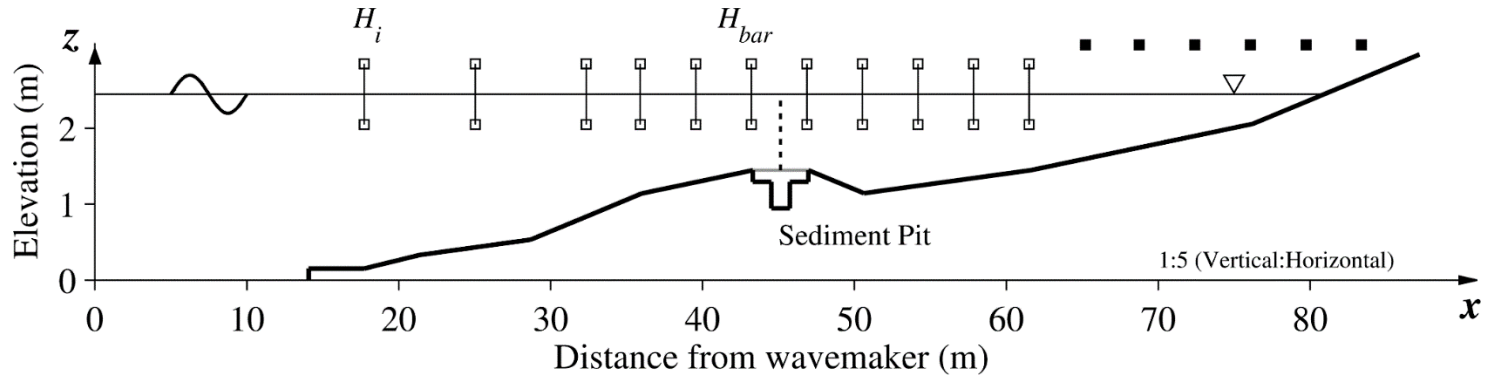


- Median grain diameters, d_{50} = **0.17 (S1) & 0.27 (S2) mm**
- Wave periods, T = **5.0, 7.0 & 9.0 s**
- Wave heights at the sandbar, **0.49 m** $\leq H_{bar} \leq$ **0.94 m**

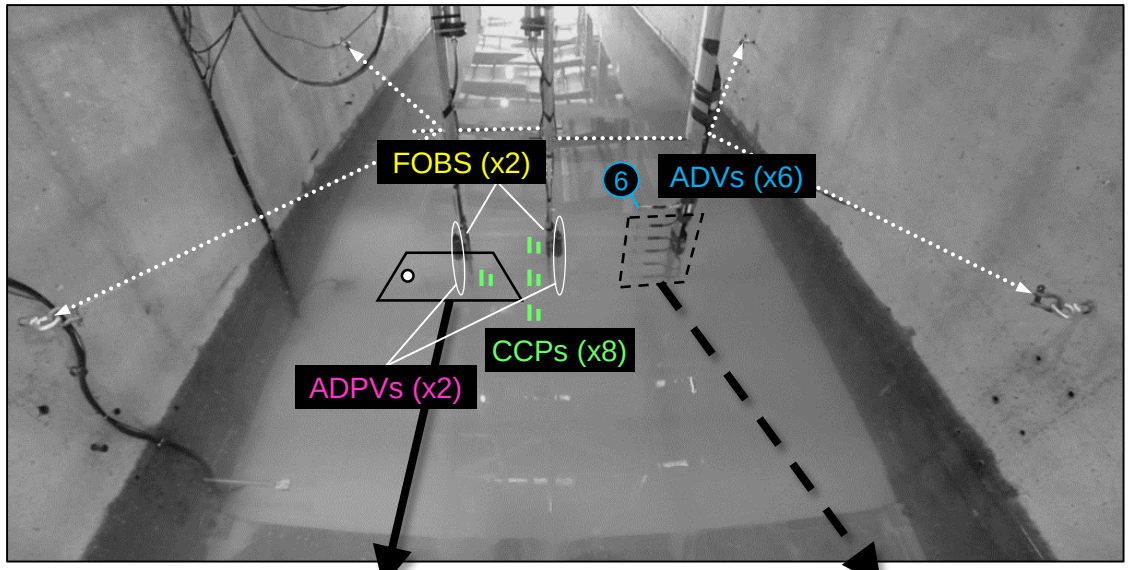
19 wave cases

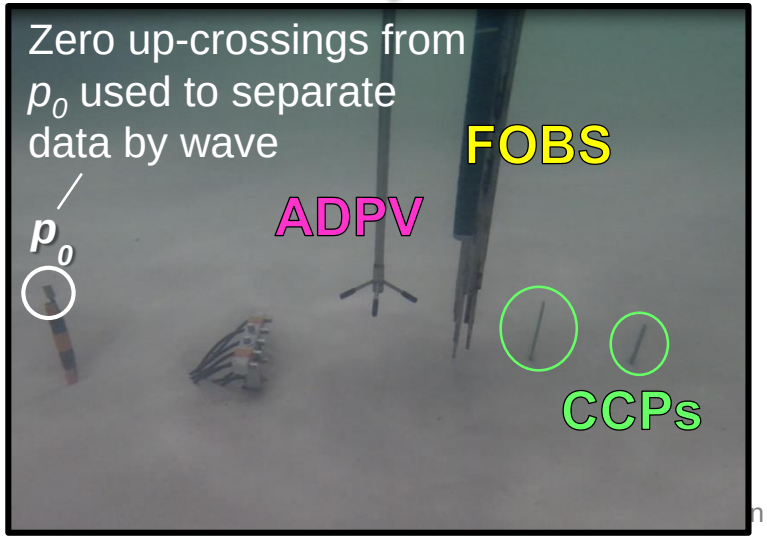
S1: 11 cases

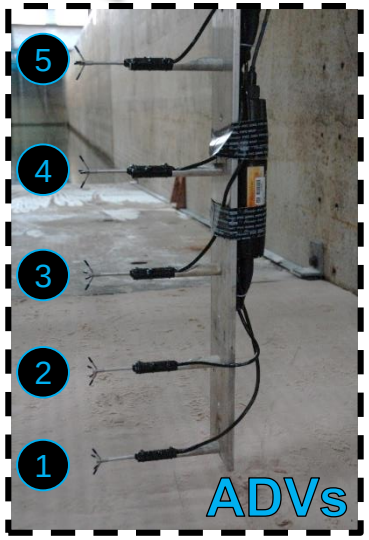
S2: 8 cases

Repeat trials of 10 monochromatic waves (1 wave = 1 realization)

