Sediment Transport and Morphological Response to Nearshore Nourishment Projects

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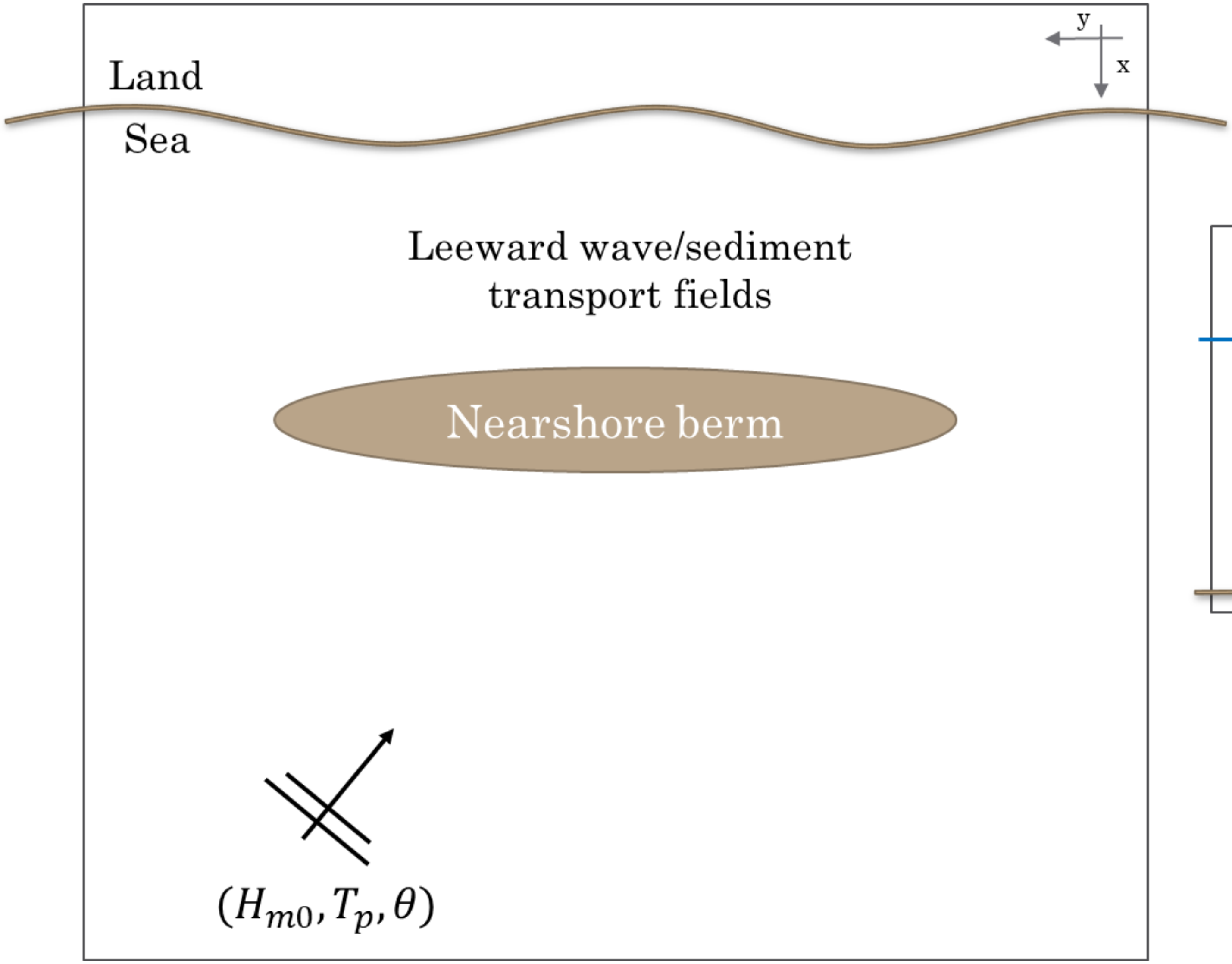
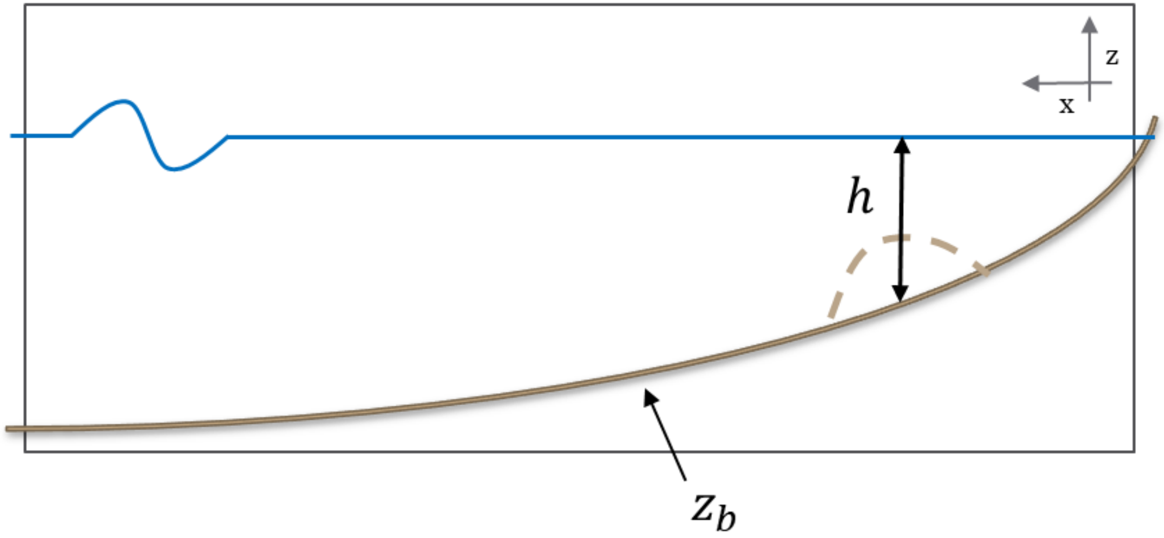
Introduction

- Placement shape and depth of nearshore nourishments (NN) affect nearshore/shoreline processes in poorly understood ways.
- Direct observations and generalizations about NN related processes are difficult to make.
- Employ the Coastal Modeling System as a research-grade model to investigate idealized NN scenarios.
- Quantify wave attenuation/sediment transport within realistically parameterized environments to provide justifiable conclusions about NN shape/depth effects.

Johnson, Cody L., Brian McFall, Douglas Krafft, and Mitchell Brown (2021). "Sediment Transport and Morphological Response to Nearshore Nourishment Projects on Wave-Dominated Coasts." Journal of Marine Science and Engineering 9(11), 1182. https://doi.org/10.3390/jmse9111182

Conceptual Framework





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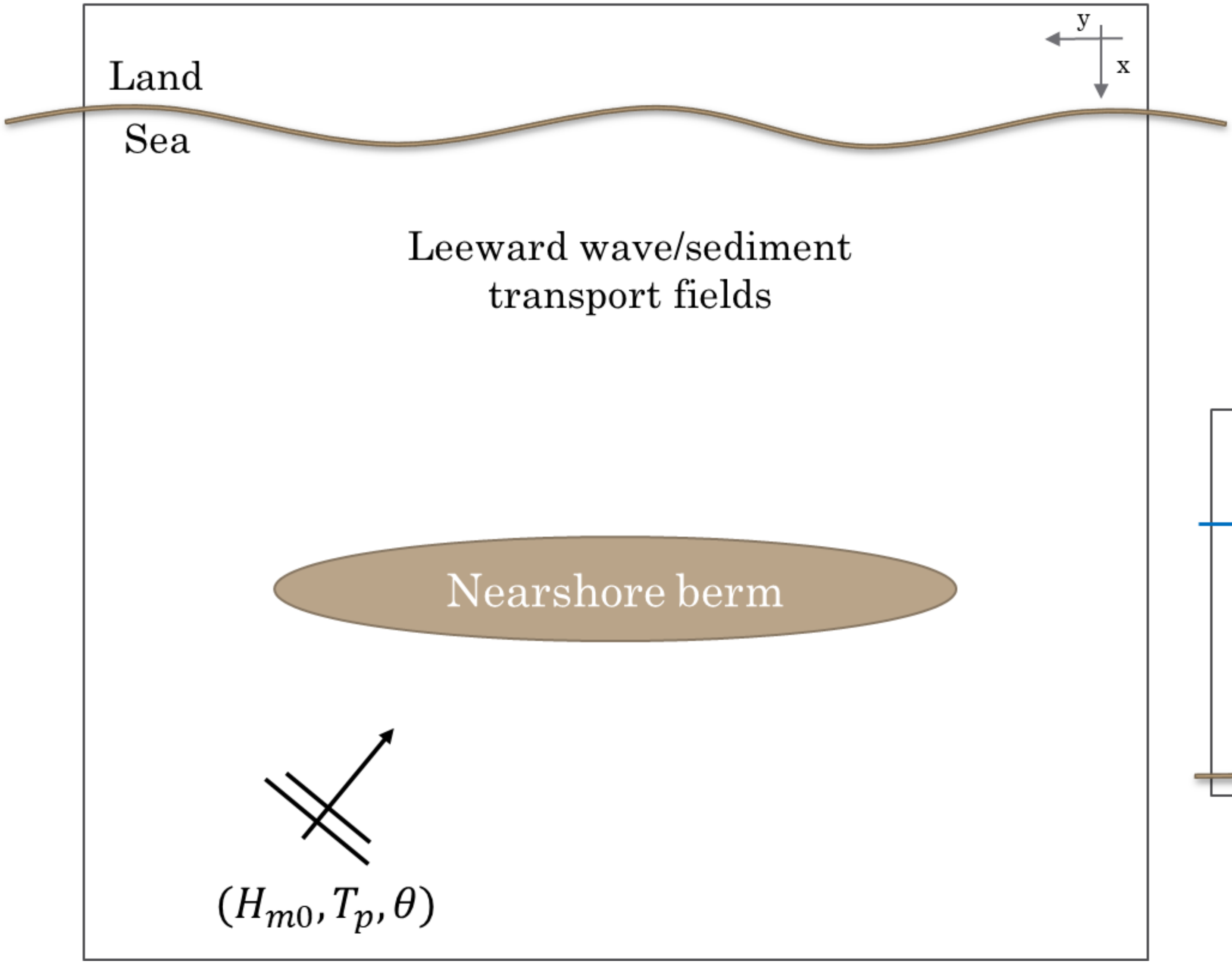

