Towards Inclusion of Swash Processes in CMS

CIRP Tech Discussion
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A Swash Closure in CMS

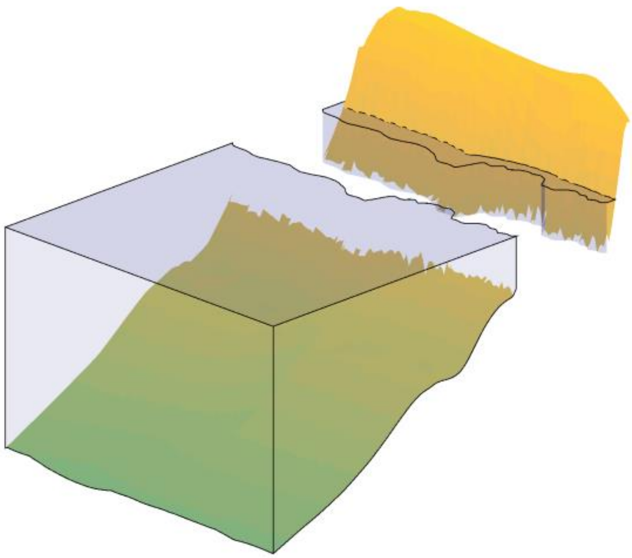
- New subroutines and not a module, so not portable.
- FY20 objective was to introduce a swash closure into CMS numerically, with only a cursory treatment of the physics
- Code outline
- New simple physics closure – the model is wrong, they are all wrong
- Numerical recipe for finding swash zone characteristics
- Comparison with limited data
- The model is dependent on high-quality data for comparison and justification of empirical devices. Brittany has 6.1 project

Swash is essential in development of reliable and general model:

•Dune erosion is a swash process

•Evidence the 2DH swash is necessary for beach accretion

•Transport has a local peak in the swash



Scope of CMS SWASH:

•Instantaneous

•Wave and currents are combined

•Demarcation is a minimum depth

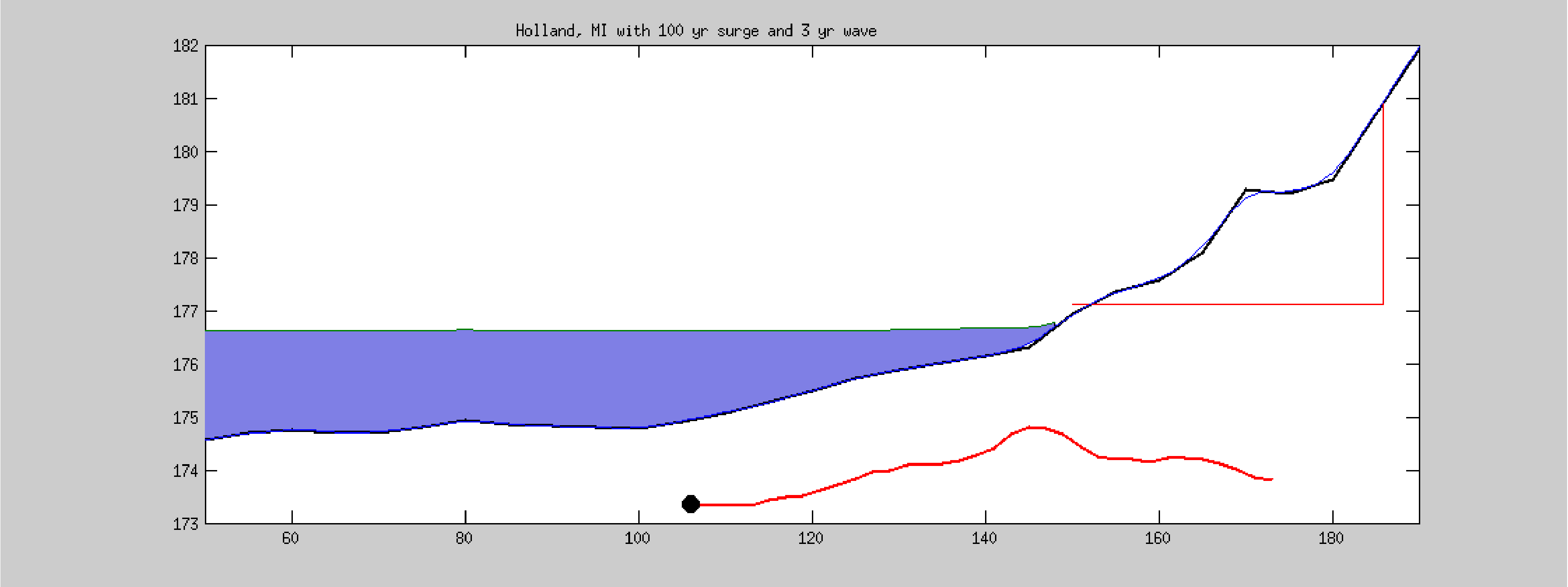
•Hydrodynamics are one-way coupled(appropriate for simulations with low current at interface)