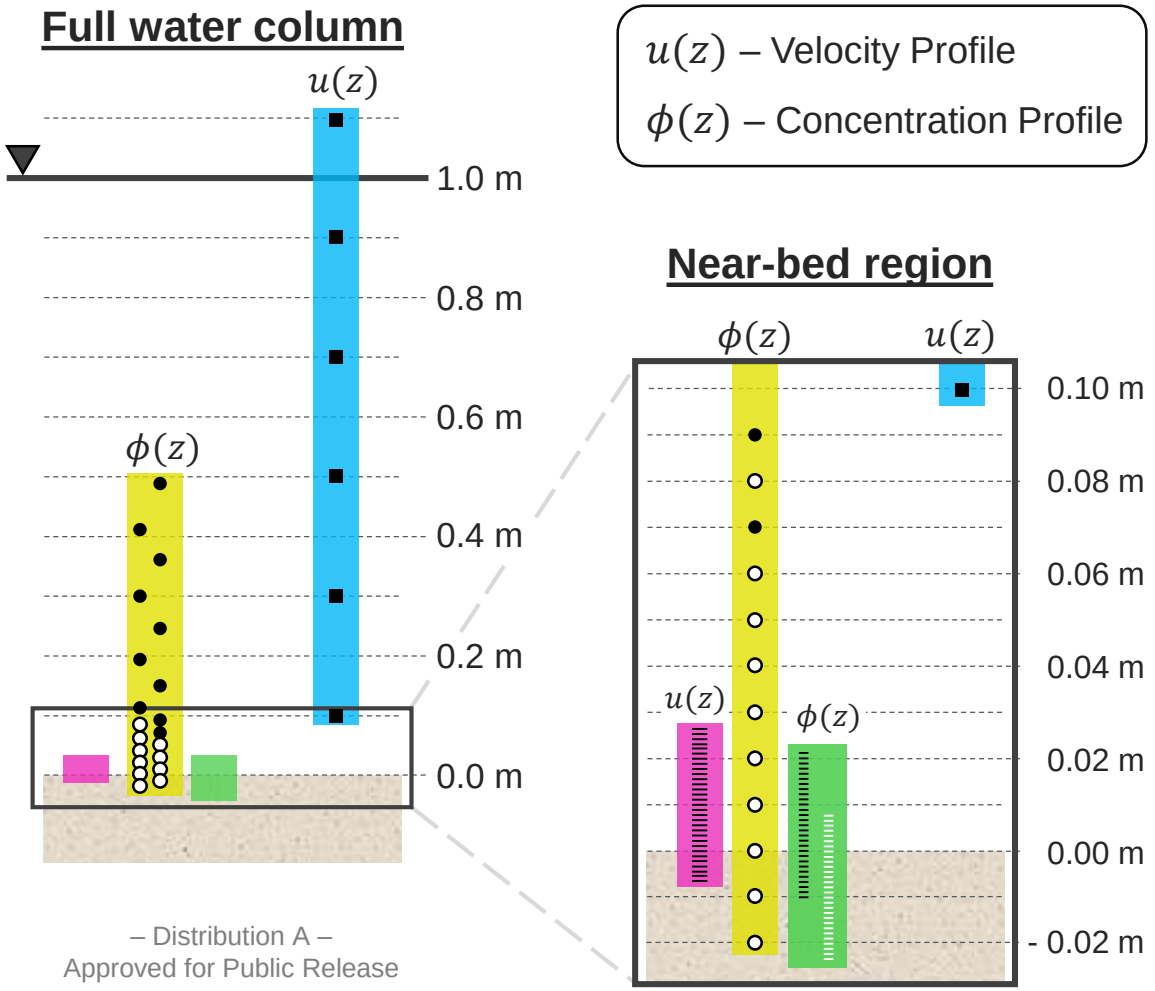
Laboratory Experiment



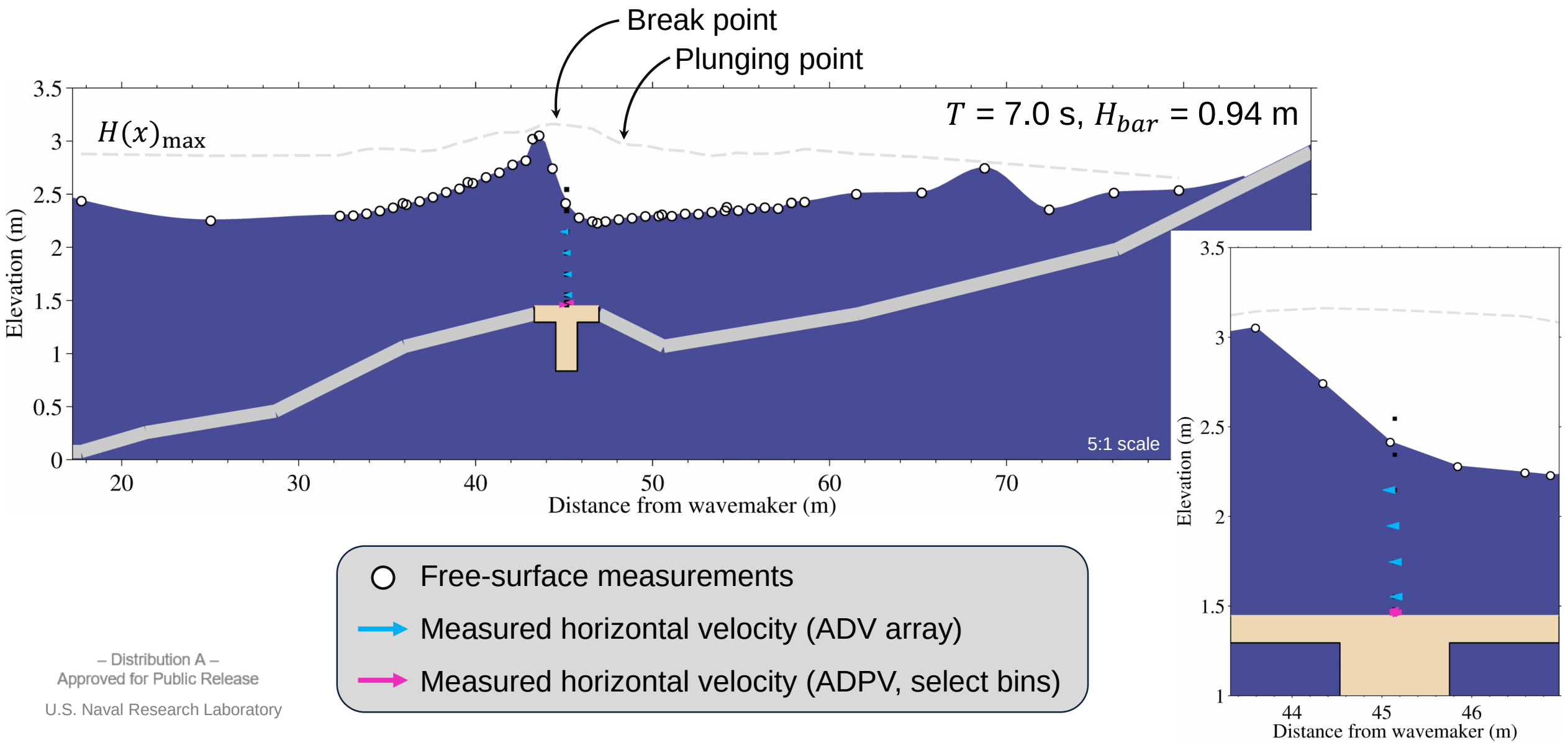