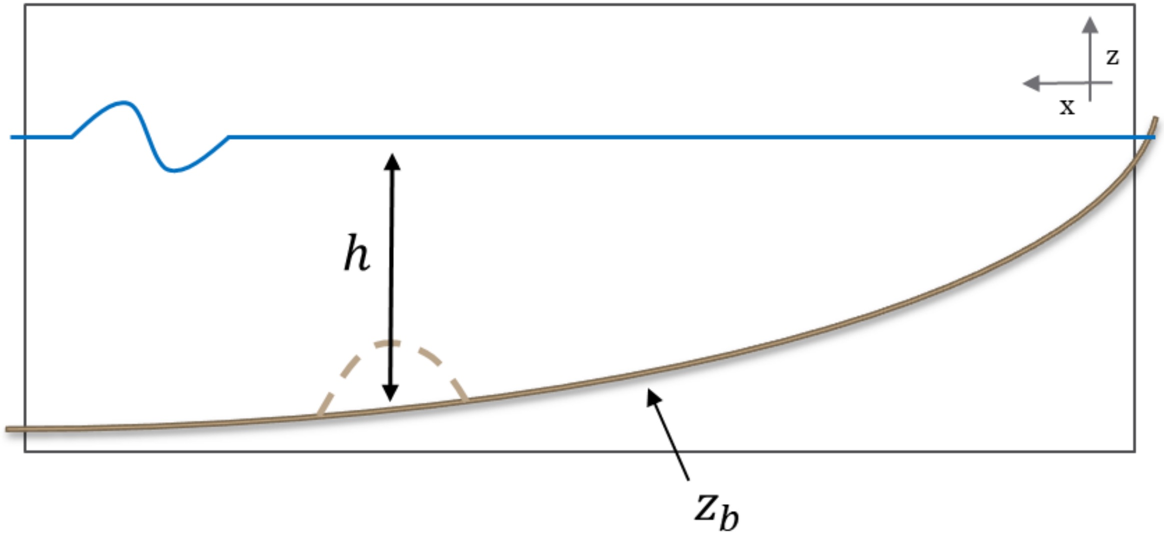

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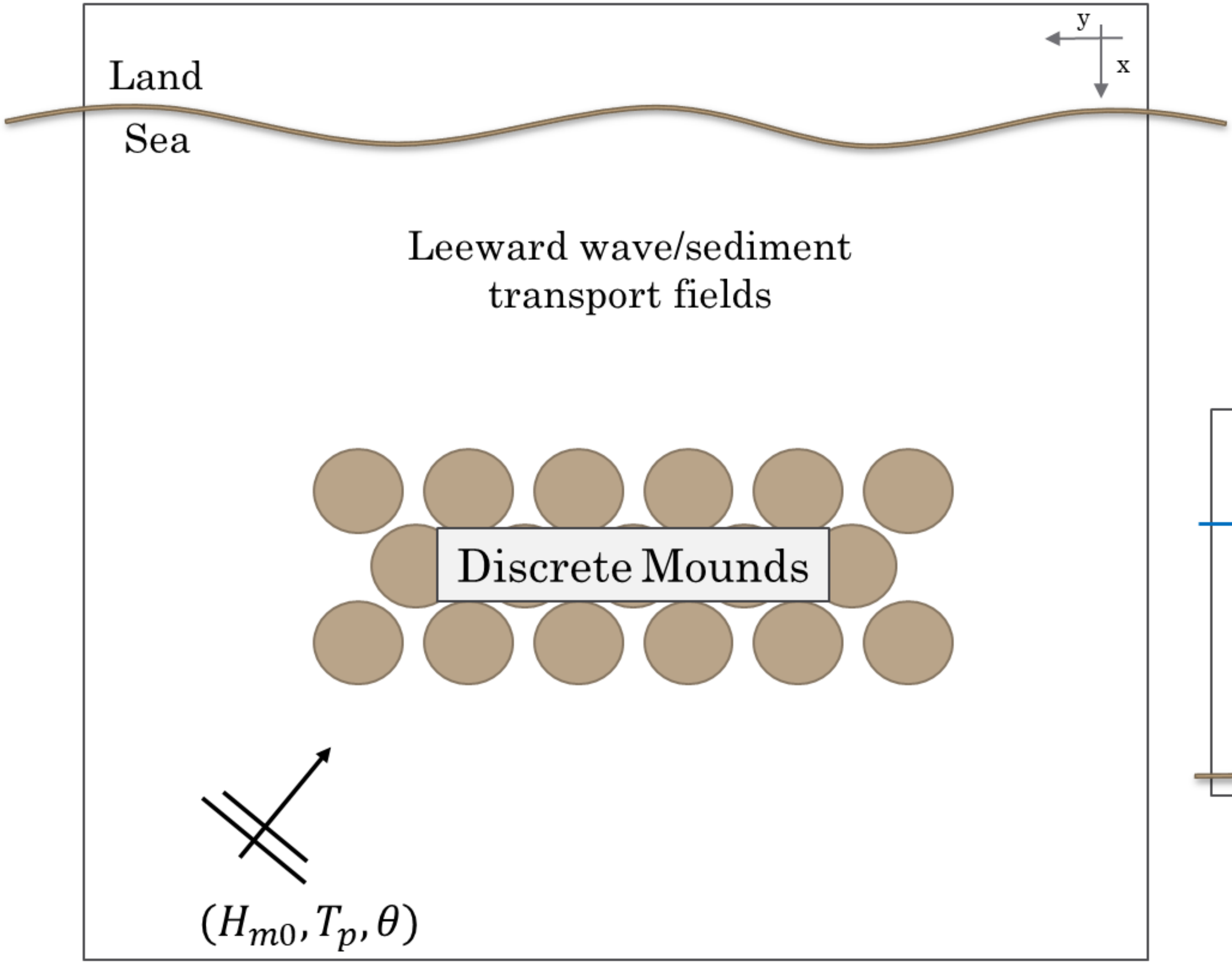
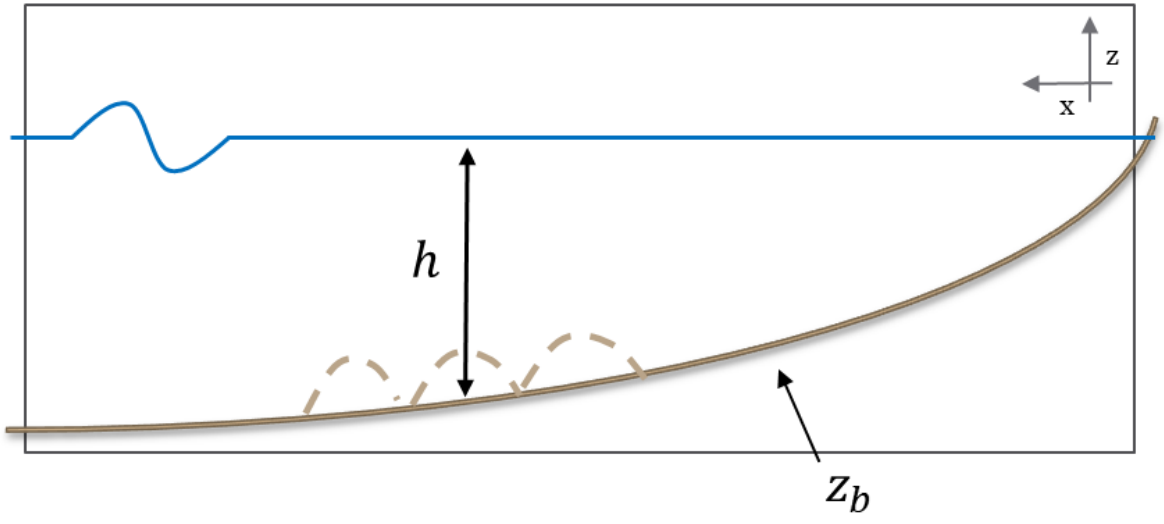


