Examining shoreface disequilibrium morphodynamics and their influence on shoreline change

Megan Gillen[1], Andrew Ashton[2], Jen Miselis[3], Emily Wei[3], Dan Ciarletta[3], Chris Sherwood[4]

[1]MIT-WHOI Joint Program in Oceanography, MA, USA
[2]Woods Hole Oceanographic Institution, MA, USA
[3]USGS Coastal and Marine Science Center St. Petersburg, FL, USA
[4]USGS Coastal and Marine Science Center Woods Hole, MA, USA

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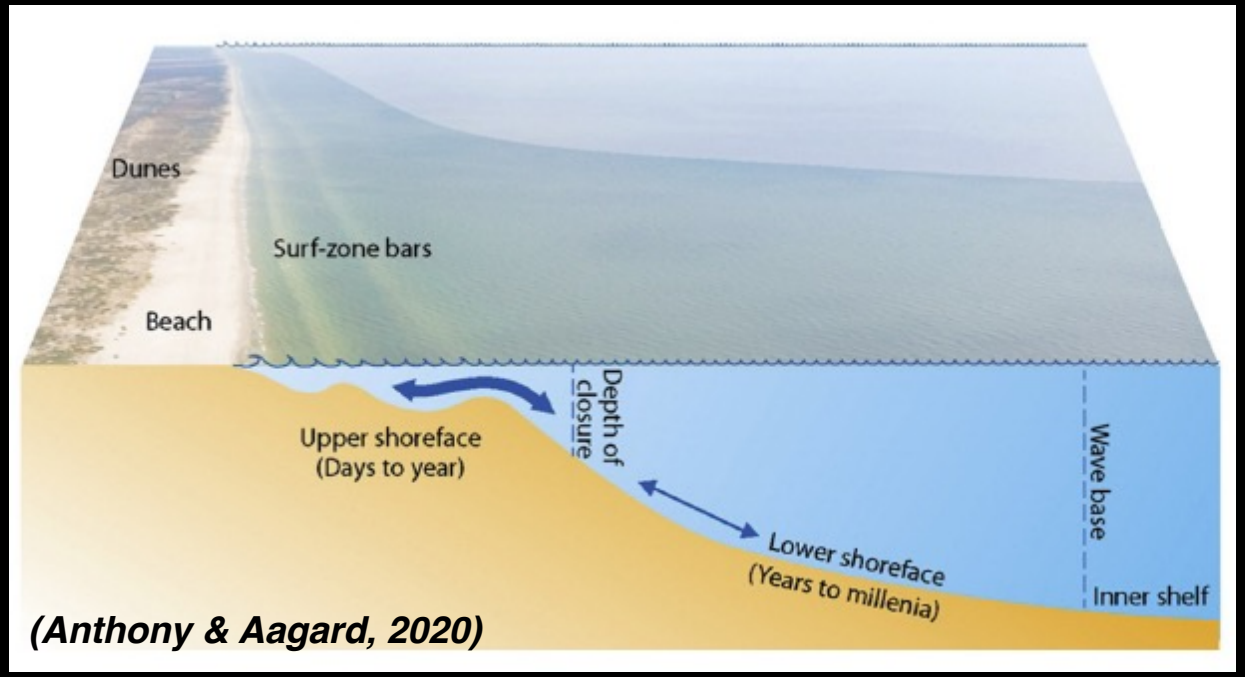
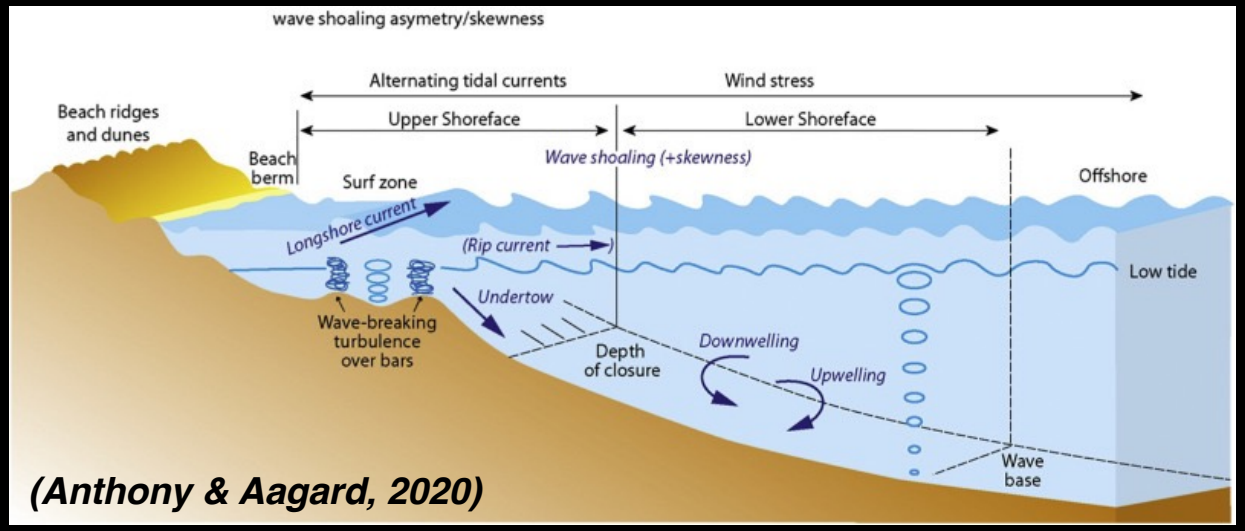
https://roadtrippers.com/magazine/virginia-barrier-islands/

Background

- Transitional zone on passive margins
- Morphodynamic evolution not well understood
  - Lack of sediment data
  - Long timescales (10^1-10^3 yrs)
- Steady-state assumptions



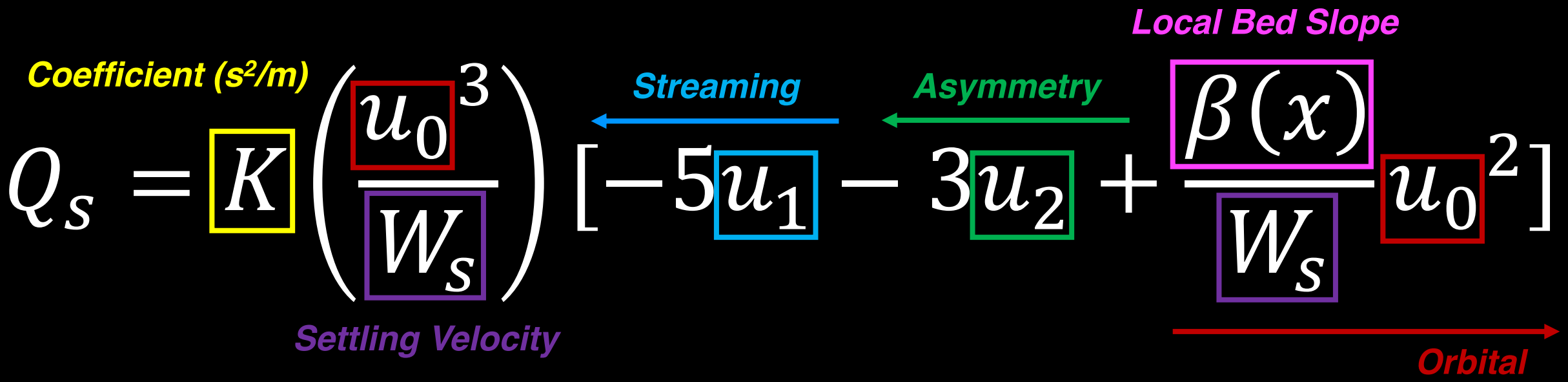
(Anthony & Aagard, 2020)



(Anthony & Aagard, 2020)

(Ortiz & Ashton 2016; Derived from Bagnold 1963, Bowen 1980, Stive & deVriend 1995)

Energetics Transport Equation



(Ortiz & Ashton 2016; Derived from Bagnold 1963, Bowen 1980, Stive & deVriend 1995)

Energetics Transport Equation

Coefficient (s^2/m)

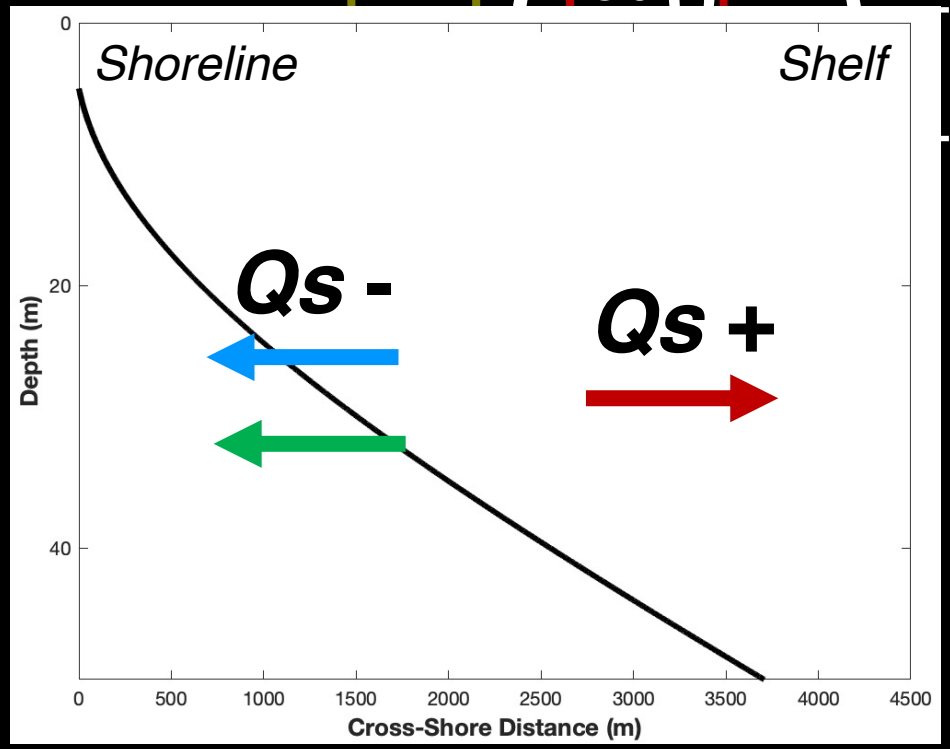
$$\left(u_0^3\right)\left[-5u_1 - 3u_2 + \frac{\beta(x)}{W_s}u_0^2\right]$$