•Transport is two-way coupled

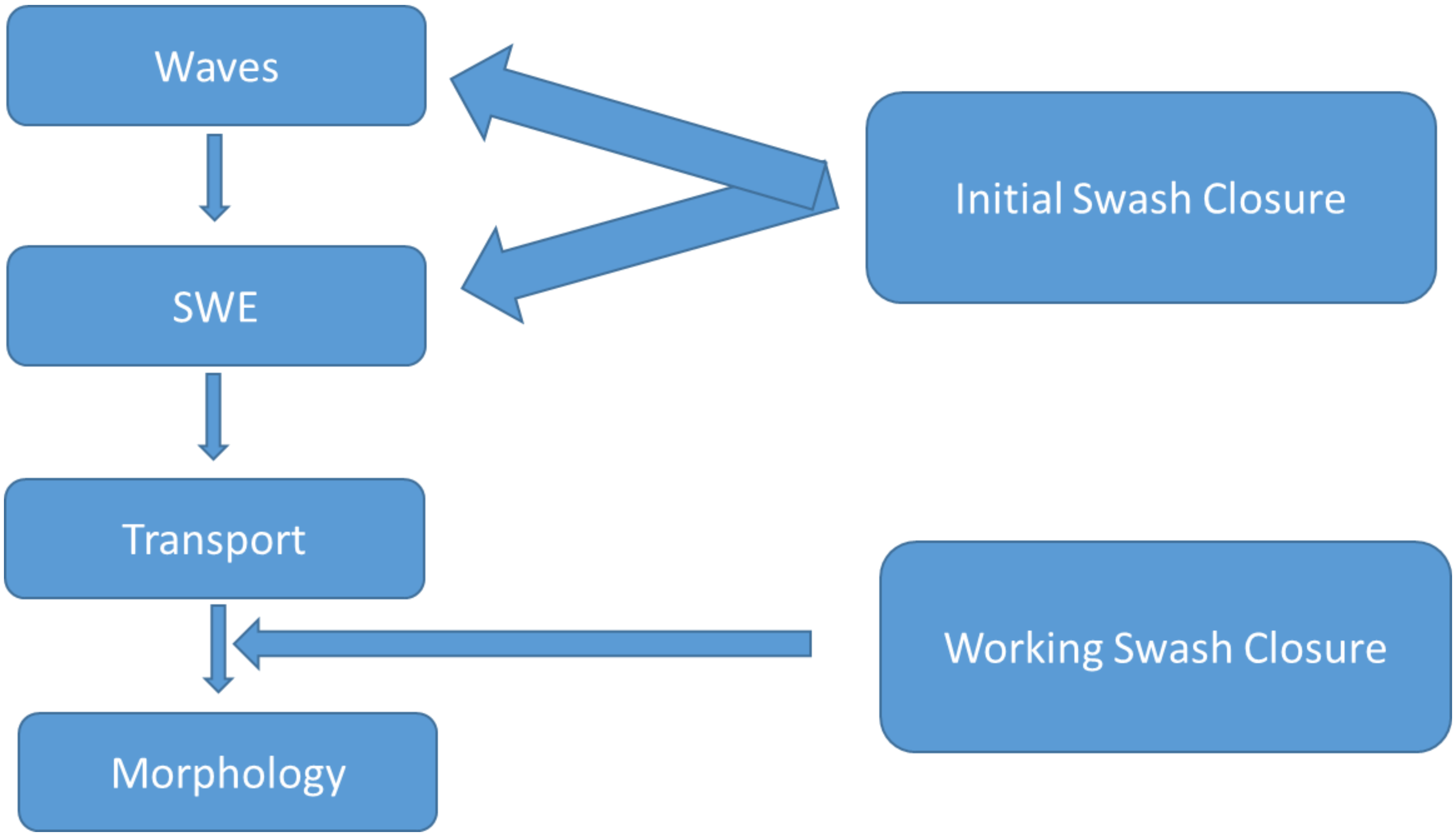
•Bed conservation is rigid

CSHORE in 2DH?