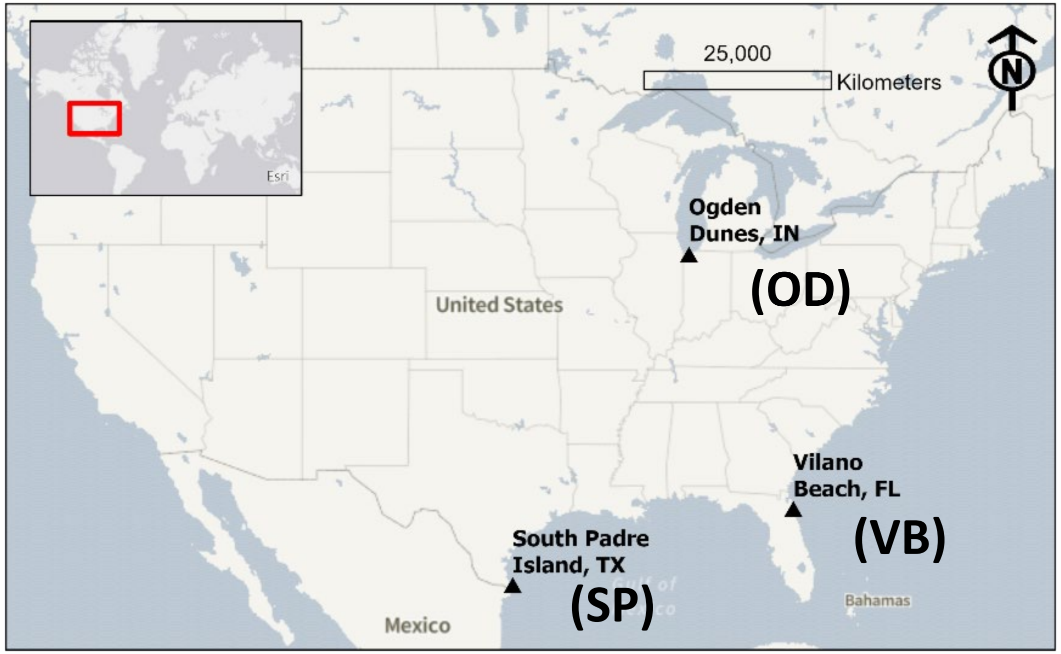


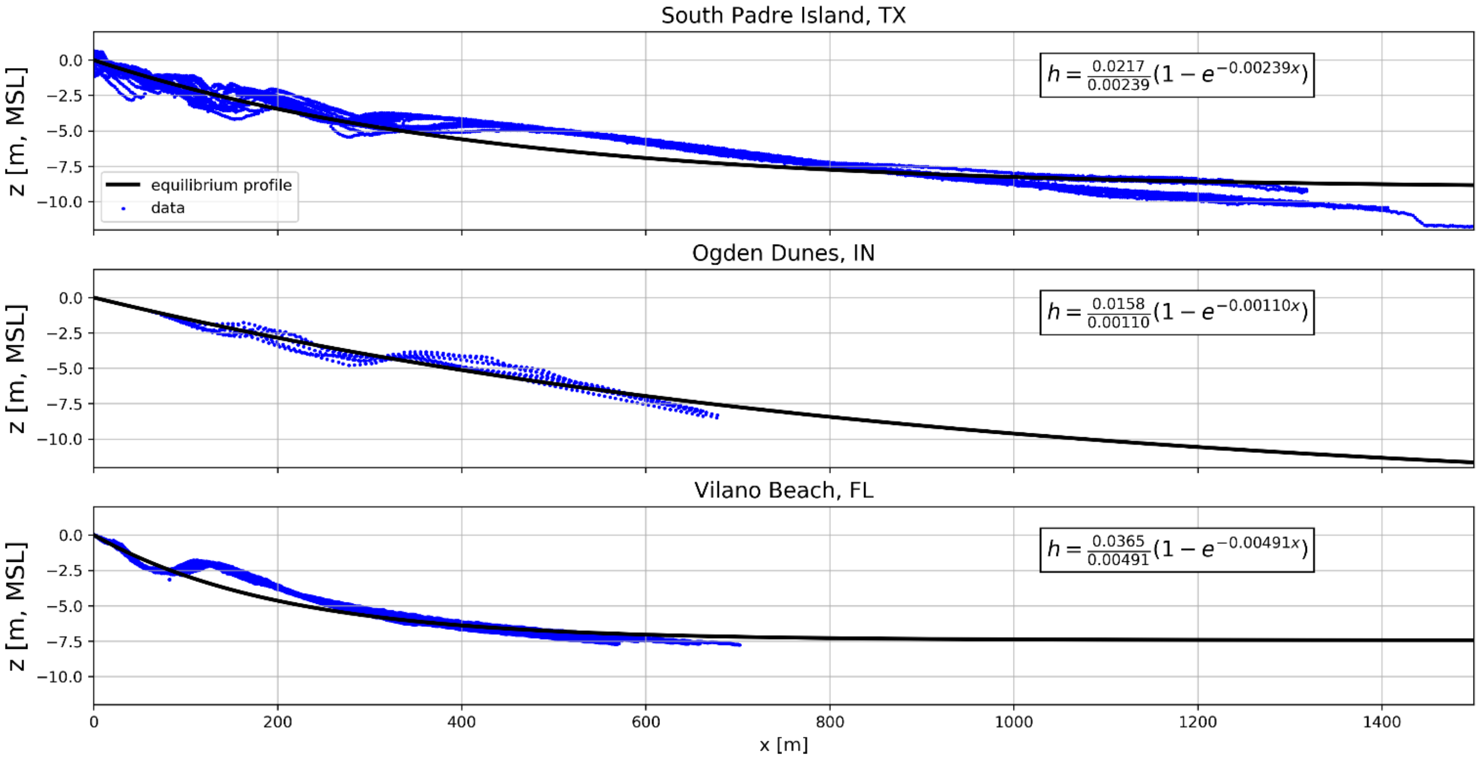
Idealized Scenarios

$$z_b = -h = -\frac{S_0}{k}(1 - e^{-kx})$$

$S_0 = shoreline\ slope$

$k = profile\ decay\ coeffiecent$

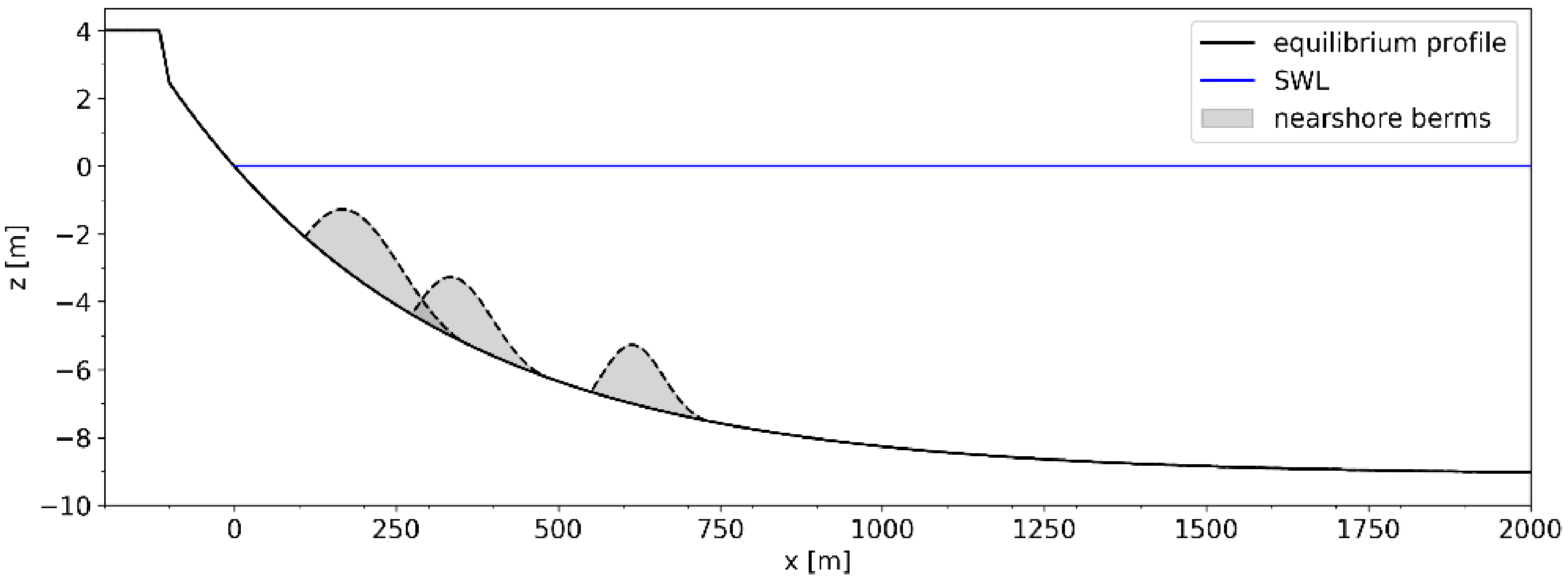


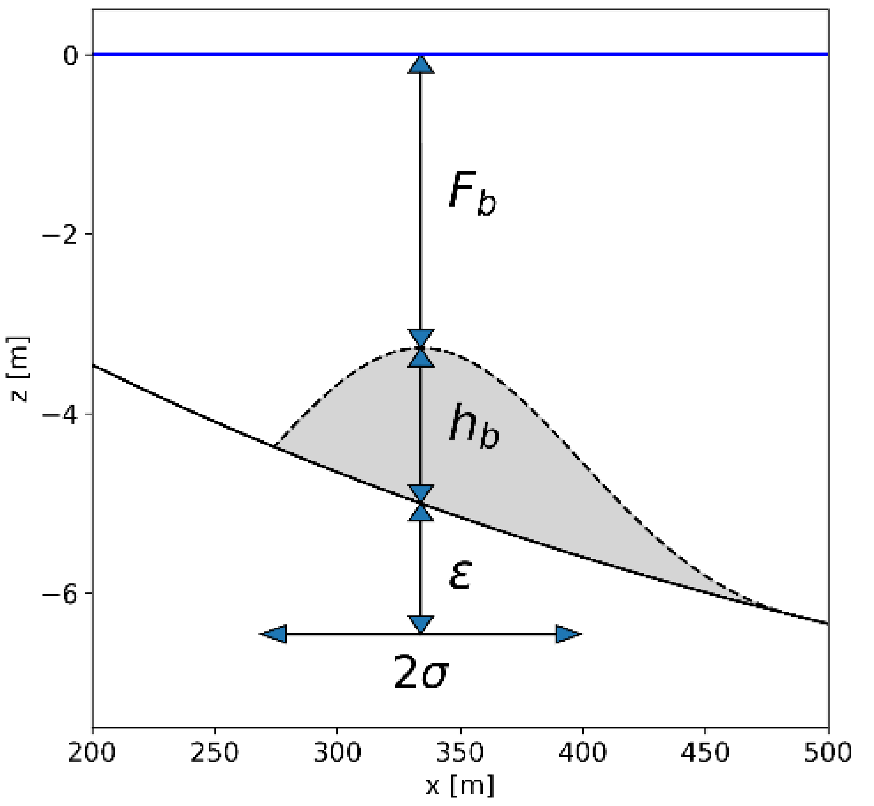


McFall, B. C. (2019). The Relationship between Breach Grain Size and Intertidal Beach Face Slope. *Journal of Coastal Research*, 35(5), 1080-1086.