Streaming ← $-5u_1$

Asymmetry ← $-3u_2$

Local Bed Slope → $\frac{\beta(x)}{W_s}u_0^2$

Orbital →



(Ortiz & Ashton 2016; Derived from Bagnold 1963, Bowen 1980, Stive & deVriend 1995)

Energetics Transport Equation

Coefficient (s^2/m)

Settling Velocity

Streaming

Asymmetry

Local Bed Slope

Orbital

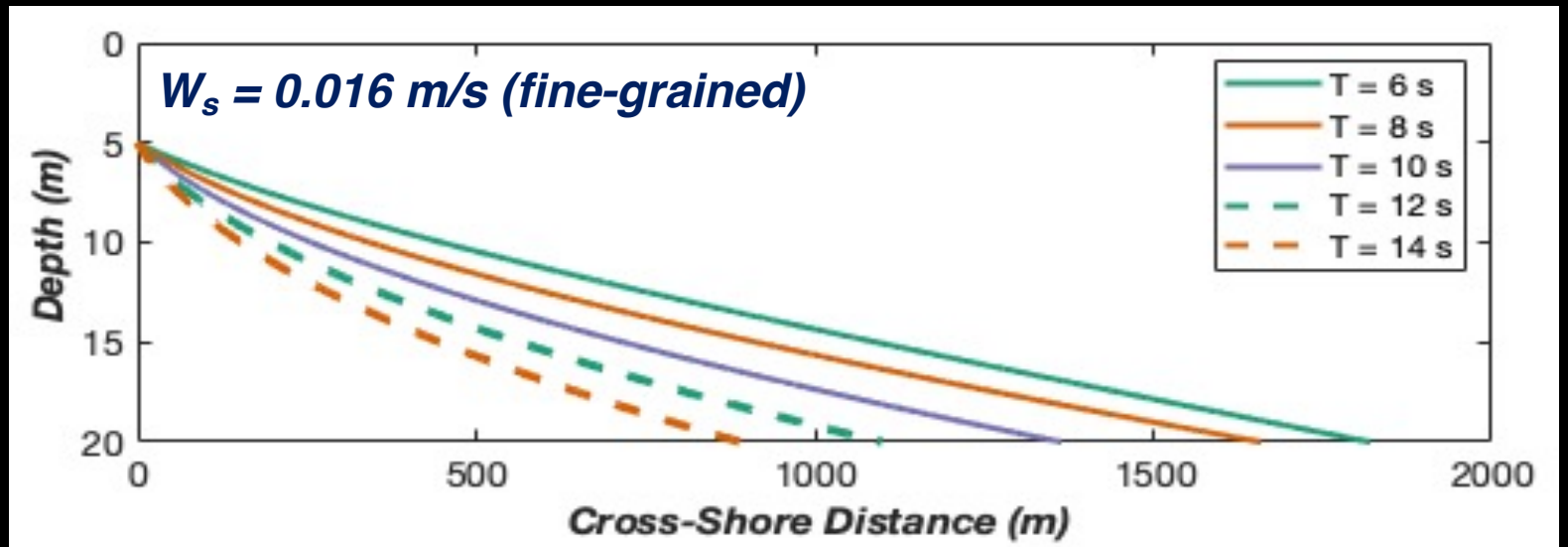
$$Q_s = K\left(\frac{u_0^{\,3}}{W_s}\right)\left[-5u_1 - 3u_2 + \frac{\beta(x)}{W_s}u_0^{\,2}\right]$$