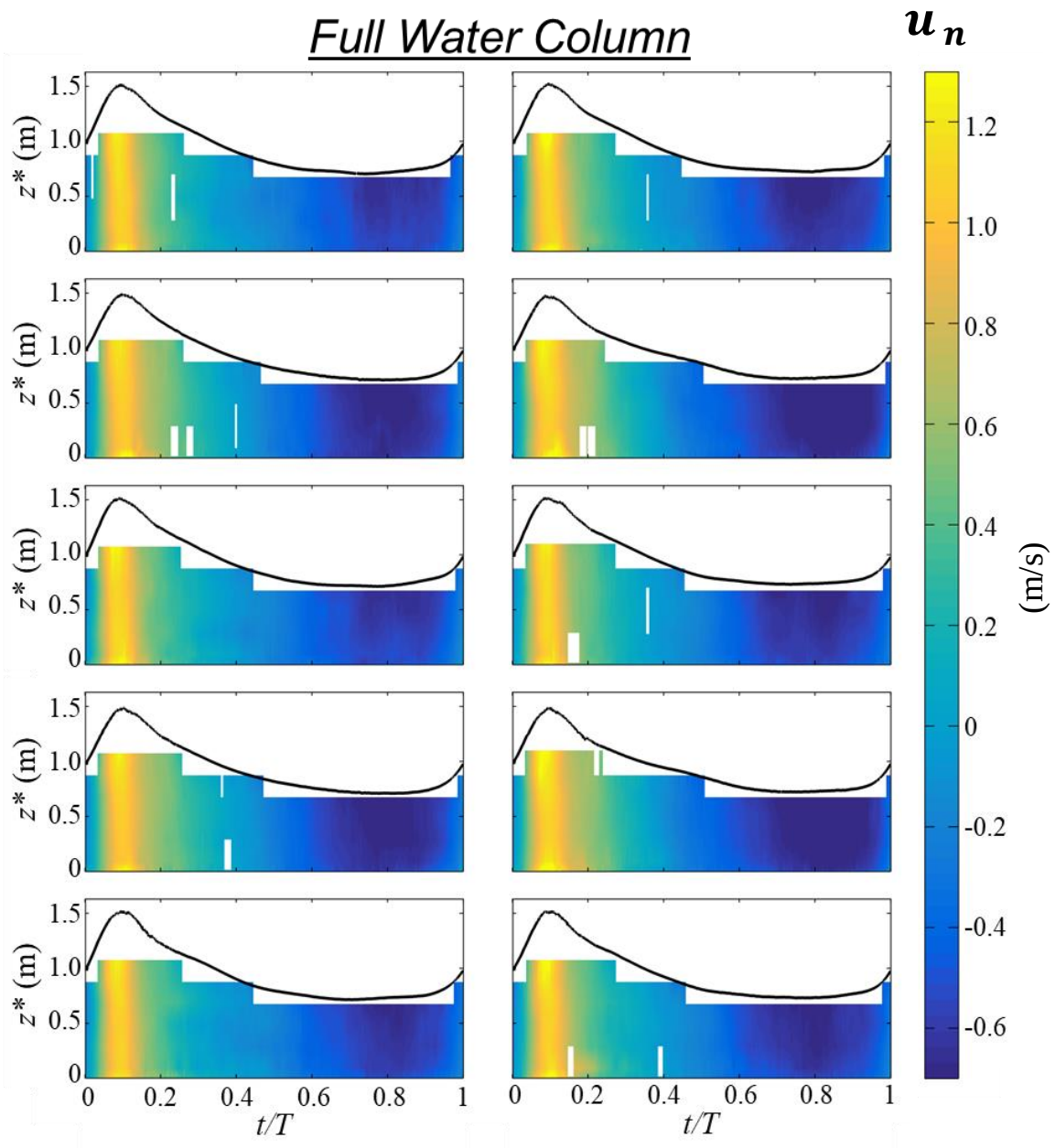
Schematic of measurement ranges

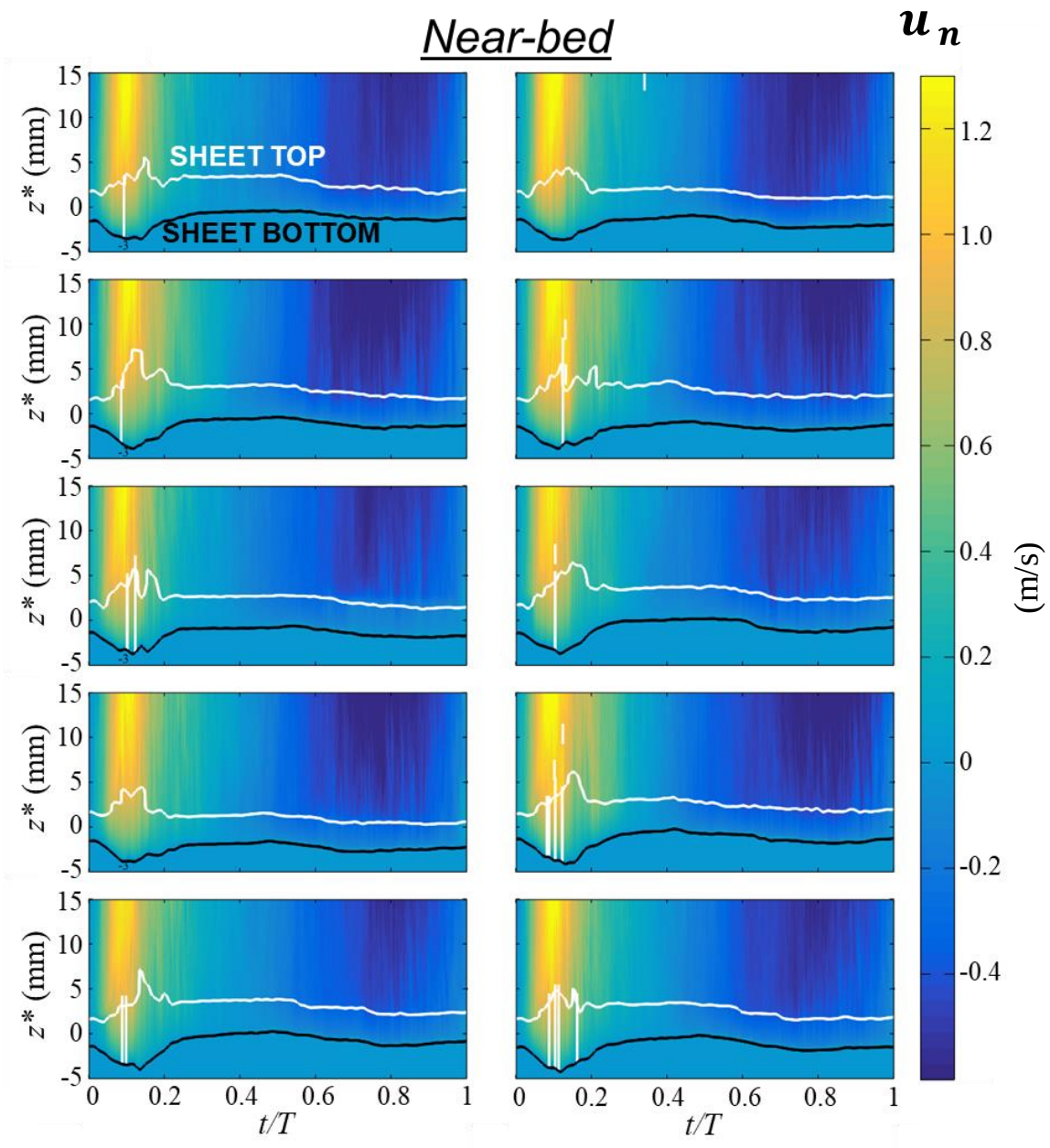


Example 10-Wave Trial