Komar, P. D. and McDougal, W. G. (1994) The analysis of exponential Beach Profile. *Journal of Coastal Research*, 10(1), 59-69.

Idealized Scenarios





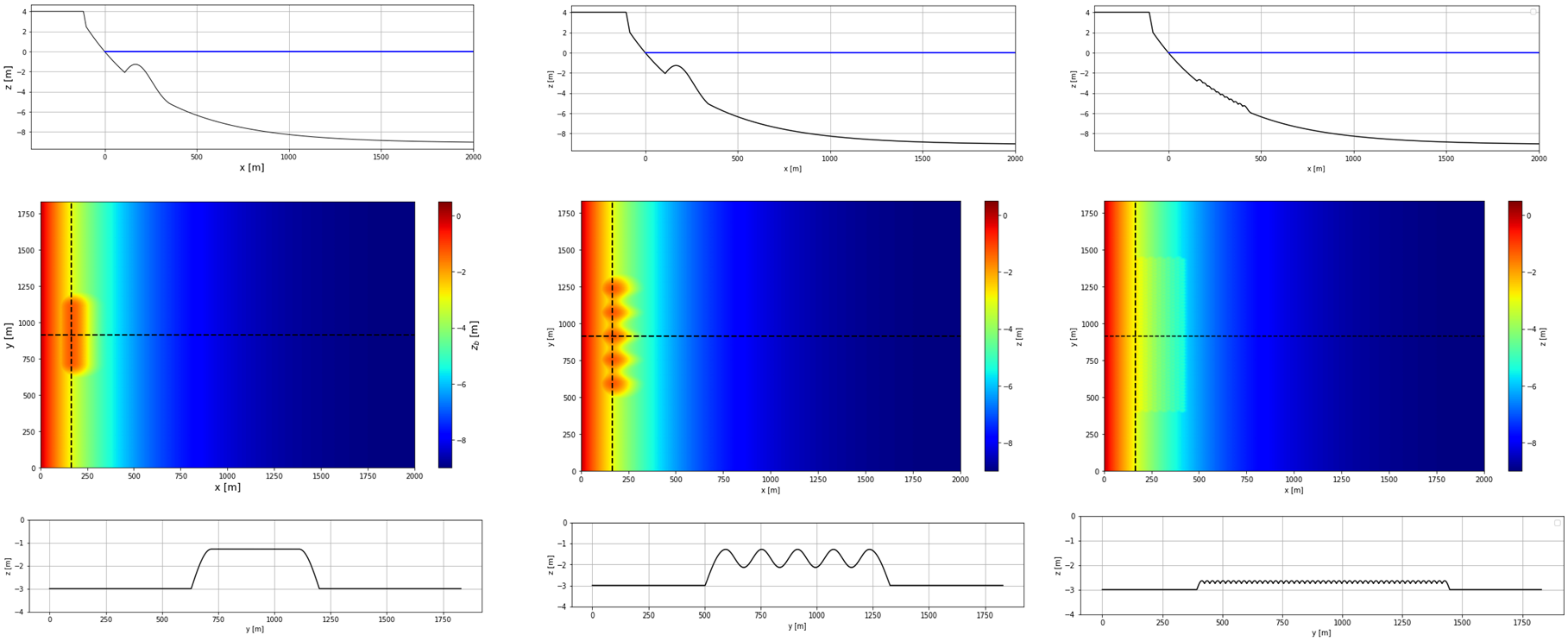
- 3 NN shapes (linear, undulated, and discrete)
- 3 placement depths (3m, 5m, and 7m)
- 1 control case
- 10 runs x 3 regions = 30 simulations