Equilibrium Slope

$$\beta_e(z(x)) = \frac{W_{s_e}}{u_0^{\,2}}\left[5u_1 + 3u_2\right]$$

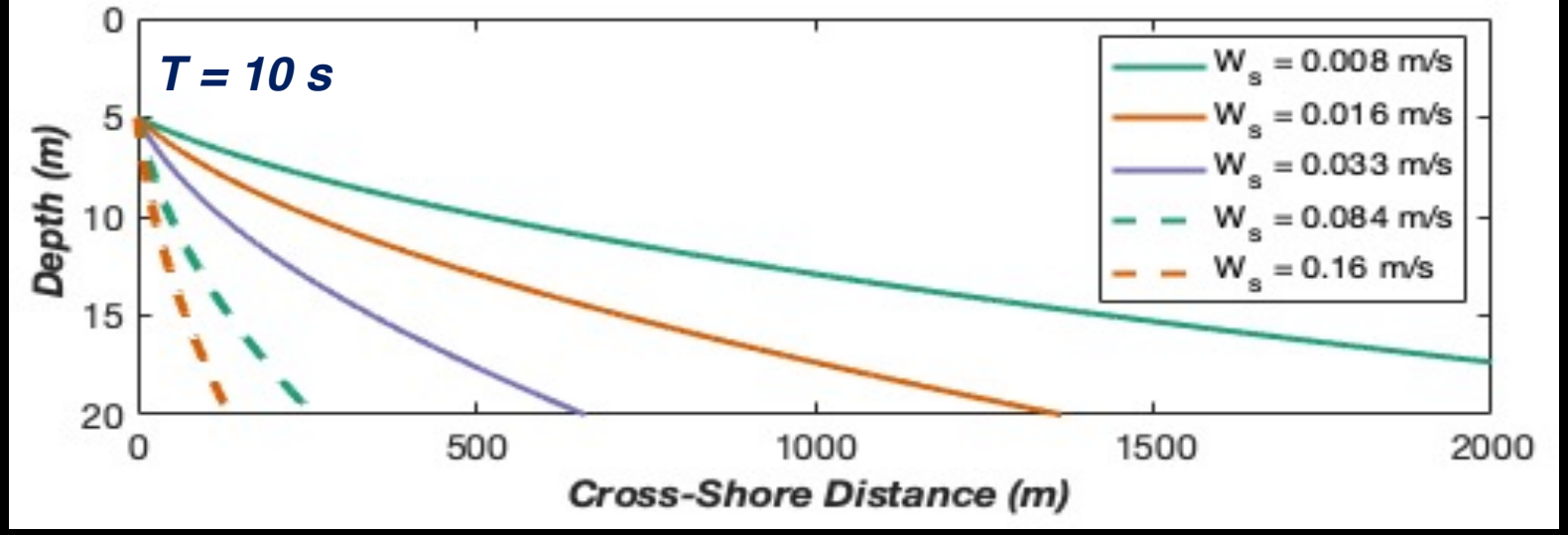
Modified from Ortiz & Ashton 2016

Wave Period



As T ↑, profile steepens

Settling Velocity



As W_s ↑, profile steepens

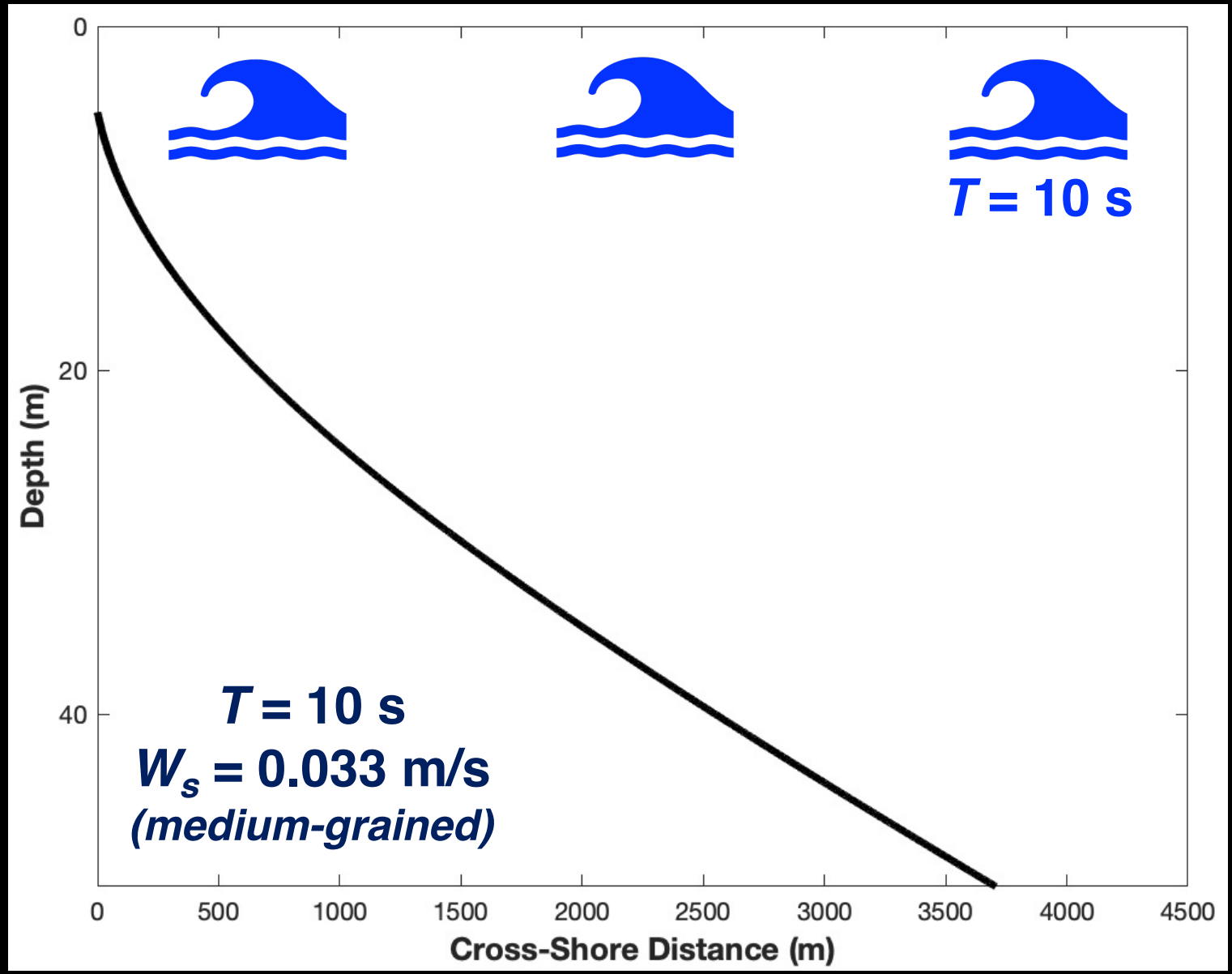
Equilibrium Profiles

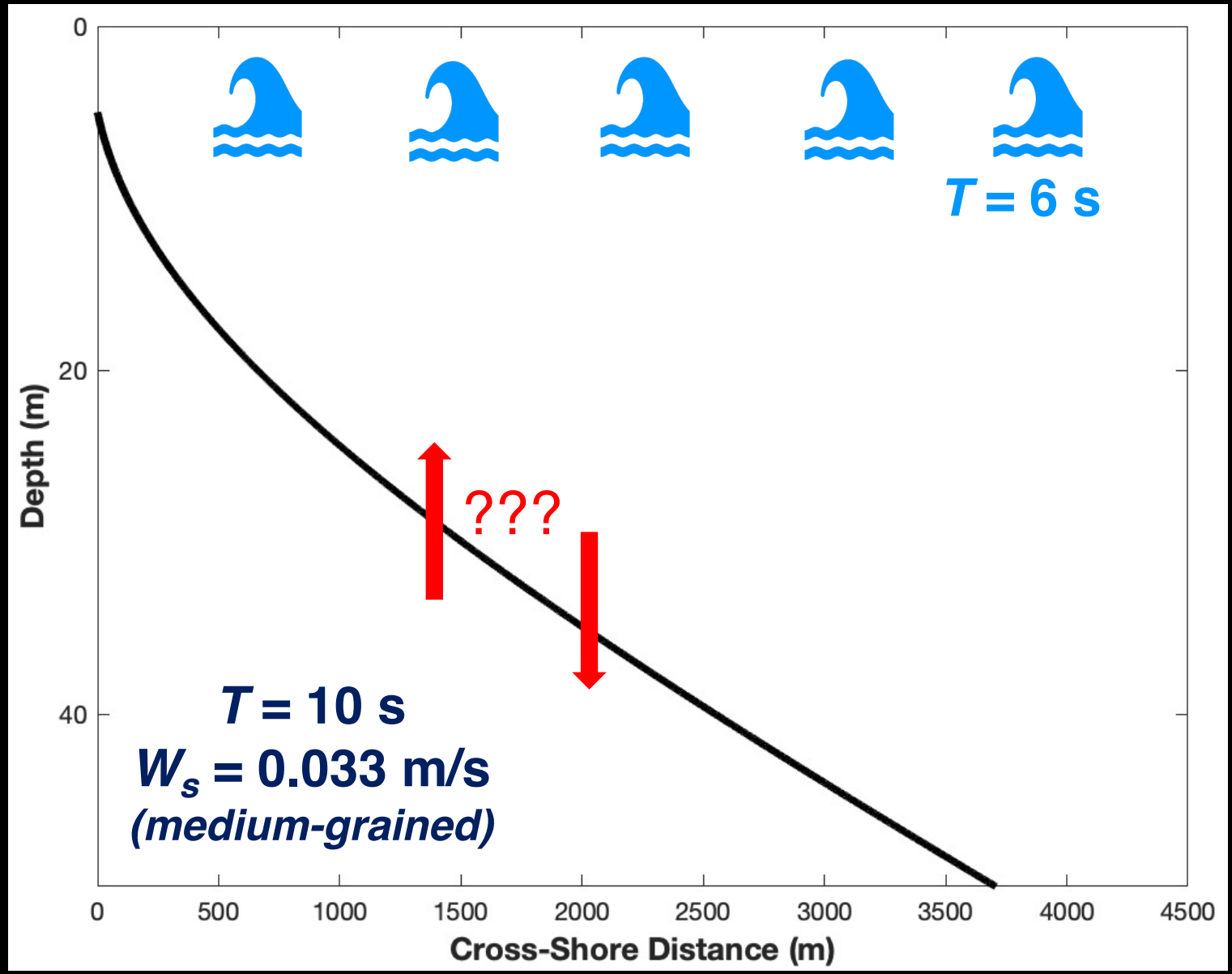
Outline

I. Shoreface Disequilibrium Modeling

II. Disequilibrium Conditions

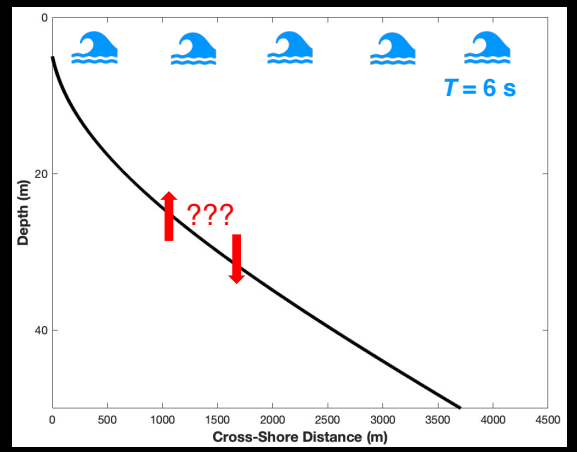
III. Time Series & Profile Change


0
20
40
Depth (m)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Cross-Shore Distance (m)
T = 10 s
T = 10 s
W_s = 0.033 m/s
(medium-grained)


0
20
40
Depth (m)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Cross-Shore Distance (m)
T = 6 s
???
T = 10 s
W_s = 0.033 m/s
(medium-grained)

(Ortiz & Ashton 2016; Derived from Bagnold 1963, Bowen 1980, Stive & deVriend 1995)

Disequilibrium Sediment Transport

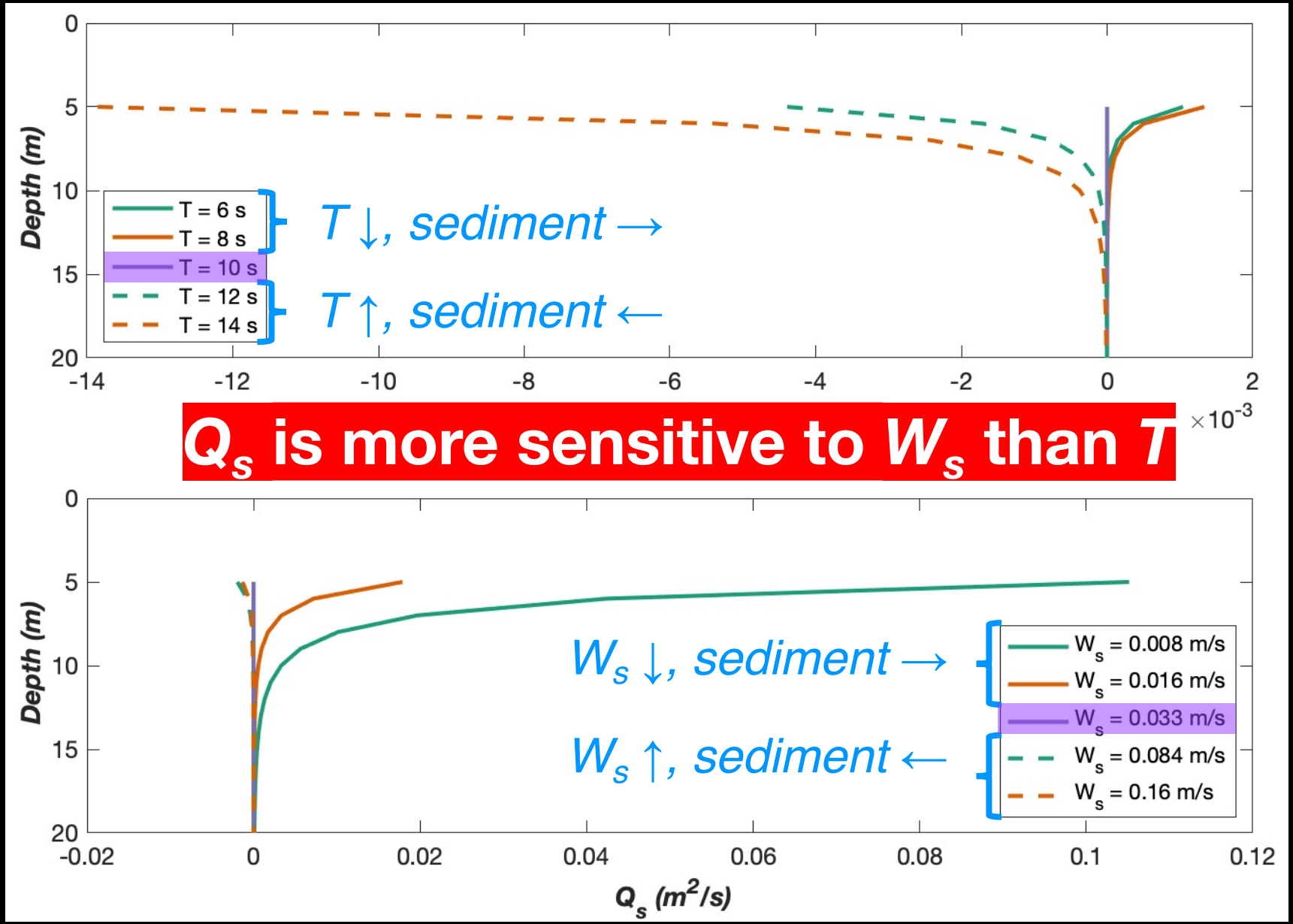


$T_e = 10\ s$
$W_{s_e} = 0.033\ m/s$
(medium-grained)