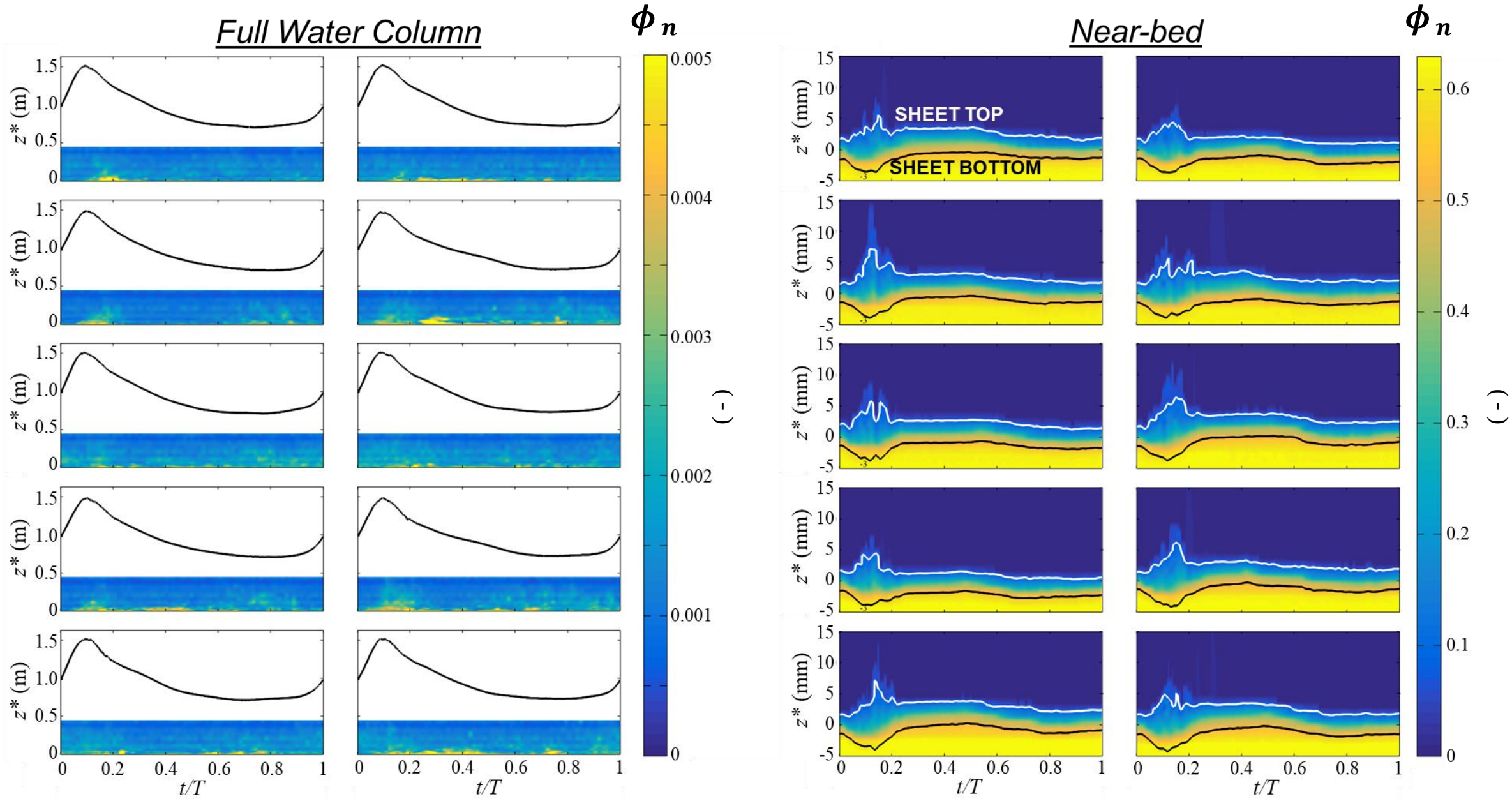


Velocity Ensembles

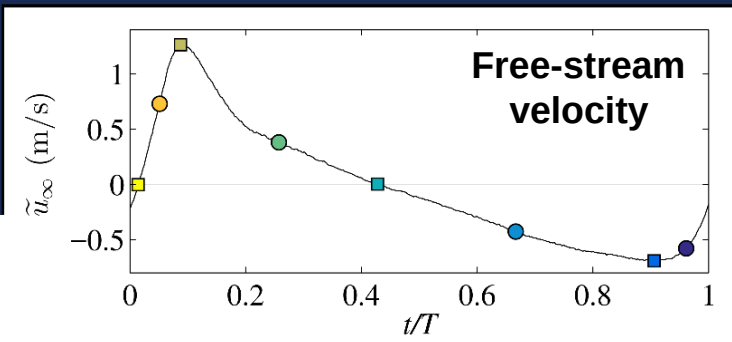




Concentration Ensembles