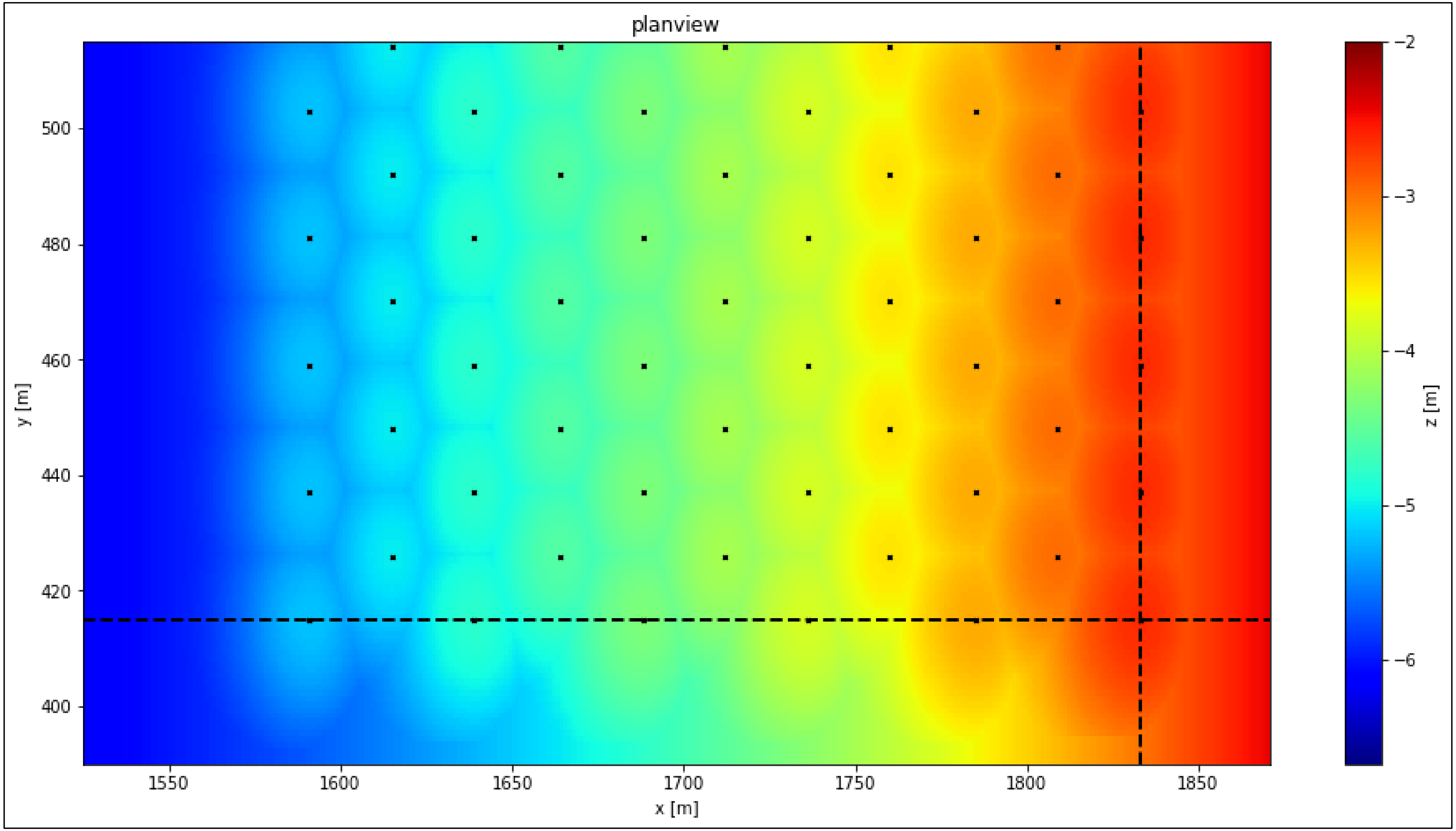
$$b(x) = \alpha \exp\left[\frac{-(x - x_b)^2}{2\sigma^2}\right]$$

α, σ Mean of observed NN at Fort Myers Beach, FL

Brutsché, K.; Pollock, C. E. Strategic Placement of Mixed Sediment in the Form of a Nearshore Berm along Fort Myers Beach, Florida. US Army Corps of Engineers Engineer Research and Development Center: Vicksburg, MS, USA, 2017, TN-EWN-17-1, 3p.

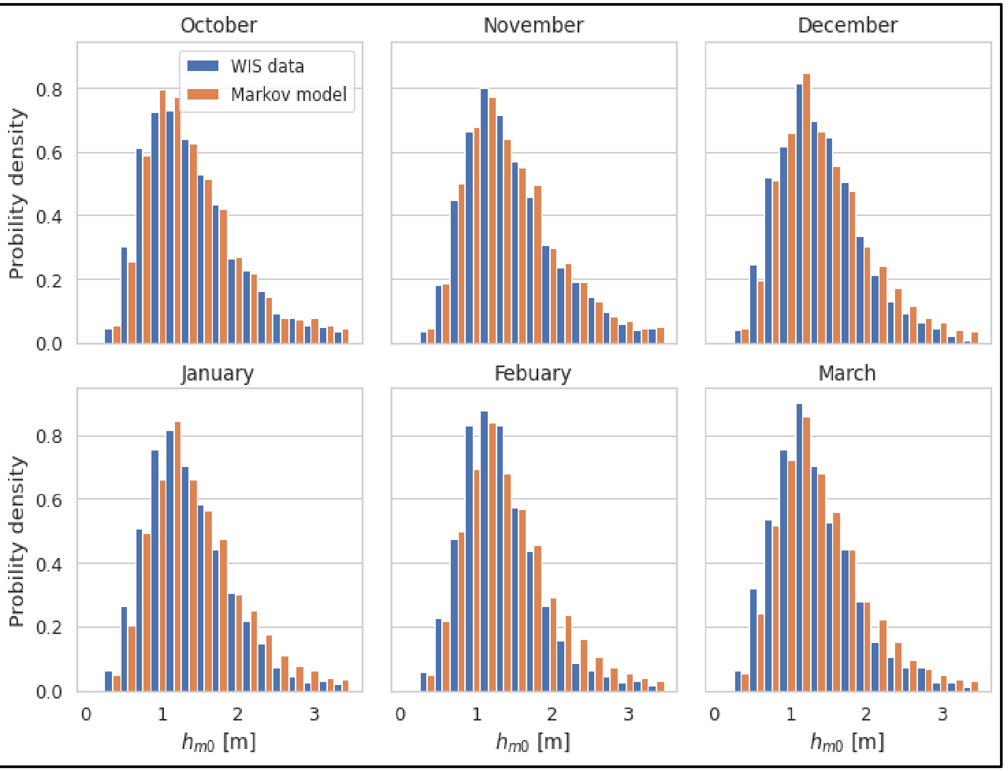
Linear Berm (LB) | Undulated Berm (UB) | Discrete Mounds (DM)



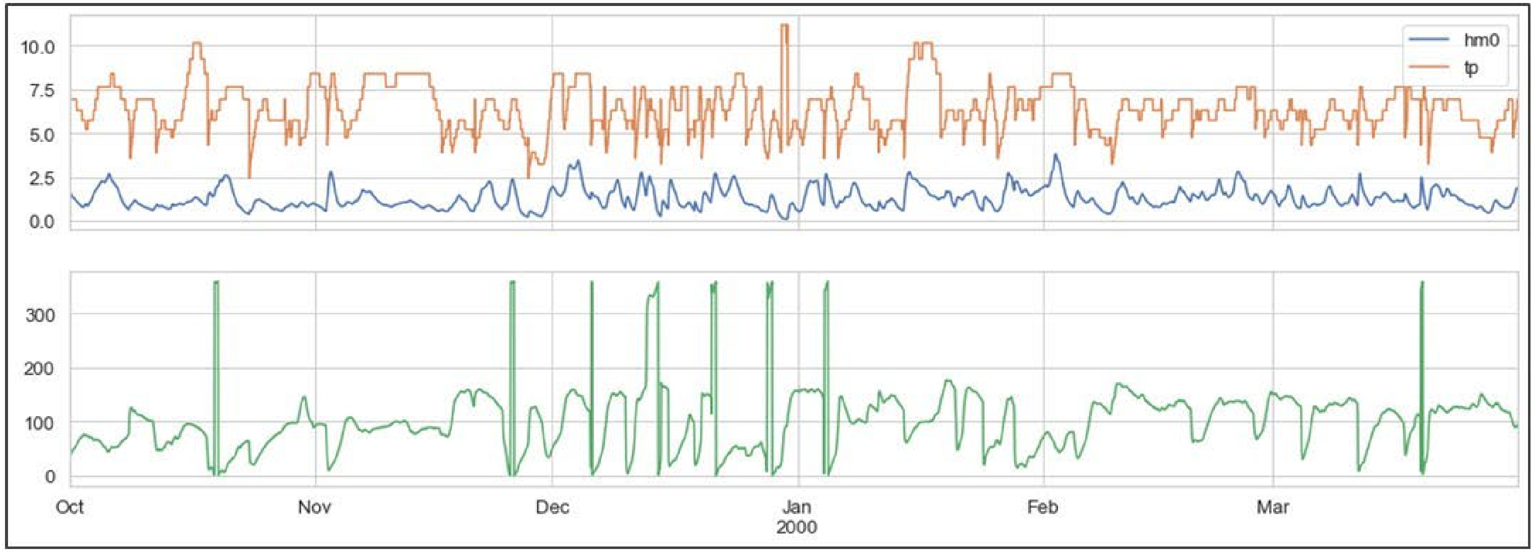


planview
y [m]
500
480
460
440
420
400
1550
1600
1650
1700
1750
1800
1850
x [m]
z [m]
−2
−3
−4
−5
−6