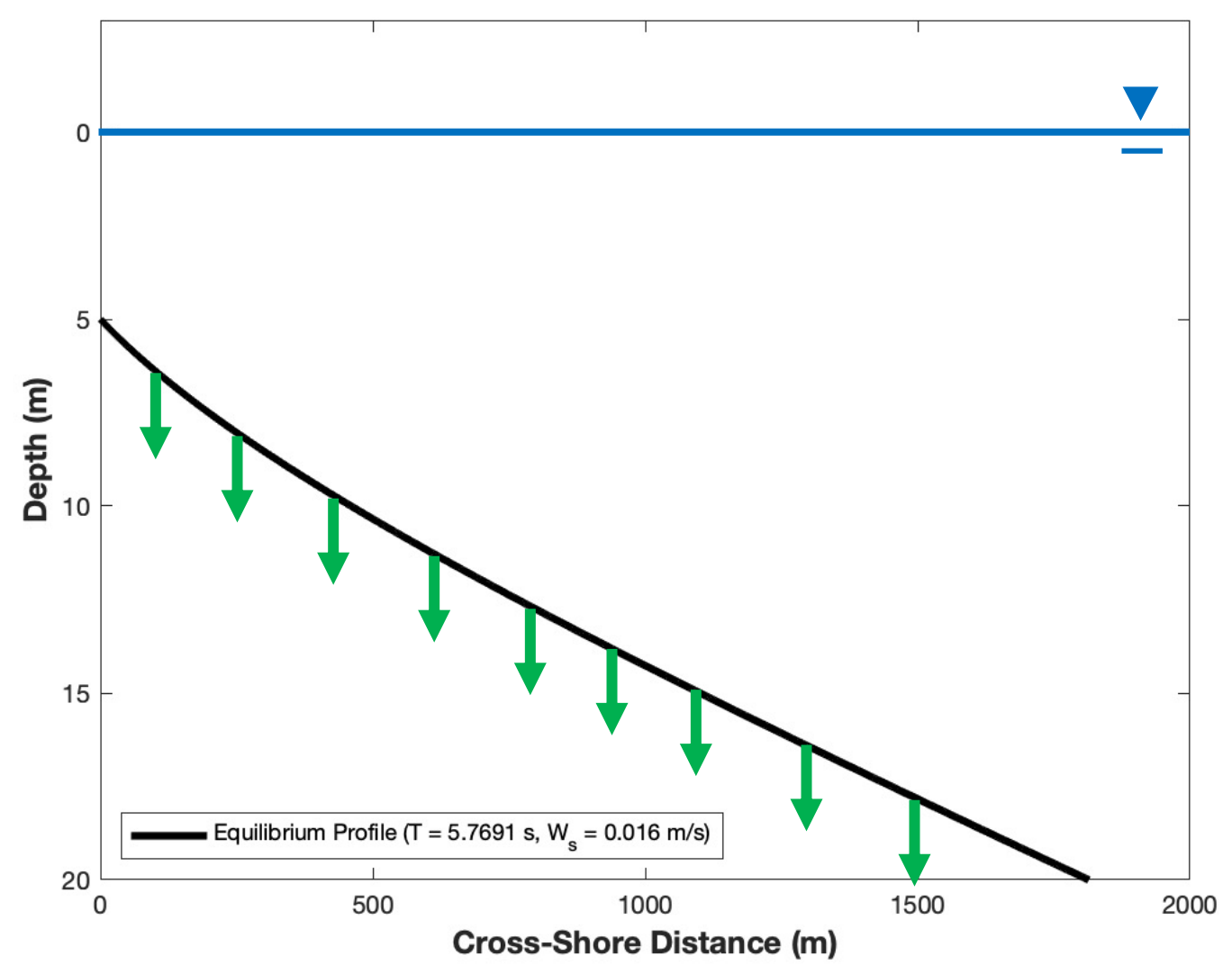
$$\beta_e(z(x)) = \frac{W_{s_e}}{{u_0}^2}\left[5u_1 + 3u_2\right]$$

$$Q_s = K\left(\frac{{u_0}^3}{W_s}\right)\left[-5u_1 - 3u_2 + \frac{\beta_e(x)}{W_s}{u_0}^2\right]$$

$T = 6\ s$
$W_s = 0.016\ m/s$ *(fine-grained)*


Depth (m)
T = 6 s
T = 8 s
T = 10 s
T = 12 s
T = 14 s
T ↓, sediment →
T ↑, sediment ←
×10^-3
Q_s is more sensitive to W_s than T
W_s ↓, sediment →
W_s ↑, sediment ←
W_s = 0.008 m/s
W_s = 0.016 m/s
W_s = 0.033 m/s
W_s = 0.084 m/s
W_s = 0.16 m/s
Q_s (m^2/s)

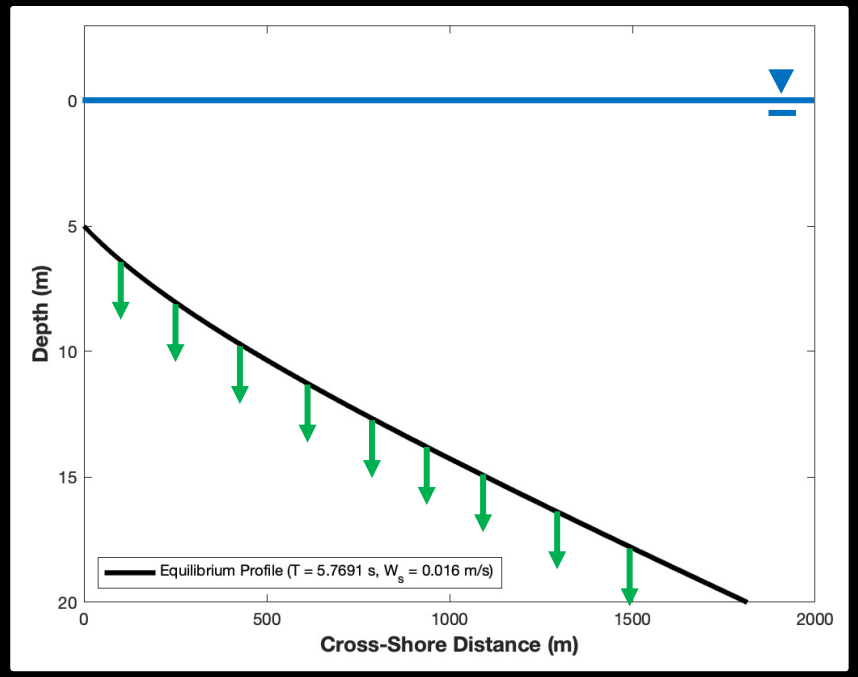
Sea-level Rise (SLR)