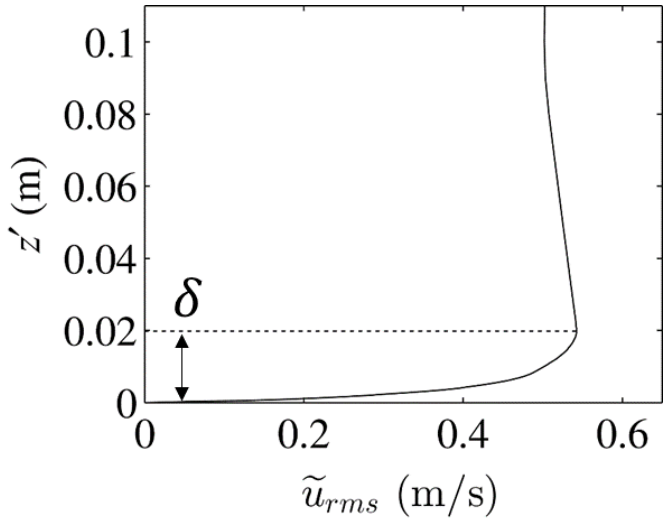
Sediment Transport Rates

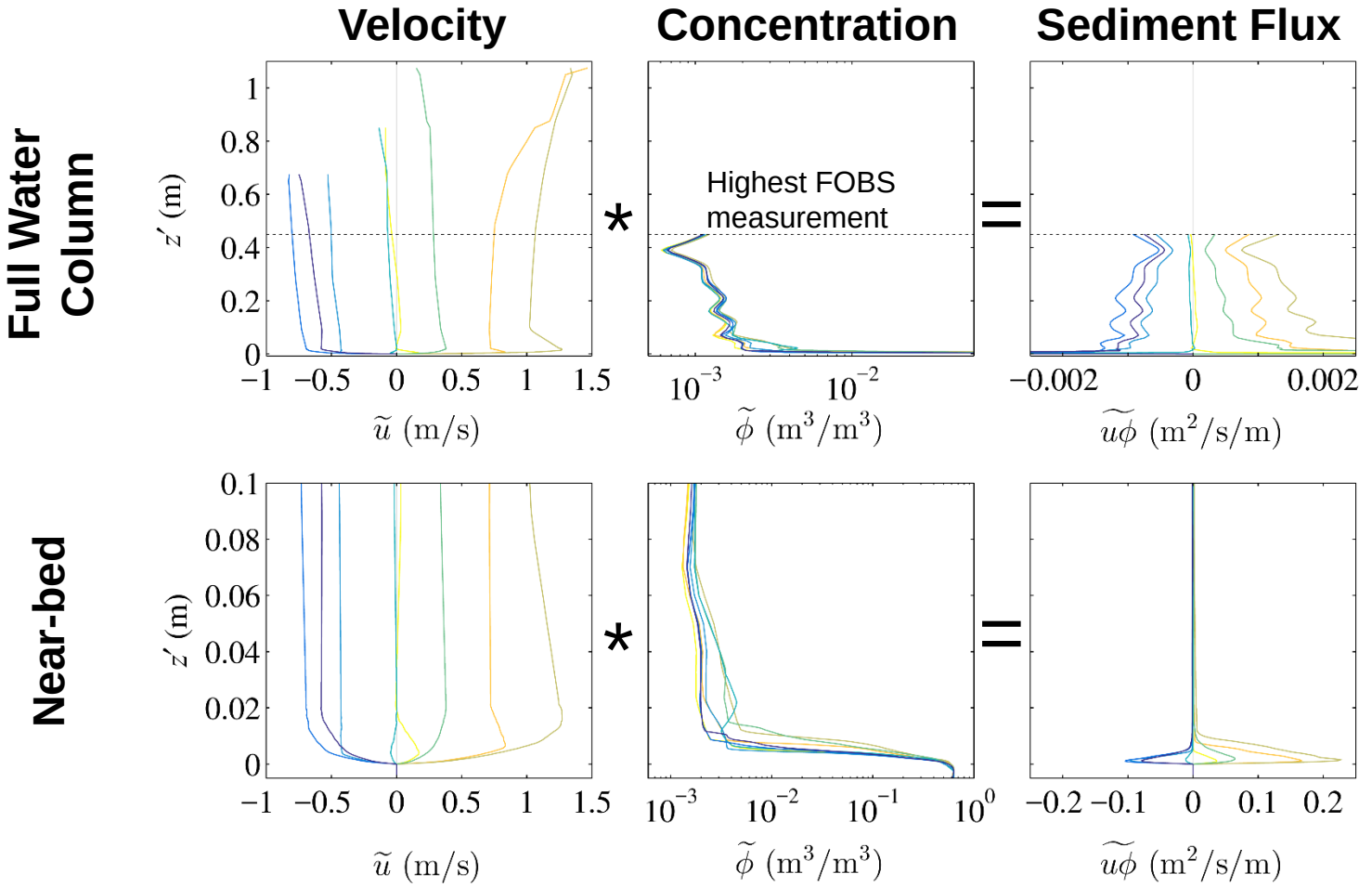


Phase-averaged Wave Case