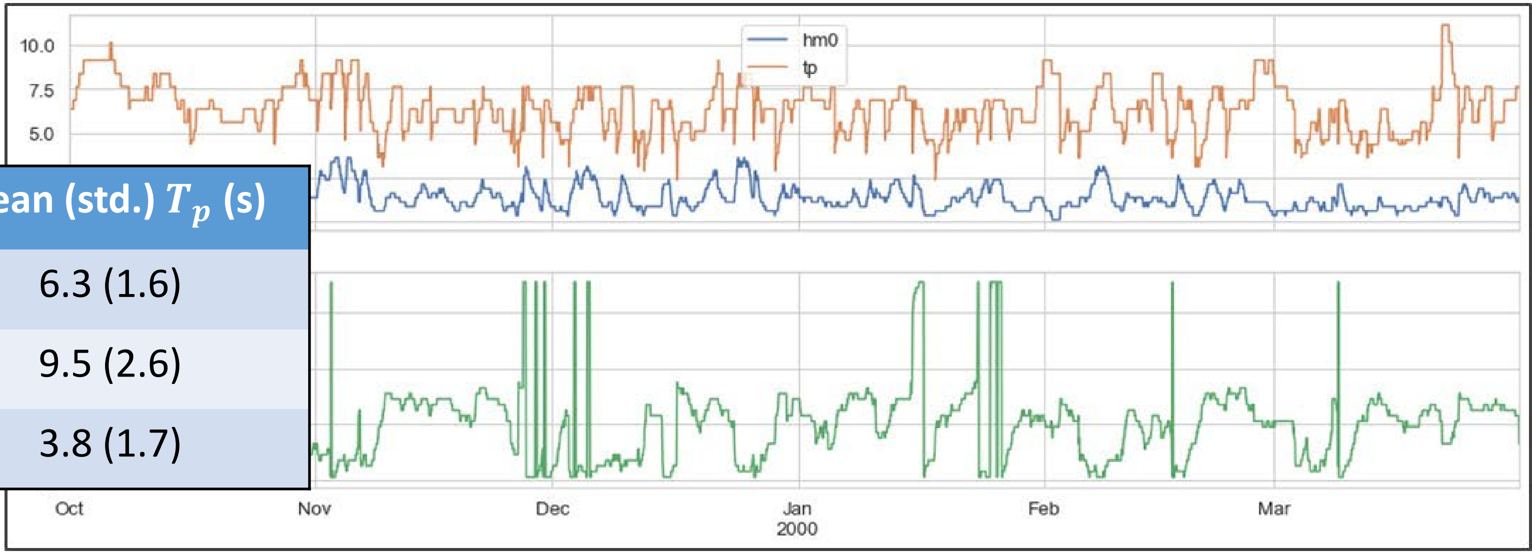
Markov Chain model



WIS data

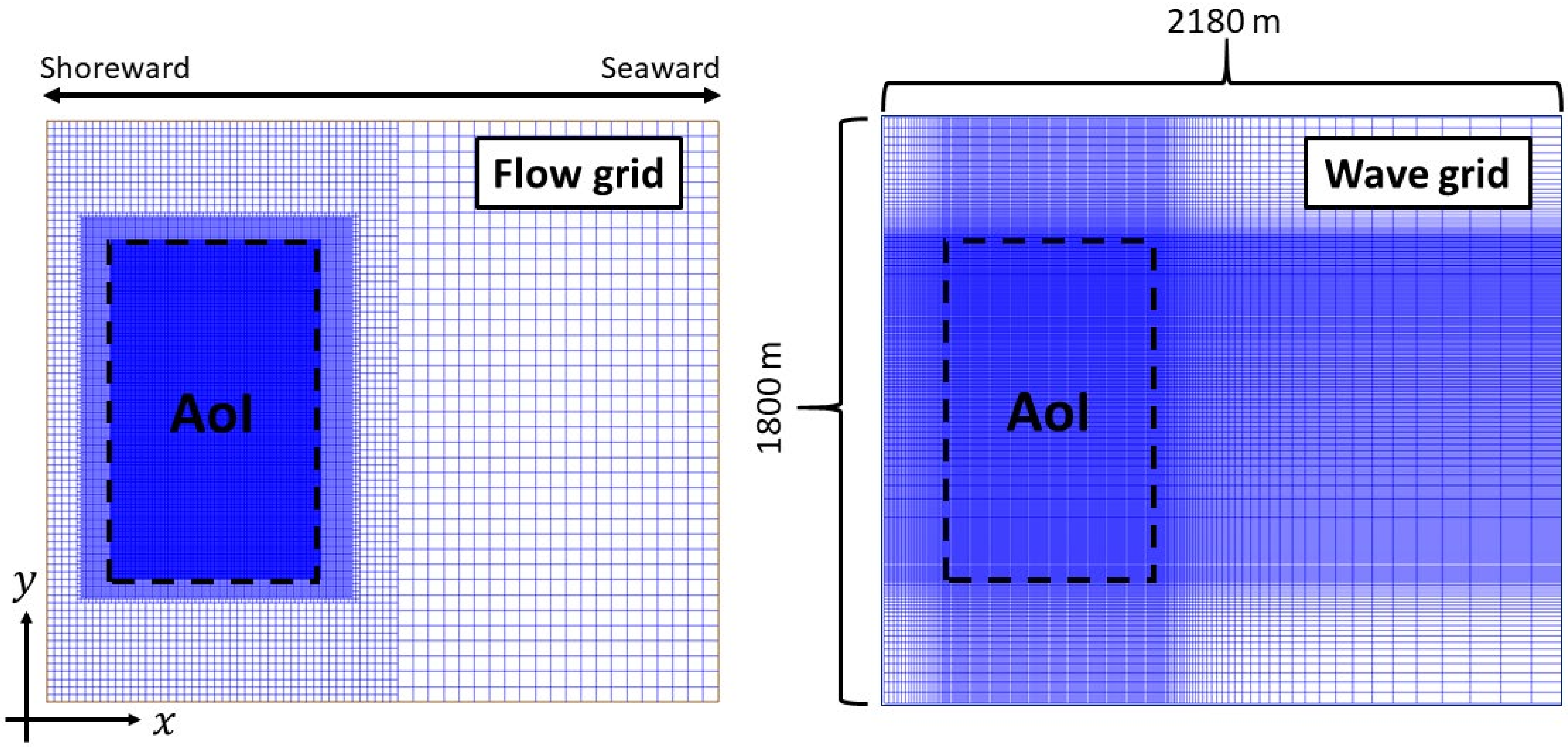


Synthetic time series



Region	max. H_{m0} (m)	mean (std.) H_{m0} (m)	mean (std.) T_p (s)
SP	4.16	1.11 (0.48)	6.3 (1.6)
VB	4.17	1.45 (0.63)	9.5 (2.6)
OD	3.22	0.47 (0.44)	3.8 (1.7)

Coastal Modeling System (CMS)



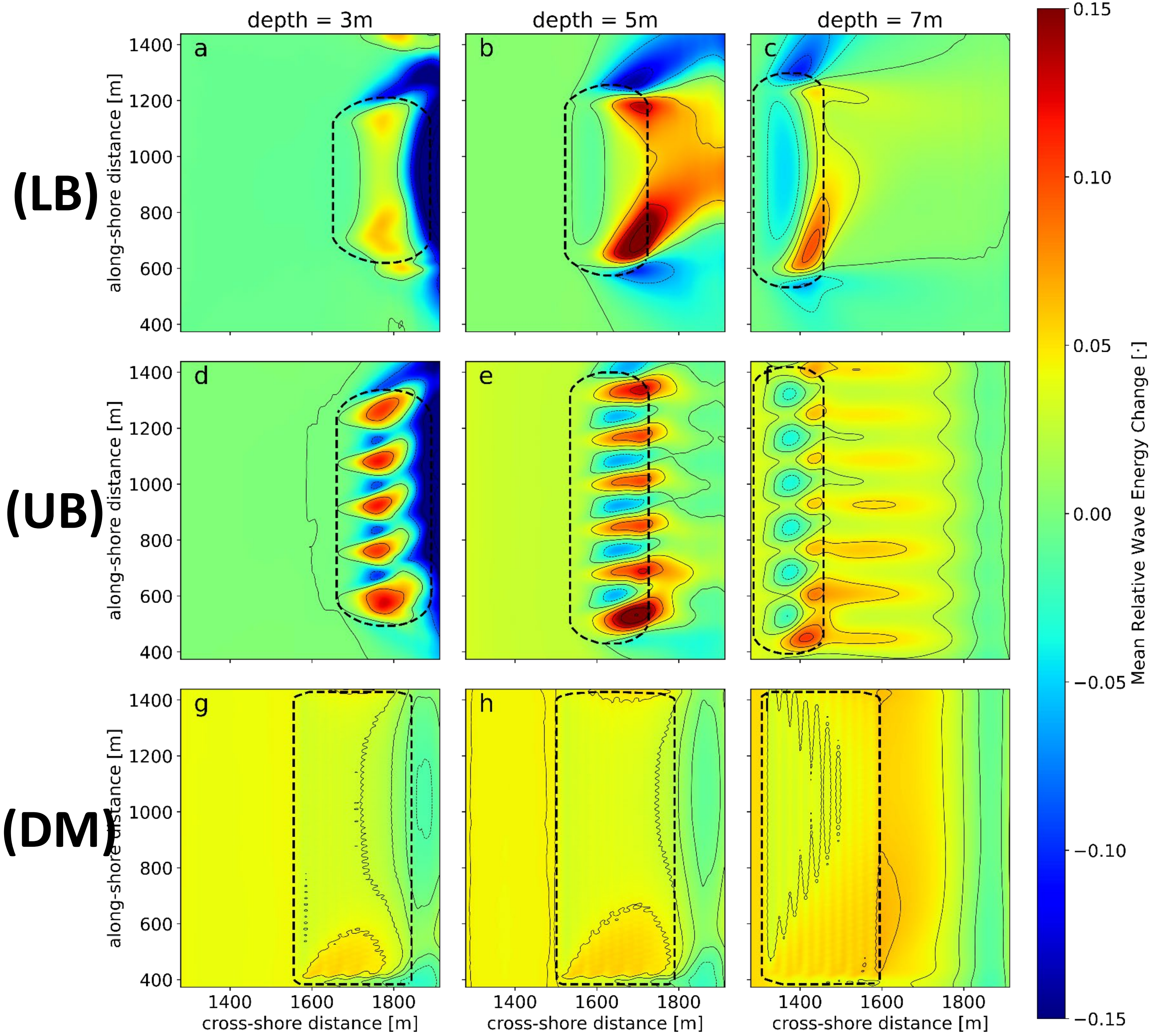
SP Scenario Results

Mean relative wave energy

$$E = \frac{1}{8}\rho g H_{m0}^2$$

$$\bar{E} = \frac{1}{N}\sum_i^N \frac{E_i}{E_i^*}$$

$E^* =$ Wave energy without berm



SP Scenario Results

Relative wave power attenuation

$$P = Ec_g = \left[\frac{1}{8}\rho g H_{m0}^2\right]\left[n\frac{L}{T_p}\right]$$