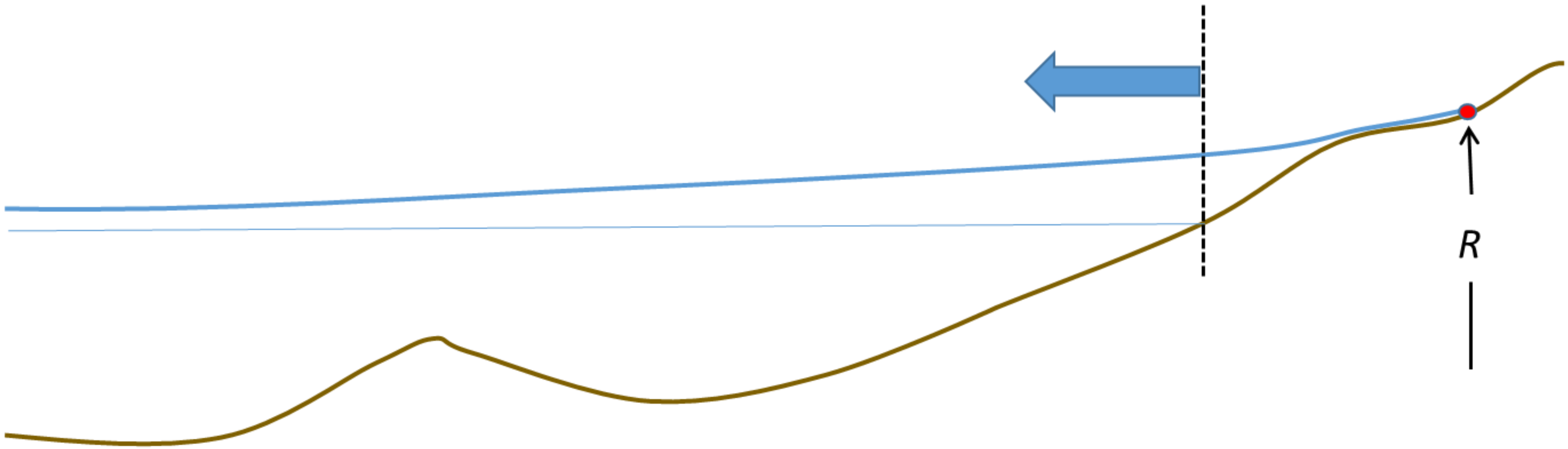
•Probabilistic hydrodynamics and transport have several empirical closures—2Dh would have more than twice
•Steady! shallow water hydrodynamics driven by waves only.



A Swash Closure in CMS



Nearshore Modeling Simplified to 1-D



$$\frac{\partial\, Enc}{\partial x} = -D_B - D_f$$

$$\frac{\partial\, S_{xx}}{\partial x} = -\rho g h \frac{\partial\, \overline{\eta}}{\partial x} - \overline{\tau_b}$$

So how do we compute the contribution to R within the swash zone?

$$\frac{R}{H_0} \sim \xi$$

Swash Modeling

- Based on momentum eqn (As the energy eqn has lost meaning)
- All time-dependent term are lost (OK for thin film)

$$\frac{\partial}{\partial s}\left(\overline{U_s^2 h} + \frac{g}{2}\overline{h^2}\right) = -g\overline{h}\frac{\partial z_b}{\partial s} - c_f\overline{|U_s|U_s}$$

$$M = \overline{U_s^2 h} + \frac{g}{2}\overline{h^2}$$

$$\frac{\partial}{\partial x}(M\cos\alpha) = -g\overline{h}\frac{\partial z_b}{\partial x} - c_f\overline{|U|U}\cos\alpha$$

$$\frac{\partial S_{xx}}{\partial x} = -\rho g h\frac{\partial \overline{\eta}}{\partial x} - \overline{\tau_b}$$