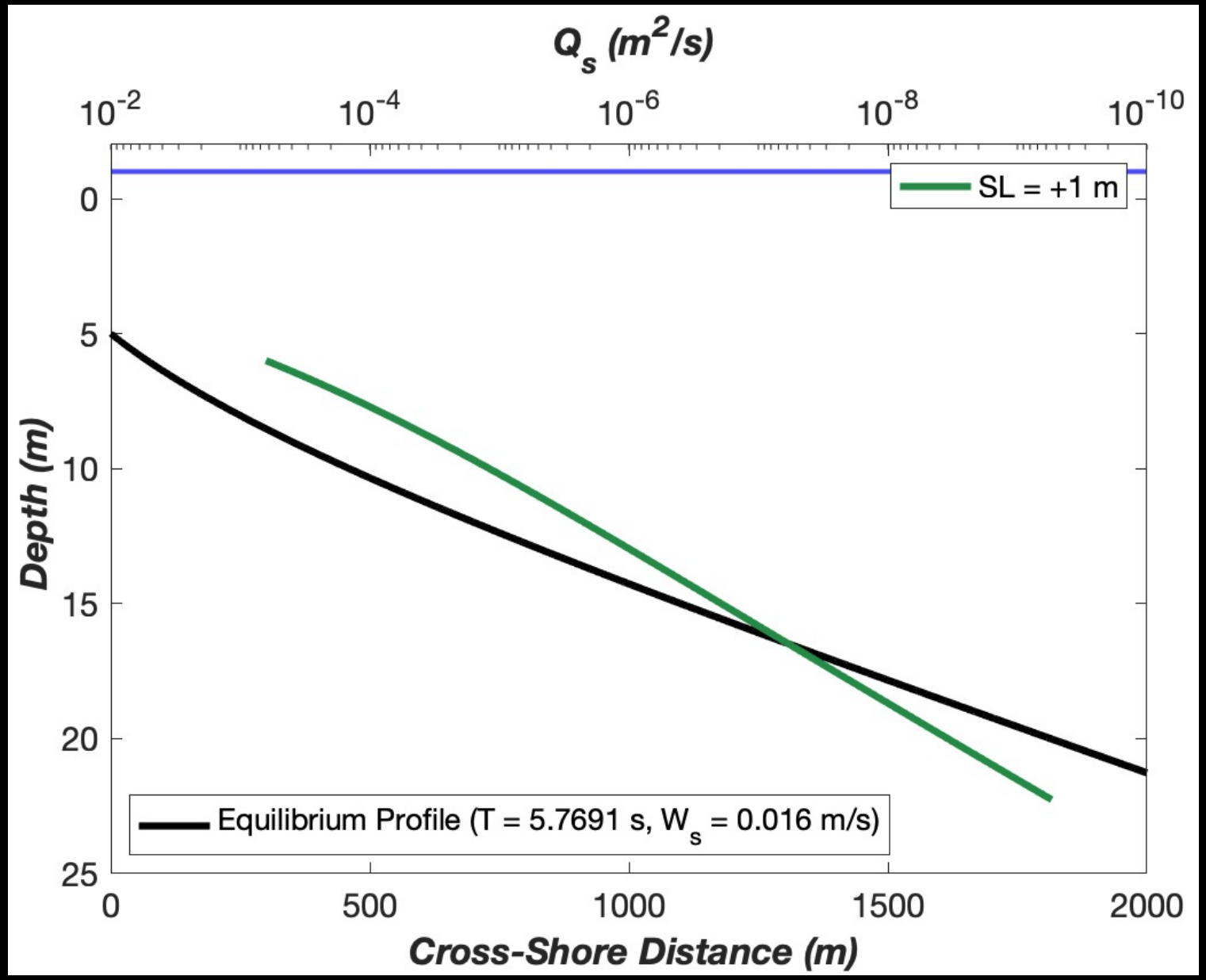


(Ortiz & Ashton 2016; Derived from Bagnold 1963 & Bowen 1980)

SLR Transport & Timescales

$$Q_s(z+1) = K\left(\frac{{u_0}^3}{W_s}\right)\left[-5u_1 - 3u_2 + \frac{\beta_e(x(z_o))}{W_s}{u_0}^2\right]$$



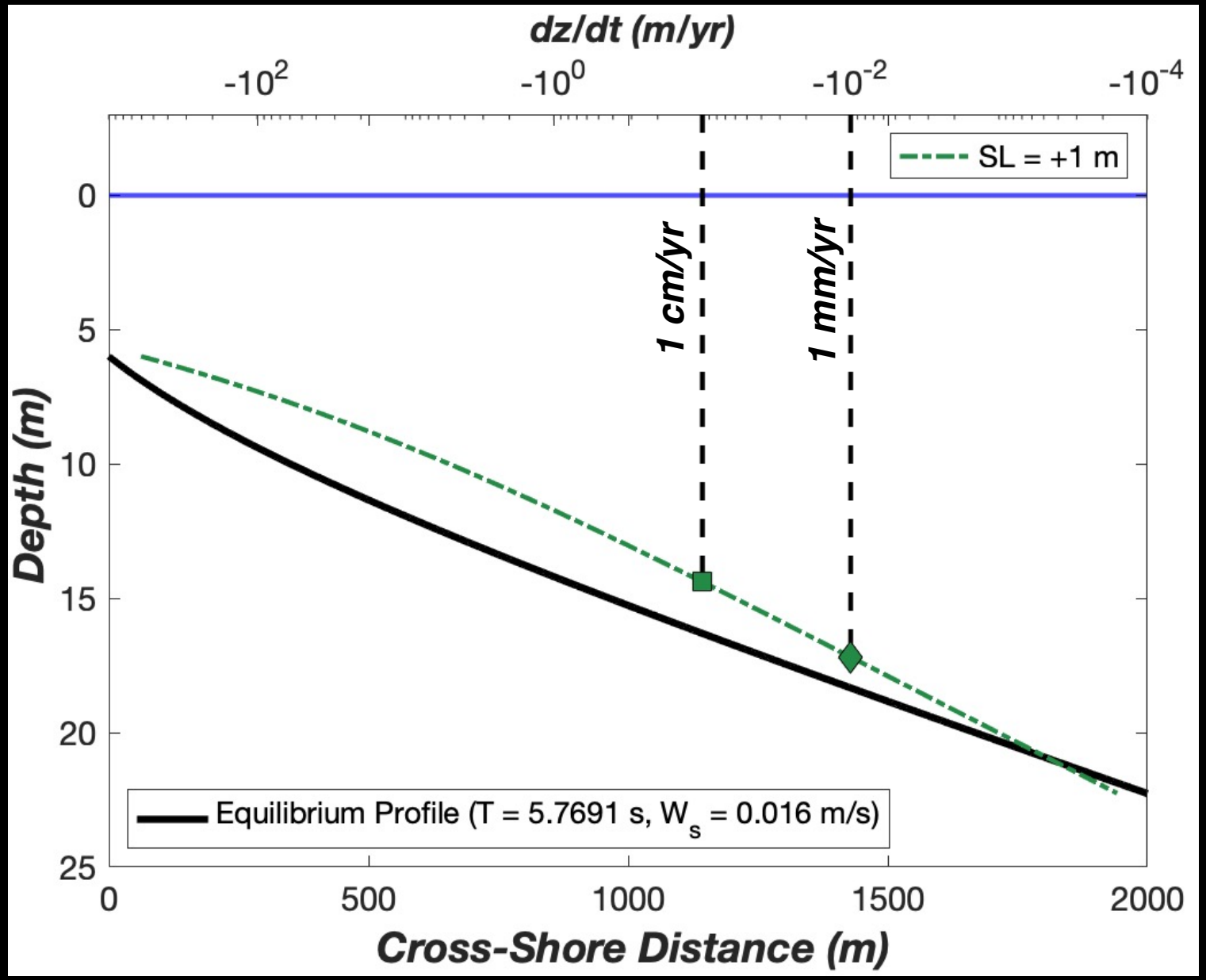


SLR Timescale

$$\frac{\partial z}{\partial t} = \frac{1}{\varepsilon}\frac{\partial Q_s}{\partial x}$$

H_{eff}: 4.1 m

(Fire Island, NY est.; Ortiz & Ashton 2016)



SLR Timescale

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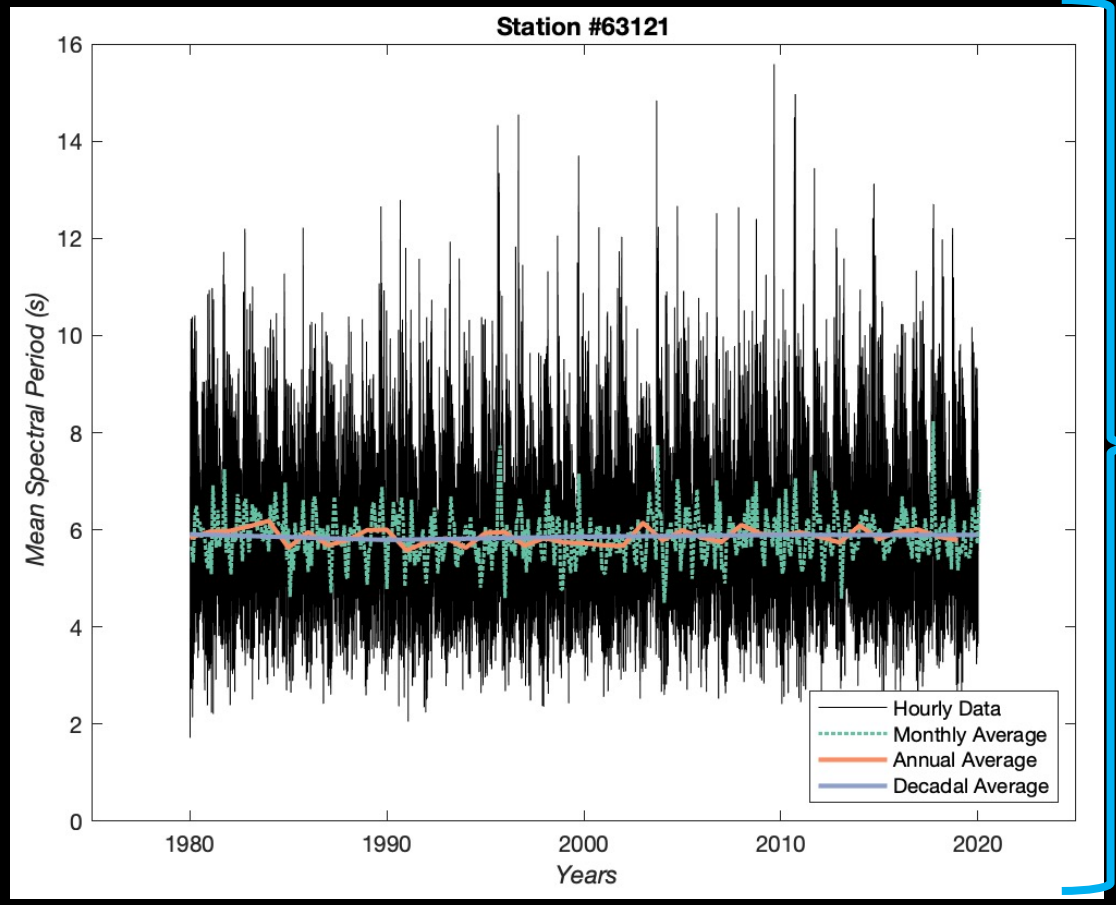