$$\bar{P} = \frac{1}{\Gamma}\int_o^{\Gamma} P dy$$

$$\bar{\alpha} = \frac{\bar{P}}{\overline{P^*}}$$

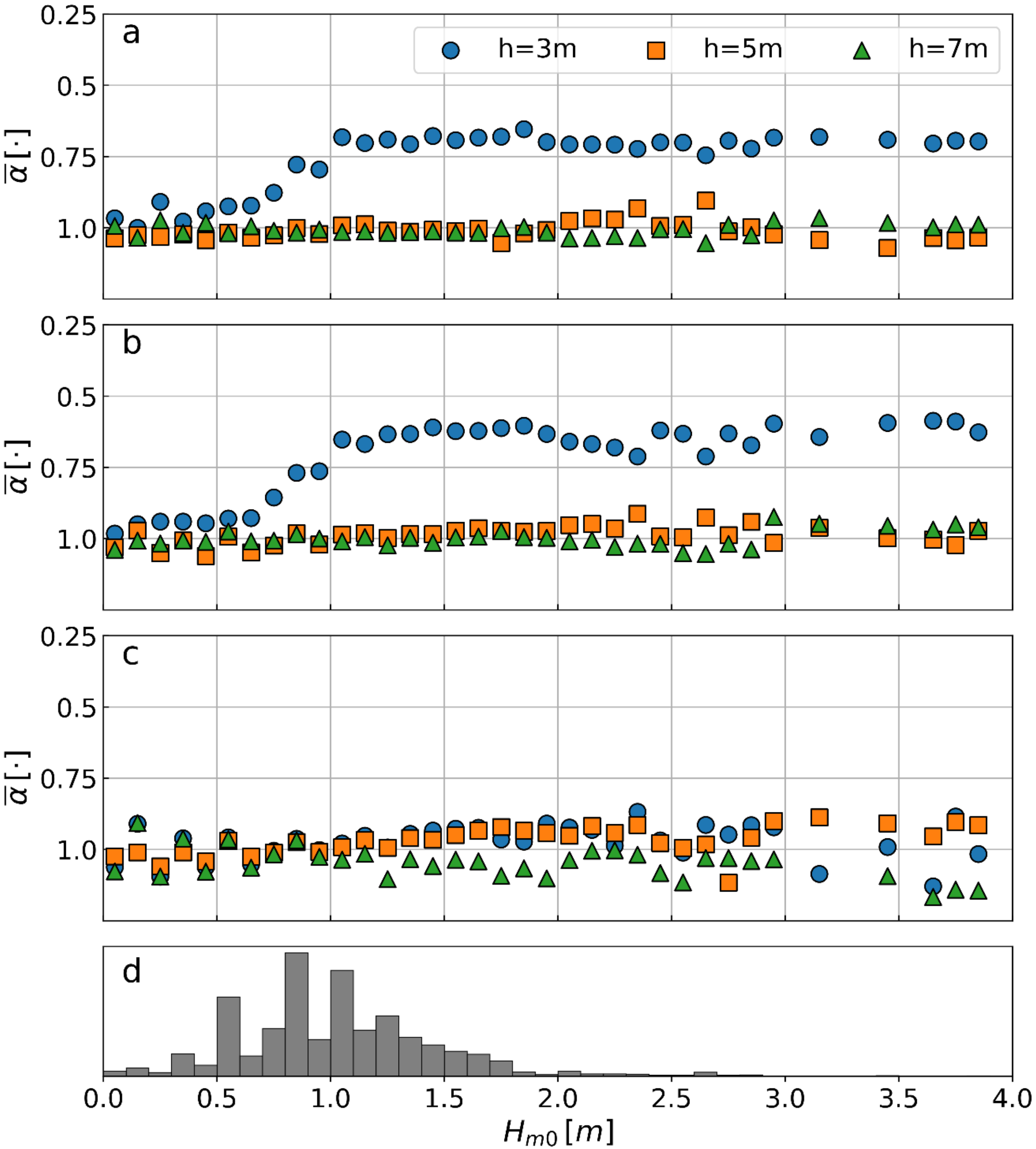
$\Gamma = AoI\ control\ surface$

$\overline{P^*} = mean\ wave\ power\ wo\ berm$

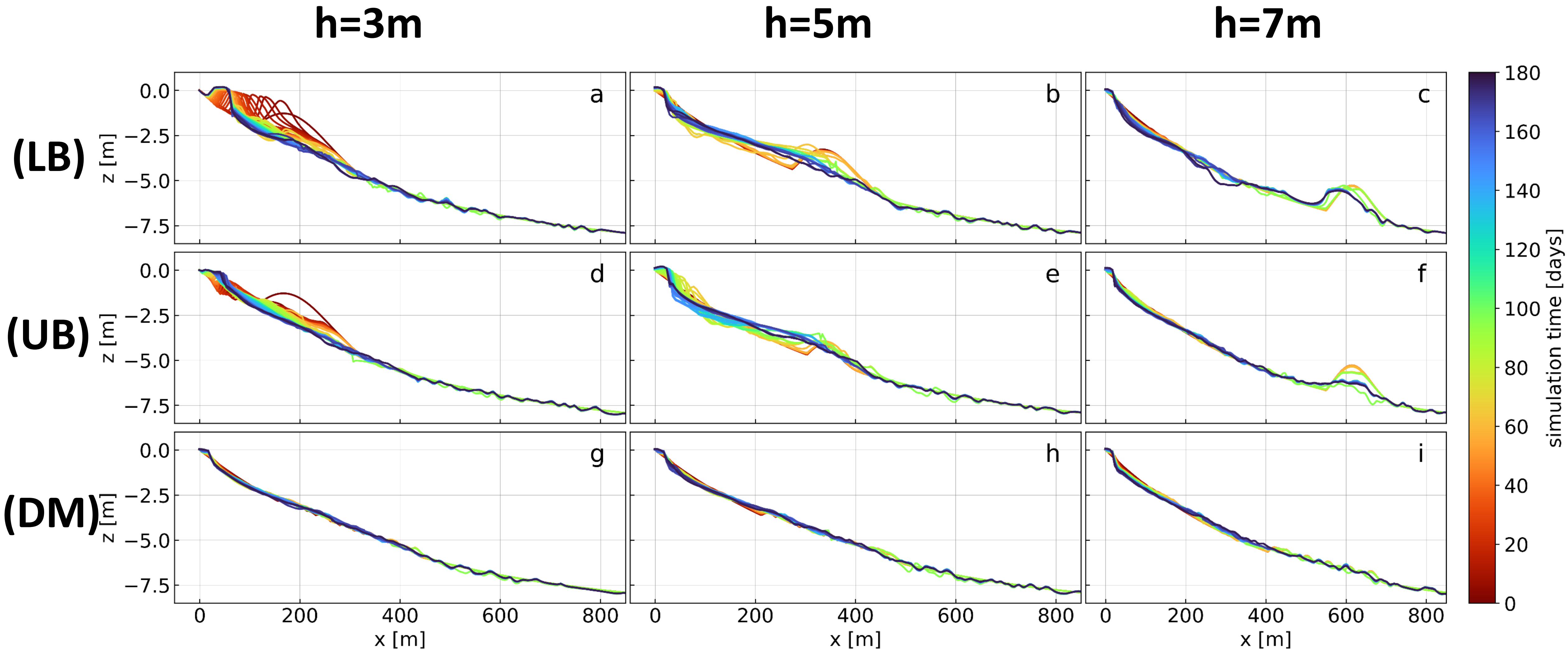
(LB)

(UB)

(DM)