Boundary layer thickness, δ

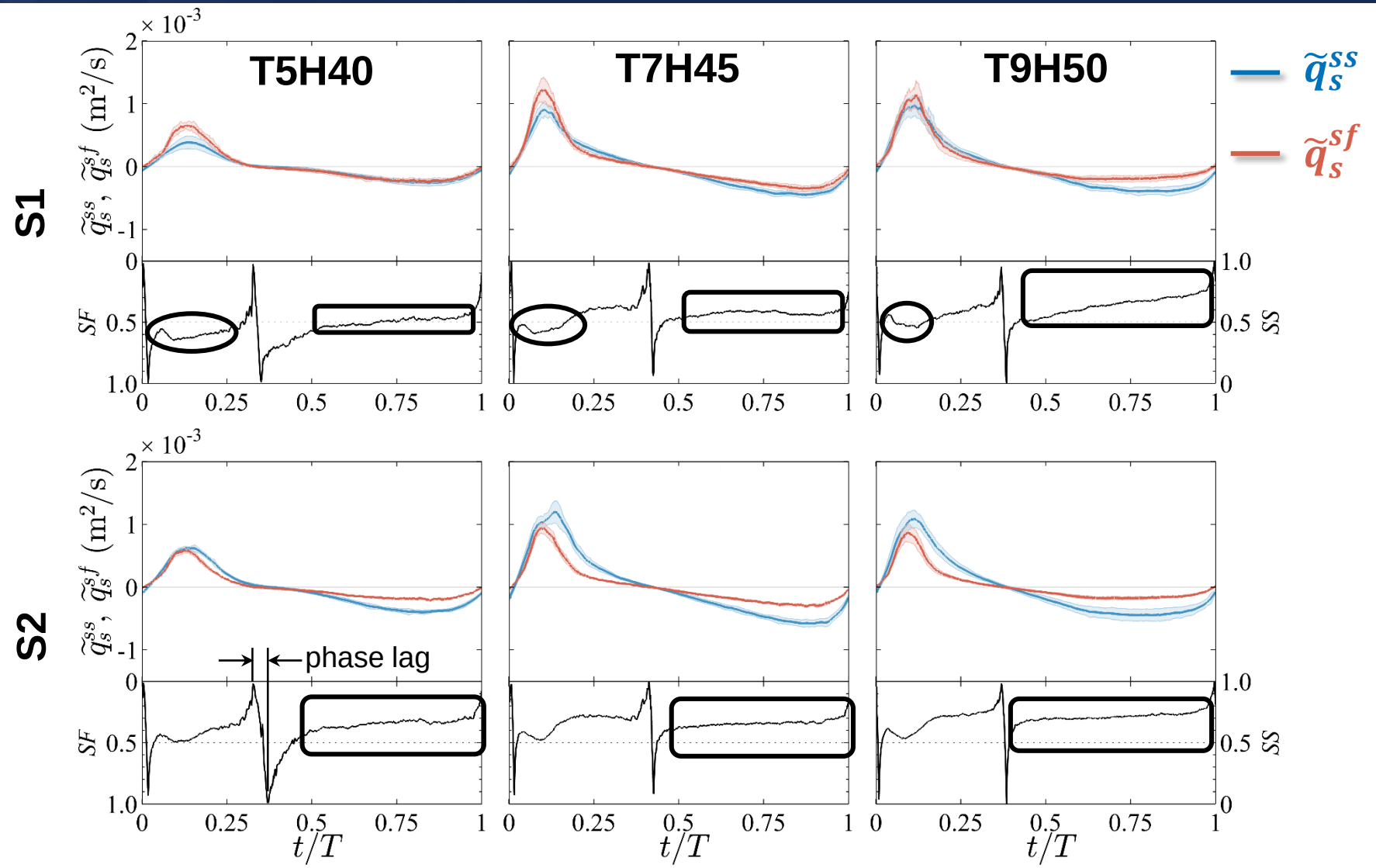
Elevation of maximum overshoot in $\tilde{u}_{rms}$