Rockaway Peninsula, NY

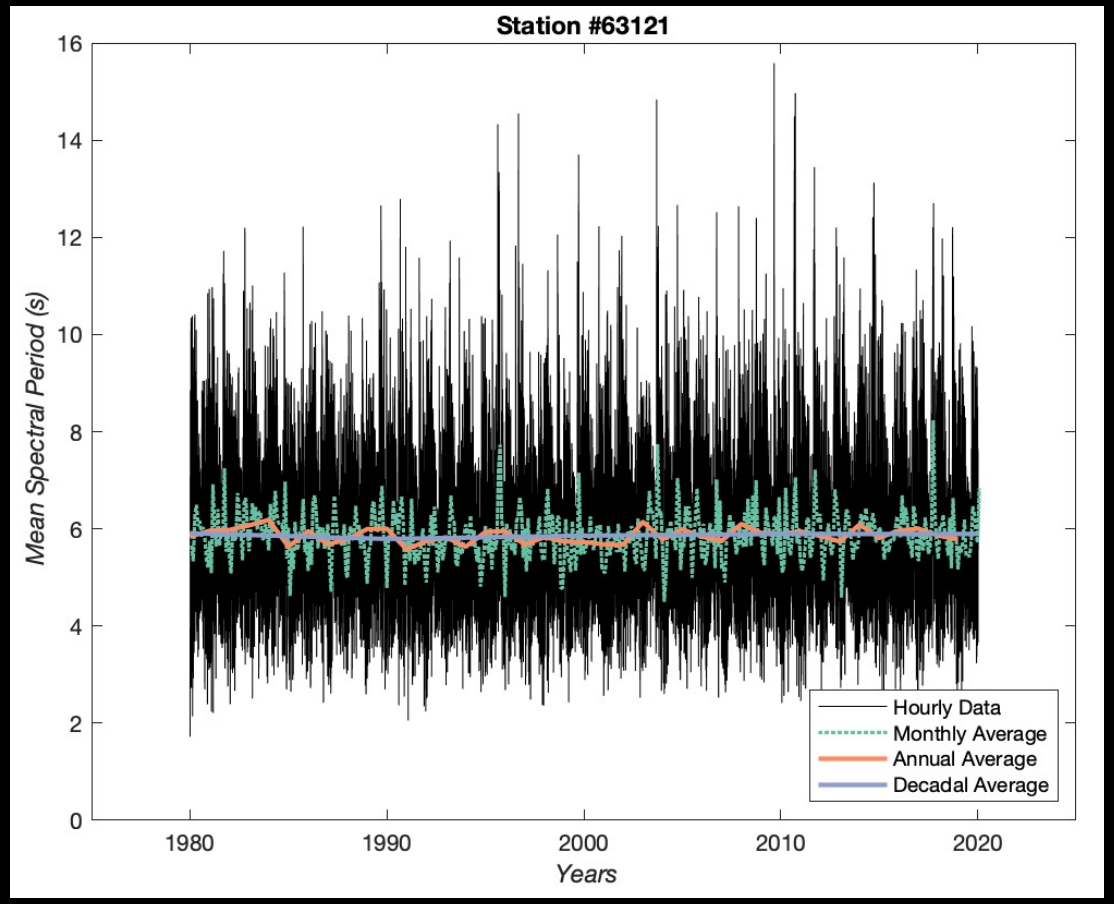
$$Q_s = K\left(\frac{{u_0}^3}{W_s}\right)\left[-5u_1 - 3u_2 + \frac{\beta(x)}{W_s}{u_0}^2\right]$$

Average T_m, H_s

$$\beta_e(z(x)) = \frac{W_{se}}{{u_0}^2}\left[5u_1 + 3u_2\right]$$

WIS Buoy Transport and Profiles

(Ortiz & Ashton 2016; Derived from Bagnold 1963, Bowen 1980, Stive & deVriend 1995)



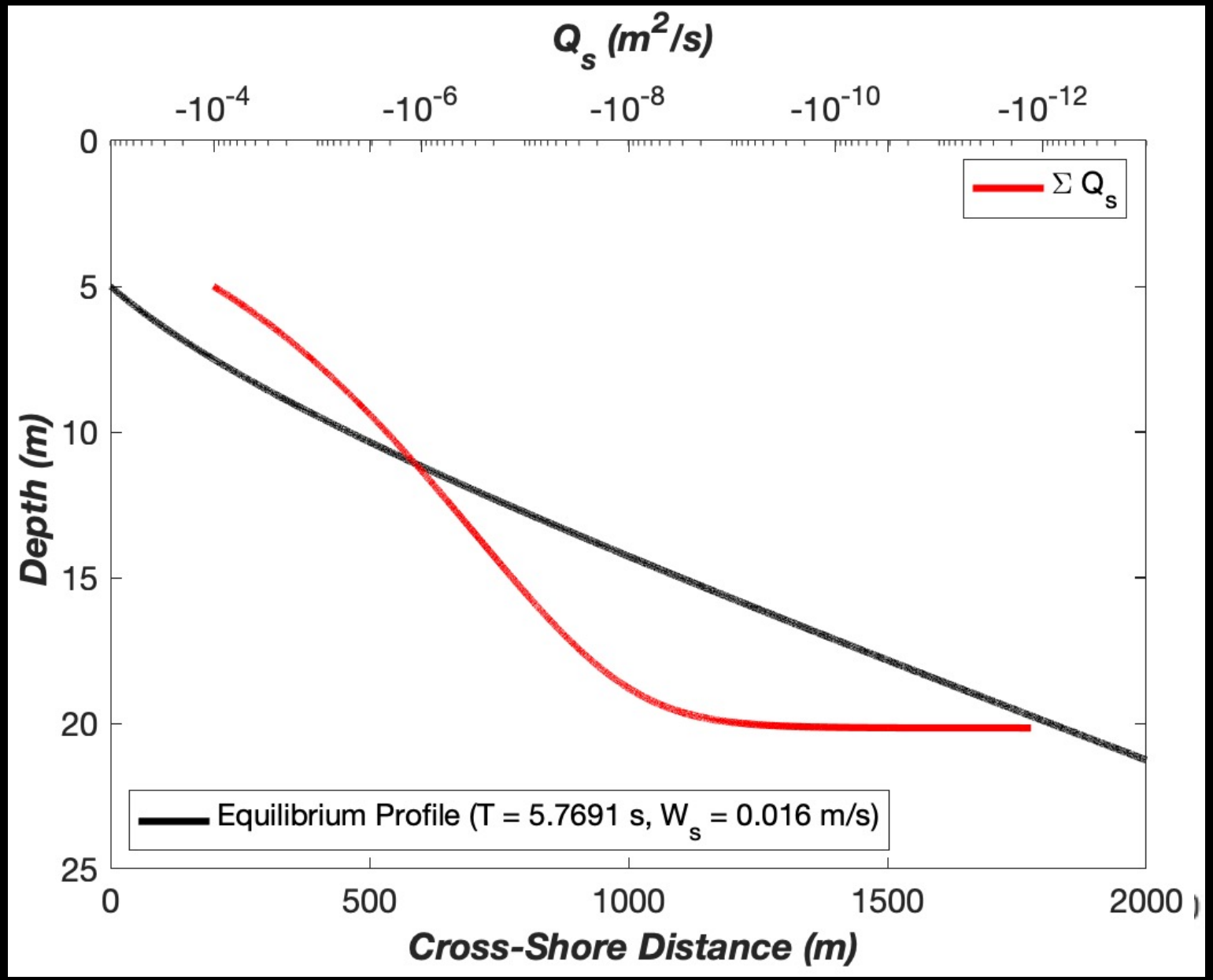
Rockaway Peninsula, NY

$$Q_s = K\left(\frac{{u_0}^3}{W_s}\right)\left[-5u_1 - 3u_2 + \frac{\beta(x)}{W_s}{u_0}^2\right]$$