SP Scenario Results



SP Scenario Results

Excess sediment volume

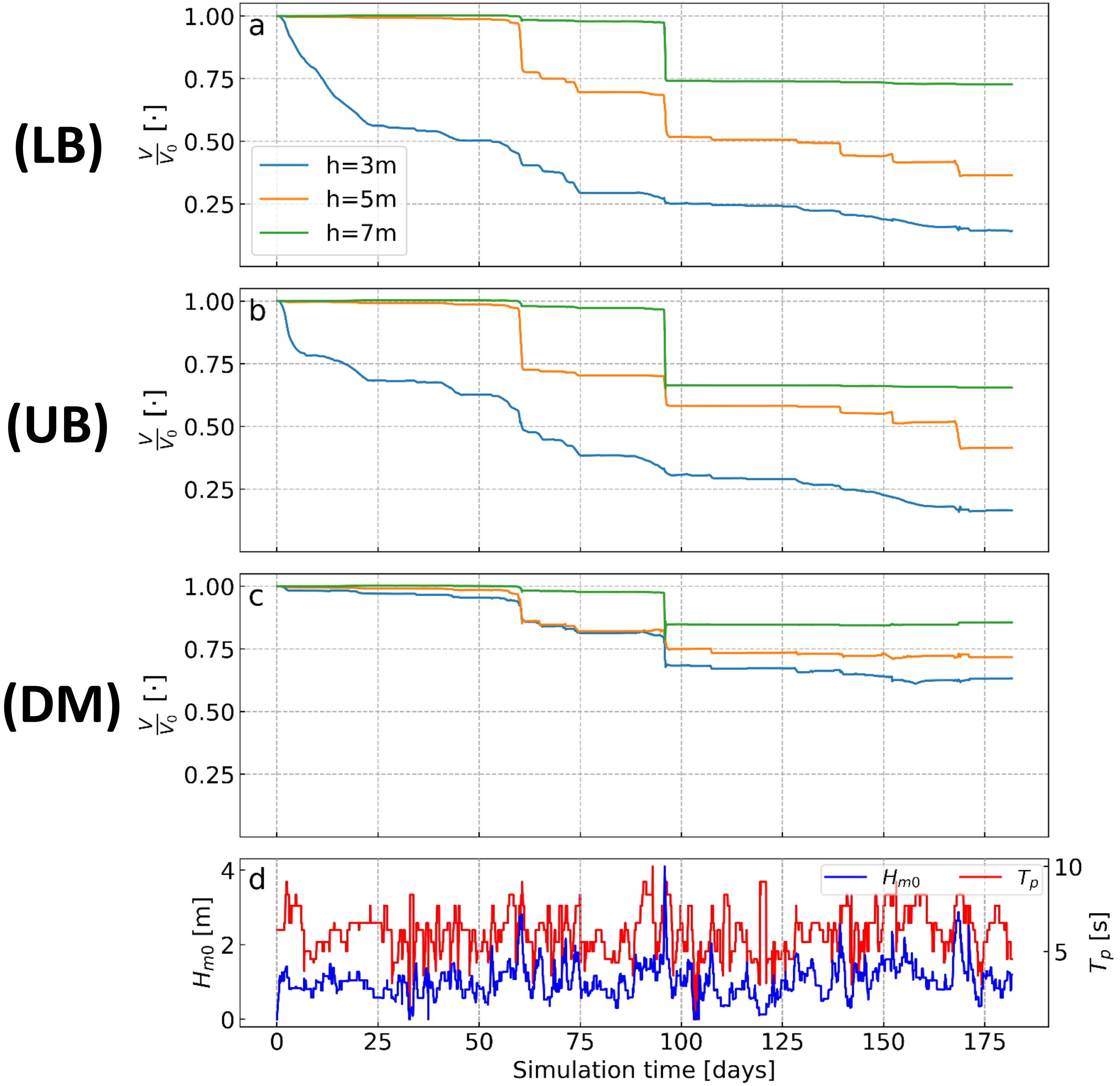
$$V(t) = \int_A [z_b(t) - z_b^*(t)] dA$$

$A = AoI\ area$

$z_b = bed\ level$

$z_b^* = bed\ level\ wo\ berm$

$V_0 = initial\ volume$



SP Scenario Results

NN centroid displacement

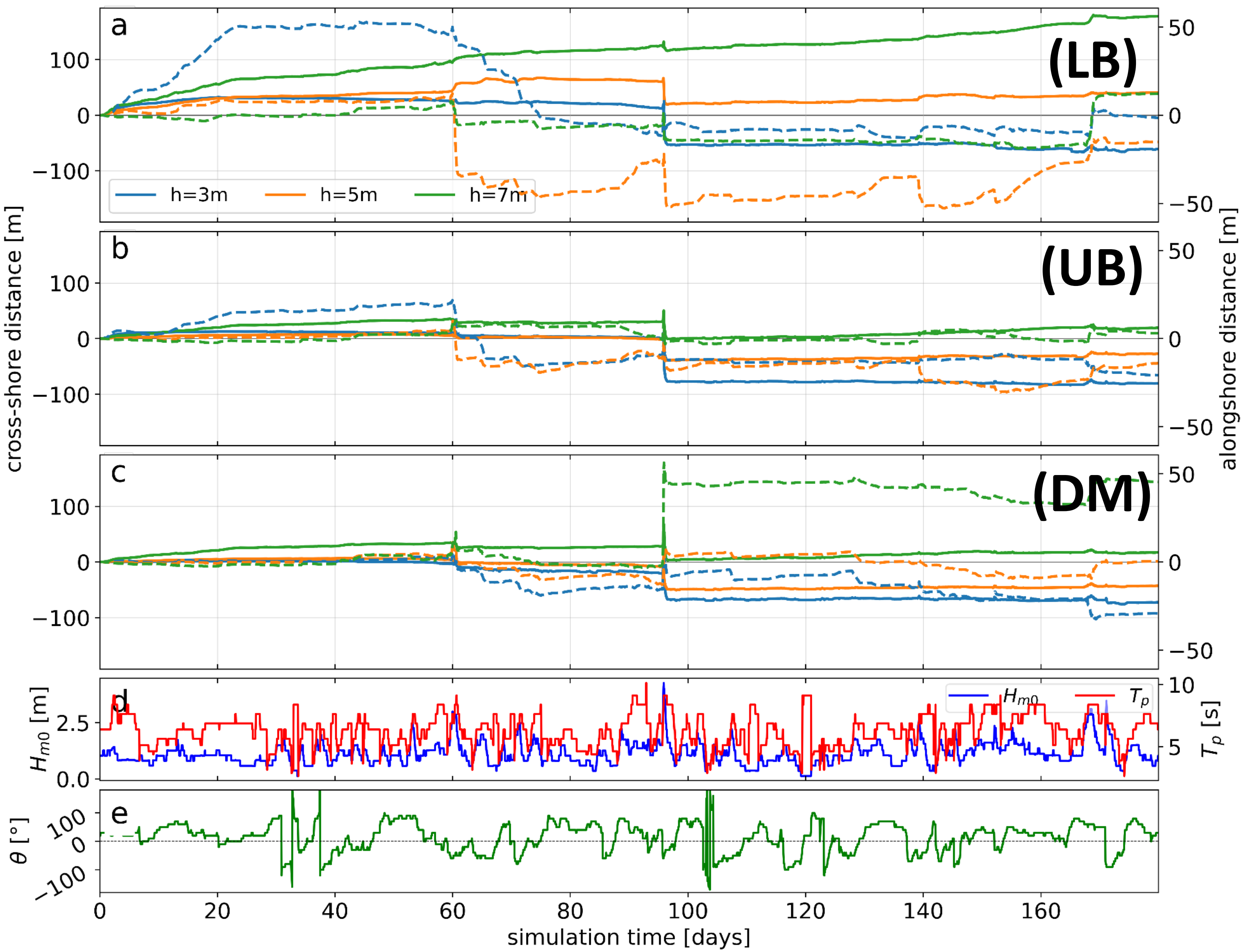
$$(\bar{x}, \bar{y}) = \left(\frac{M_y}{M}, \frac{M_x}{M}\right)$$

$$M_x = \int yM\, dA$$

$$M_y = \int xM dA$$

$$M(x, y; t) = z_b(x, y; t) - z_b^*(x, y; 0)$$

$M = volume$ above profile wo NN



Conclusions

- Shallower placements attenuate more energy than deeper placements for the linear and undulated berms.
- The linear and undulated berms dissipate more energy than the discrete mounds.
- The undulated berm dissipates more energy than the linear berm, presumably due to greater alongshore length and longer lifespans.
- Placement depth discriminates between continuous and episodic deflation. Shallower placements are subject to continuous sediment transport, while the deeper placements respond primarily to high-energy events.
- The trajectories of the modeled nourishments' centers of mass evidences onshore-directed transport of nourishment sediment which is punctuated by offshore-directed sediment transport due to high-energy events.