Sediment Transport Rates

1) Sheet flow dominates suspended sediment transport under crest for S1 cases
2) Suspended sediment transport universally dominant in the trough
3) In general, sheet flow and suspended sediment transport of same order of magnitude
4) Sheet flow LEADS suspended sediment transport



Sediment Transport Rates

Net Sheet Flow Transport Rates

Relationship with 3rd moments of velocity

Recall, in general:

$$Q \propto C_f U^2 |U|$$ *(Bailard, 1981;*

⬇ *Meyer-Peter &*

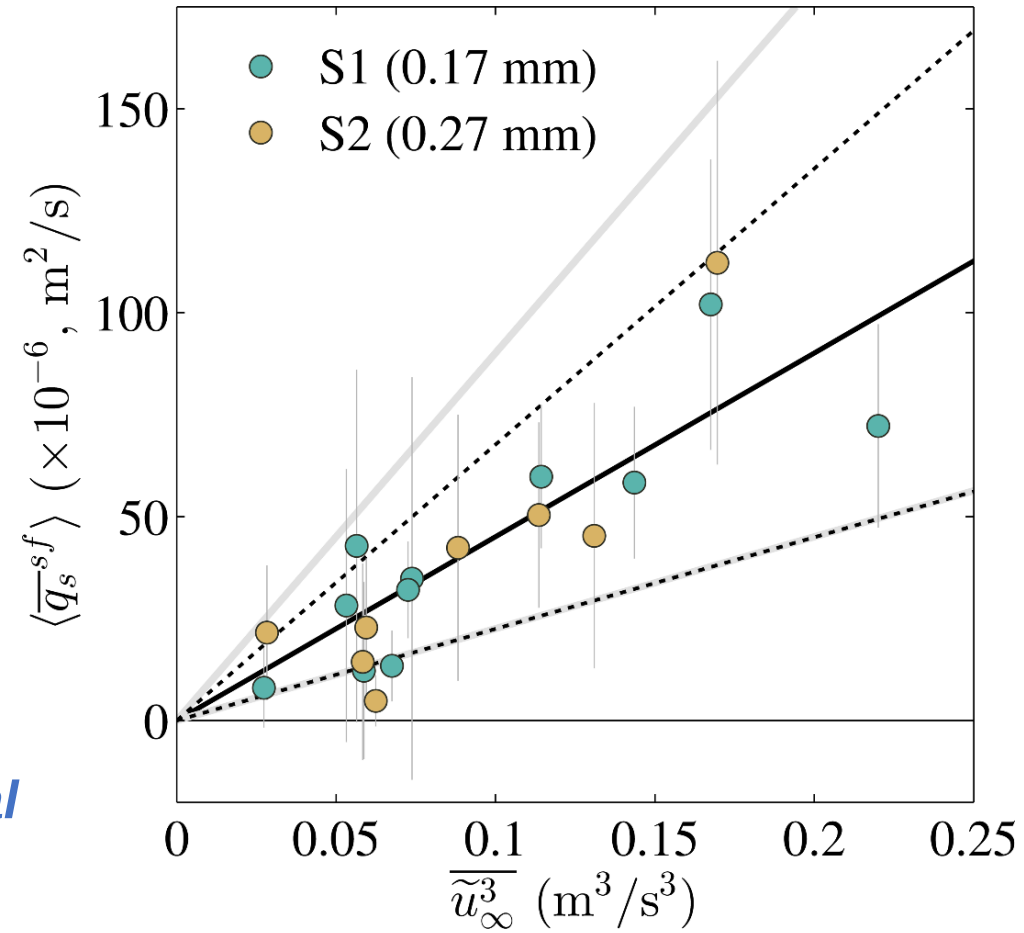
$$q_s(t) \propto u(t)^3$$ *Muller, 1948)*