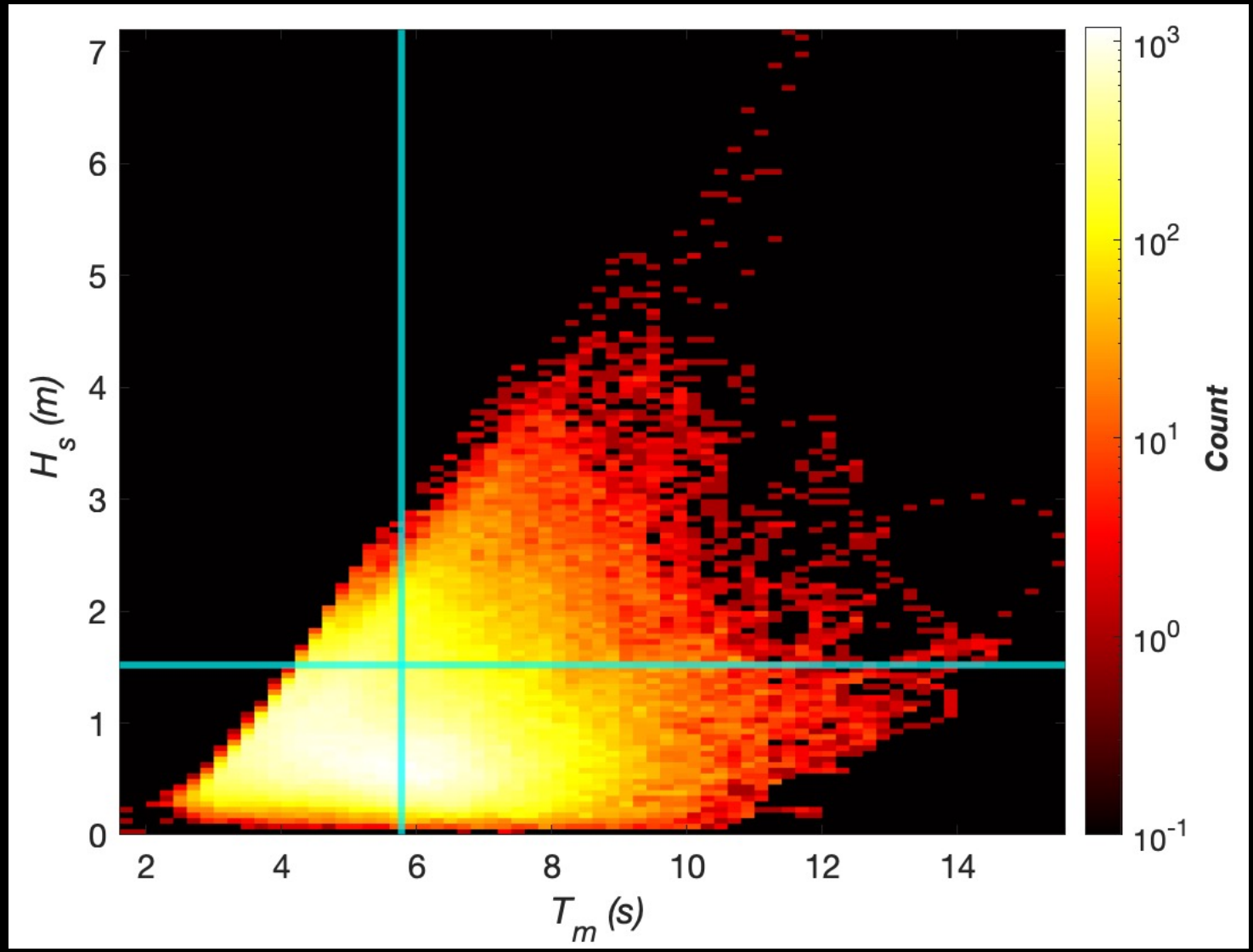
$$Q_{s_i}(T_{m_i}, H_{s_i}) \text{ @ time } i$$

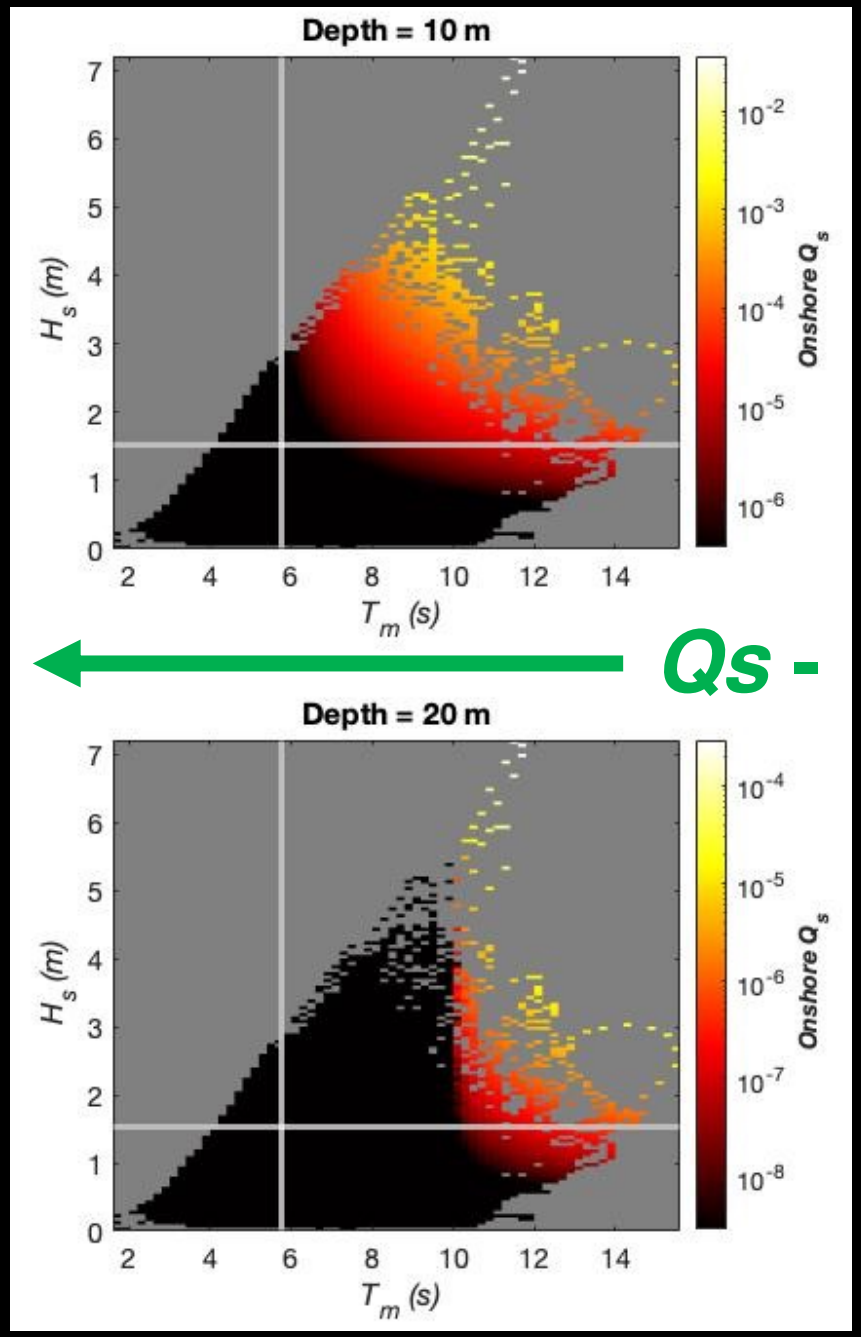
$$Q_{s_e} = \frac{\sum_{i=1}^{n} Q_s * \Delta t}{D}$$