Swash Modeling

$$\frac{\partial}{\partial x}(M\cos\alpha) = -g\overline{h}\frac{\partial z_b}{\partial x} - c_f\overline{|U|U}\cos\alpha$$

where $$M = \overline{U_s^2 h} + \frac{g}{2}\overline{h^2}$$

A far-reach here: $$U \sim \sqrt{g\overline{h}} \quad M \sim g\overline{h}^2 \sim gH_{rms}^2$$

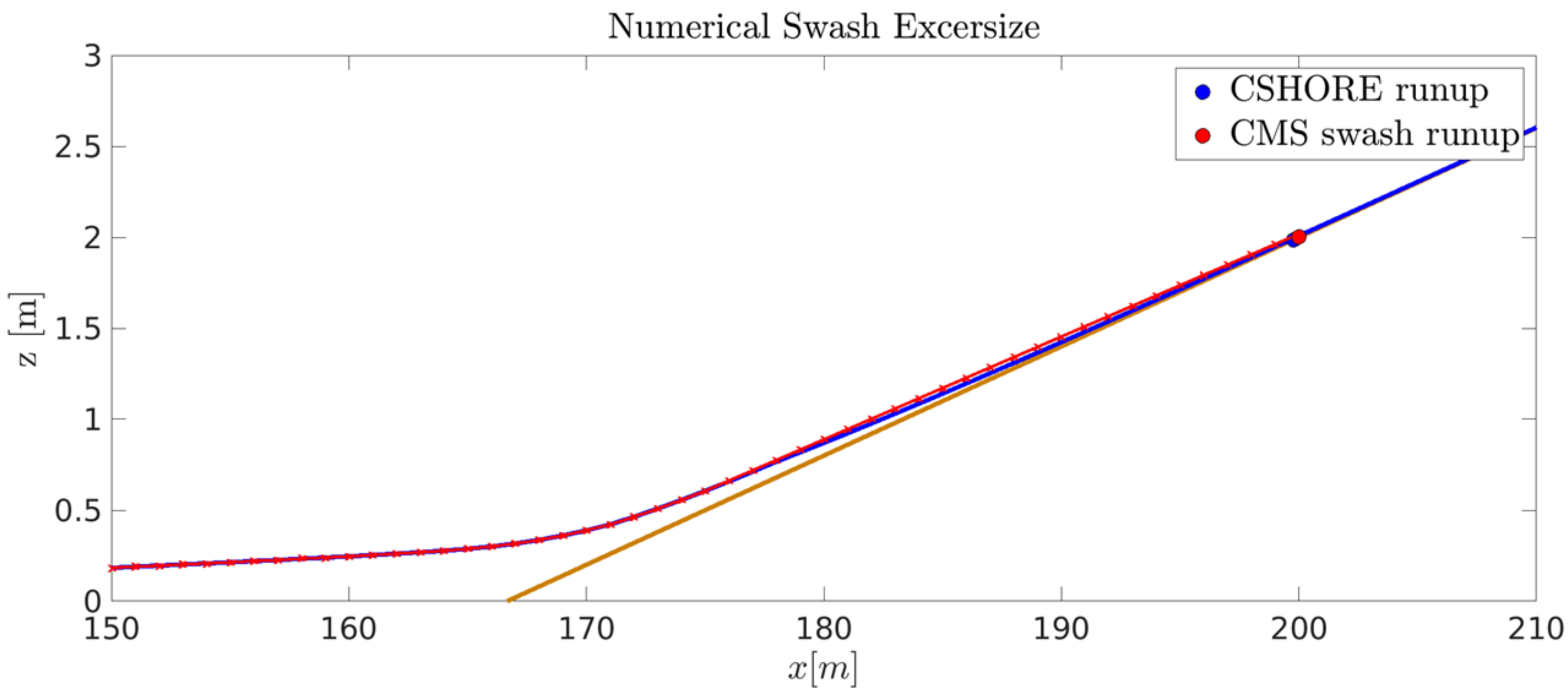
$$M \simeq A_0 g\overline{h}^2 \quad c_f' g\overline{h} \simeq c_f\overline{|U_s|U_s}$$