"Net" ≡ Wave-average, $\overline{\ }$

$$\overline{q_s(t)} \propto \overline{u(t)^3}$$

↳ ***Net transport rate is proportional to the third moment of velocity***

*Grey lines represent ±1 standard deviation from the ensemble-average



Sediment Transport Rates

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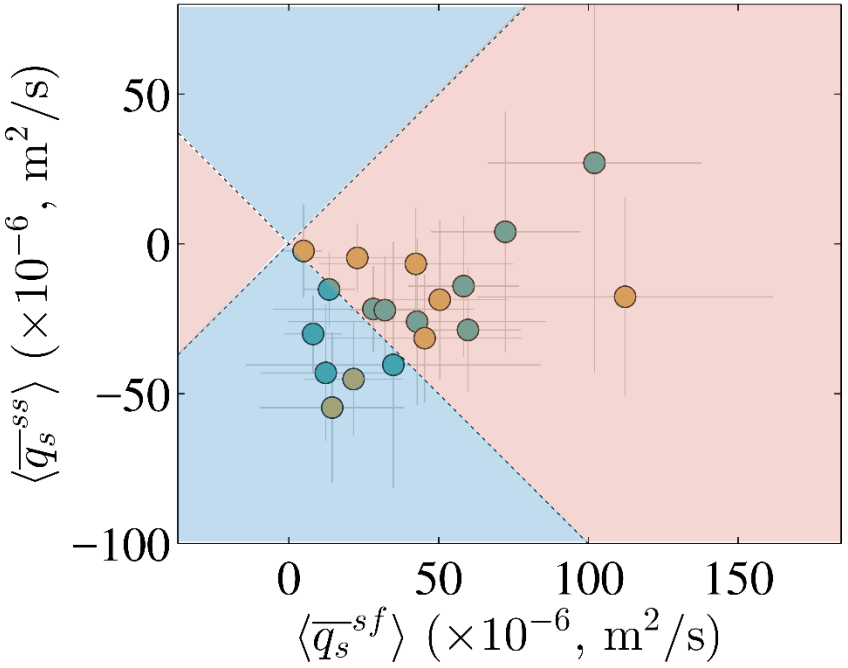
Net Transport Rates

Suspended Load versus Sheet Flow



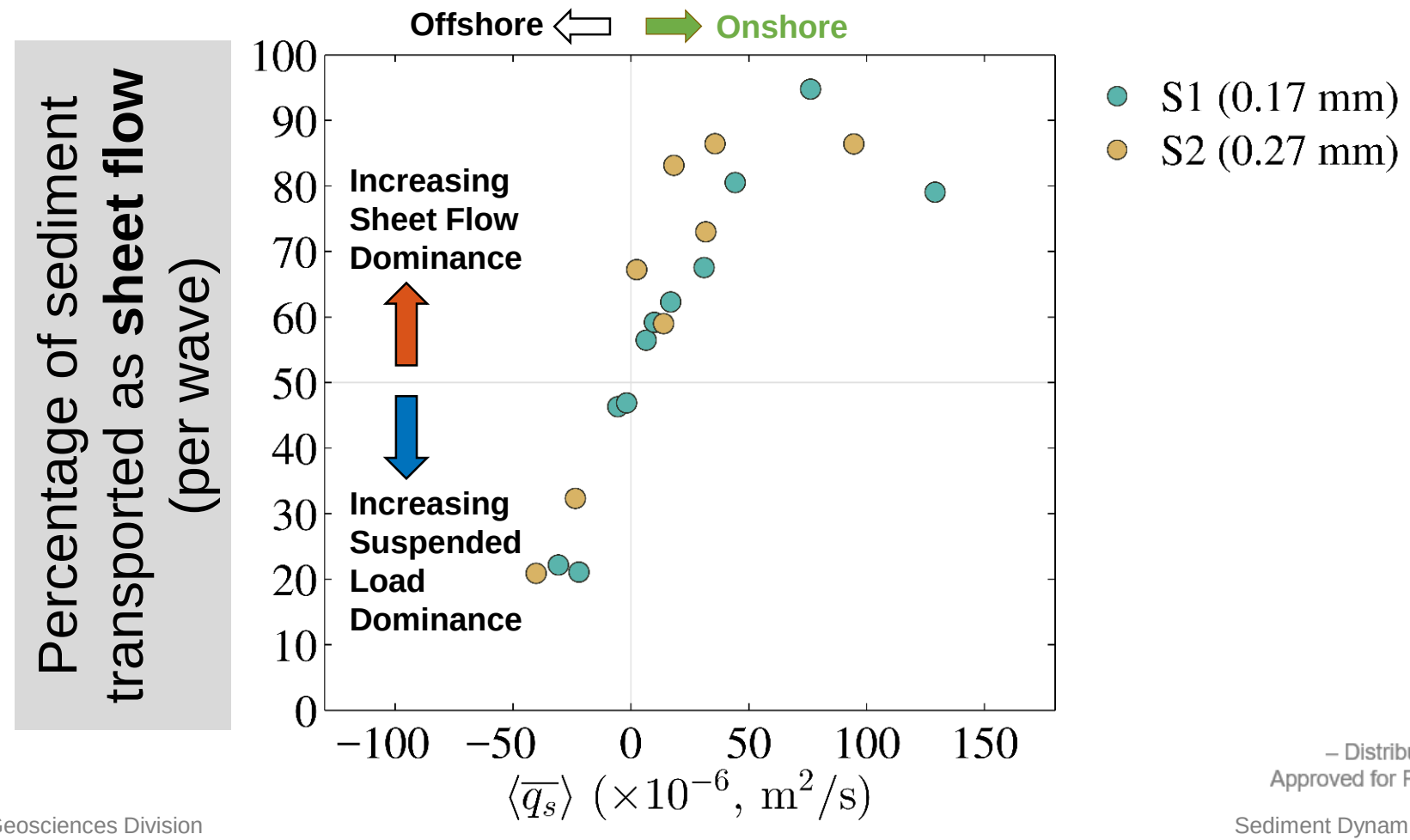
Suspended Load Dominant

Sheet Flow Dominant

- S1 (0.17 mm)
- S2 (0.27 mm)

Sediment Transport Rates

How much does sheet flow contribute to the net transport rate?



Conclusions

BARSED study

- ❑ High-resolution concurrent measurements on a sandbar of concentration and velocity profiles
- ❑ Tested wide range of forcing conditions and sediment sizes

Sediment transport

- ❑ Net sheet flow transport rates correlated well with third moments of velocity
- ❑ If SS transport dominated SF transport, net transport rate was **offshore**
- ❑ If SF transport dominated SS transport, net transport rate was **onshore**

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BARSED 2015

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Thank you for your attention.

Questions or comments?

Let's discuss!