WIS Buoy Transport and Profiles

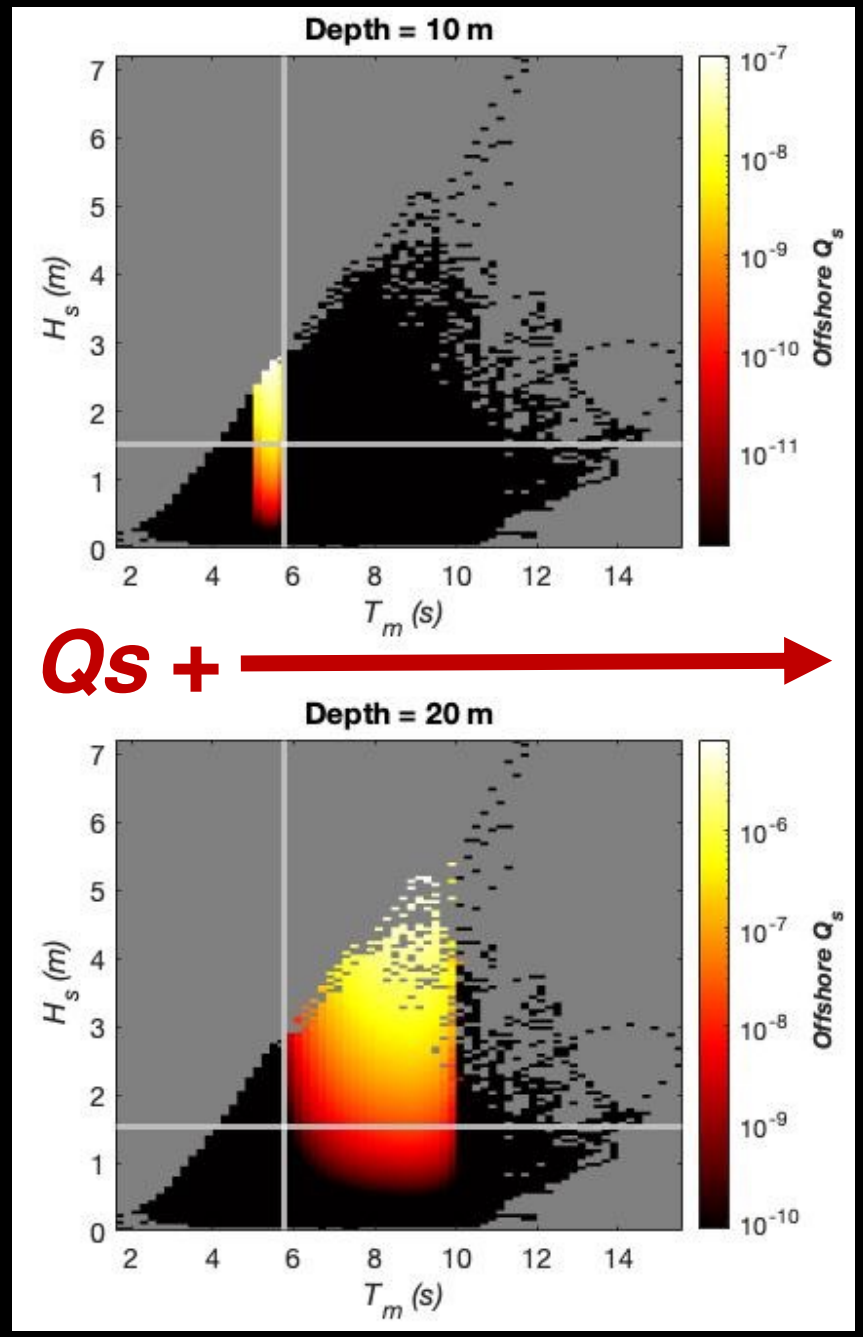


$\sum Q_s$ Transport over Avg. Profile

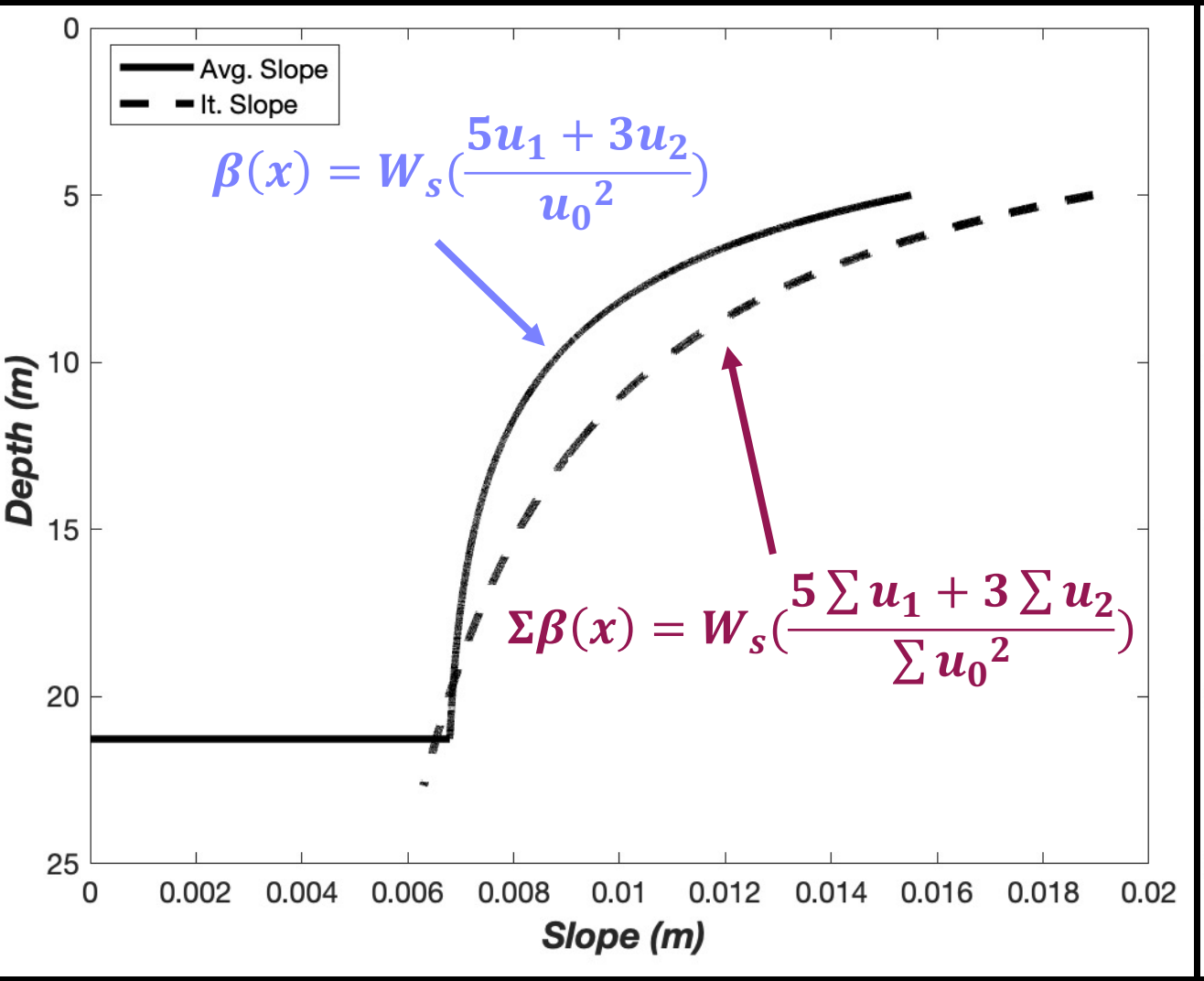

7
6
5
4
3
2
1
0
H_s (m)
2
4
6
8
10
12
14
T_m (s)
10^3
10^2
10^1
10^0
10^{-1}
Count

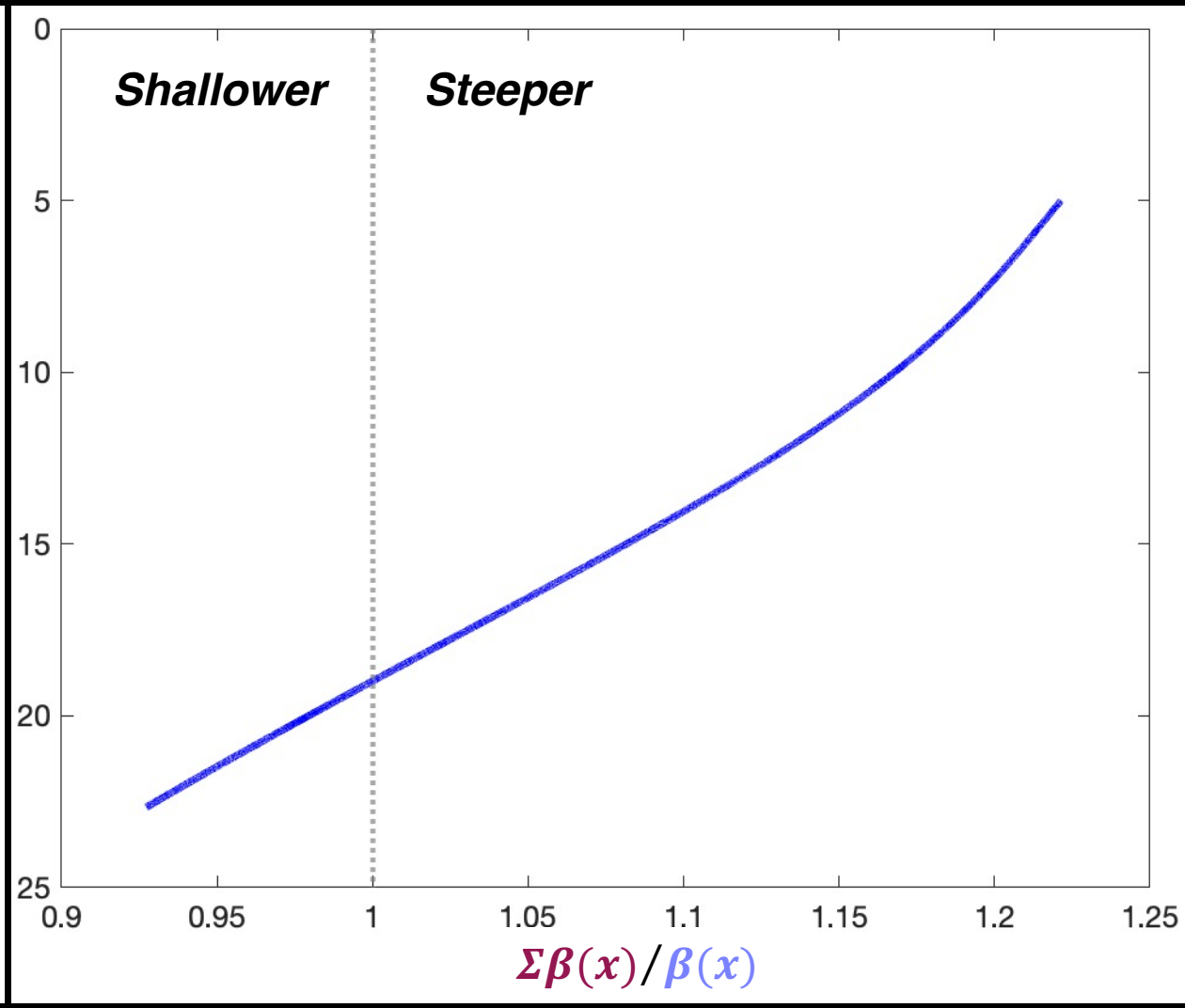

Depth = 10 m
H_s (m)
T_m (s)
Onshore Q_s
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
Depth = 20 m
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}

Qs -


Depth = 10 m
H_s (m)
T_m (s)
Offshore Q_s
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
Depth = 20 m
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}

Qs +


Avg. Slope
It. Slope
$\beta(x) = W_s(\frac{5u_1 + 3u_2}{u_0{}^2})$
$\Sigma\beta(x) = W_s(\frac{5\sum u_1 + 3\sum u_2}{\sum u_0{}^2})$
Depth (m)
Slope (m)
0
5
10
15
20
25
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0.018
0.02


Shallower
Steeper
$\Sigma\beta(x)/\beta(x)$
0
5
10
15
20
25
0.9
0.95
1
1.05
1.1
1.15
1.2
1.25

Summary

- Shoreface sediment transport is sensitive to variations in wave climate and geology
- Energetics approach can model shoreface change in response to SLR
- Different averaging techniques yield different profiles for WIS time series data

Massachusetts Institute of Technology

WOODS HOLE OCEANOGRAPHIC INSTITUTION

USGS science for a changing world

USCRP US COASTAL RESEARCH PROGRAM

Thank you!

mgillen@mit.edu

This research was conducted on ancestral Wampanoag and Massachusett lands. AGU is being held on ancestral Chitimacha land. The indigenous peoples from these tribes have and continue to suffer countless losses, exploitation, forced removal from imperialist and native erasure efforts by white settlers. All co-authors acknowledge the horrific violence these communities have endured and will continue to experience. Land where work has been conducted and information is being disseminated has been, is, and will ALWAYS be ancestral indigenous land.