How far is the reach? $$\frac{\partial S_{xx}}{\partial x} = -\rho g h\frac{\partial \overline{\eta}}{\partial x} - \overline{\tau_b}$$

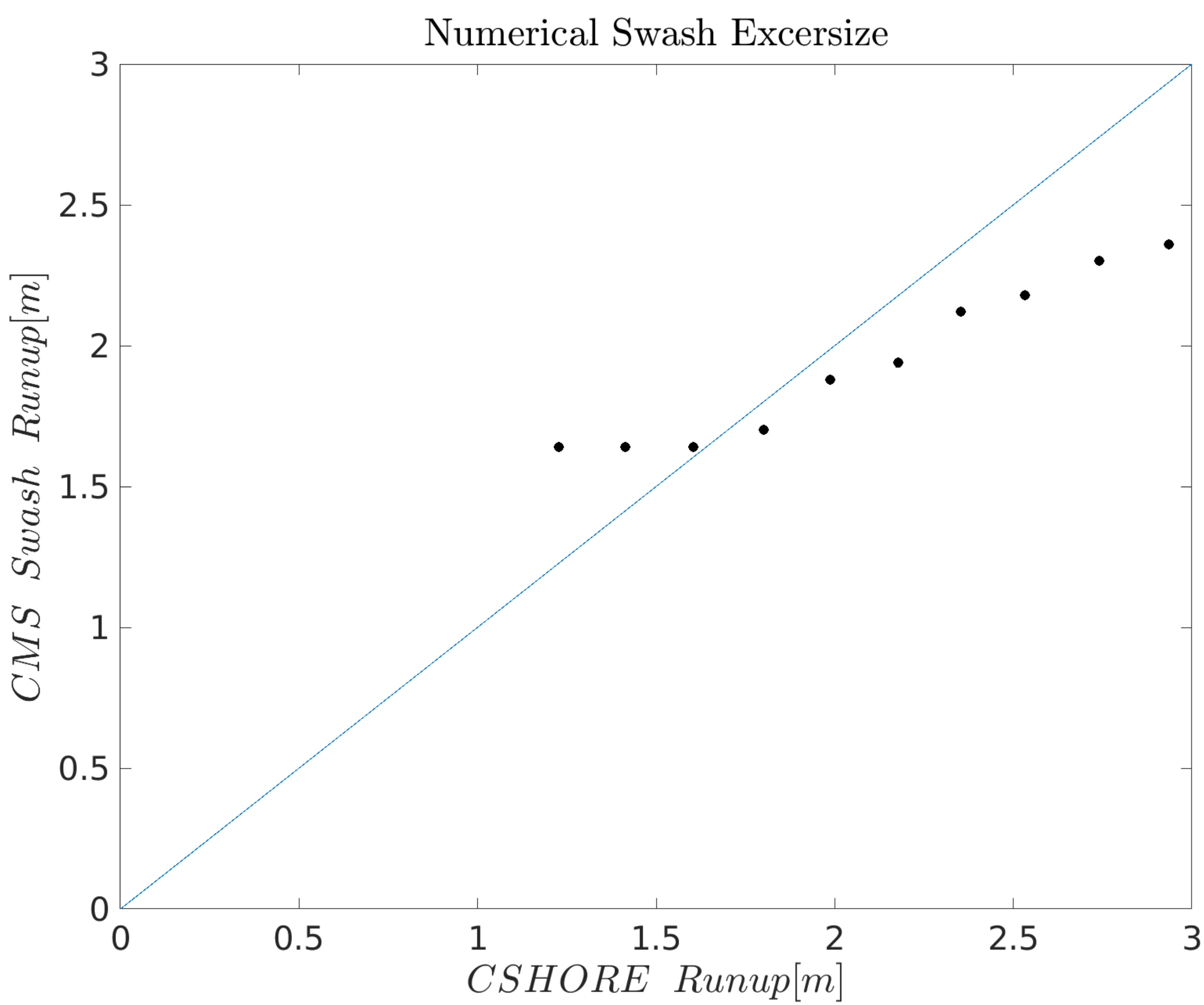
$$S_{xx} \sim g\overline{h}^2$$

Swash Modeling

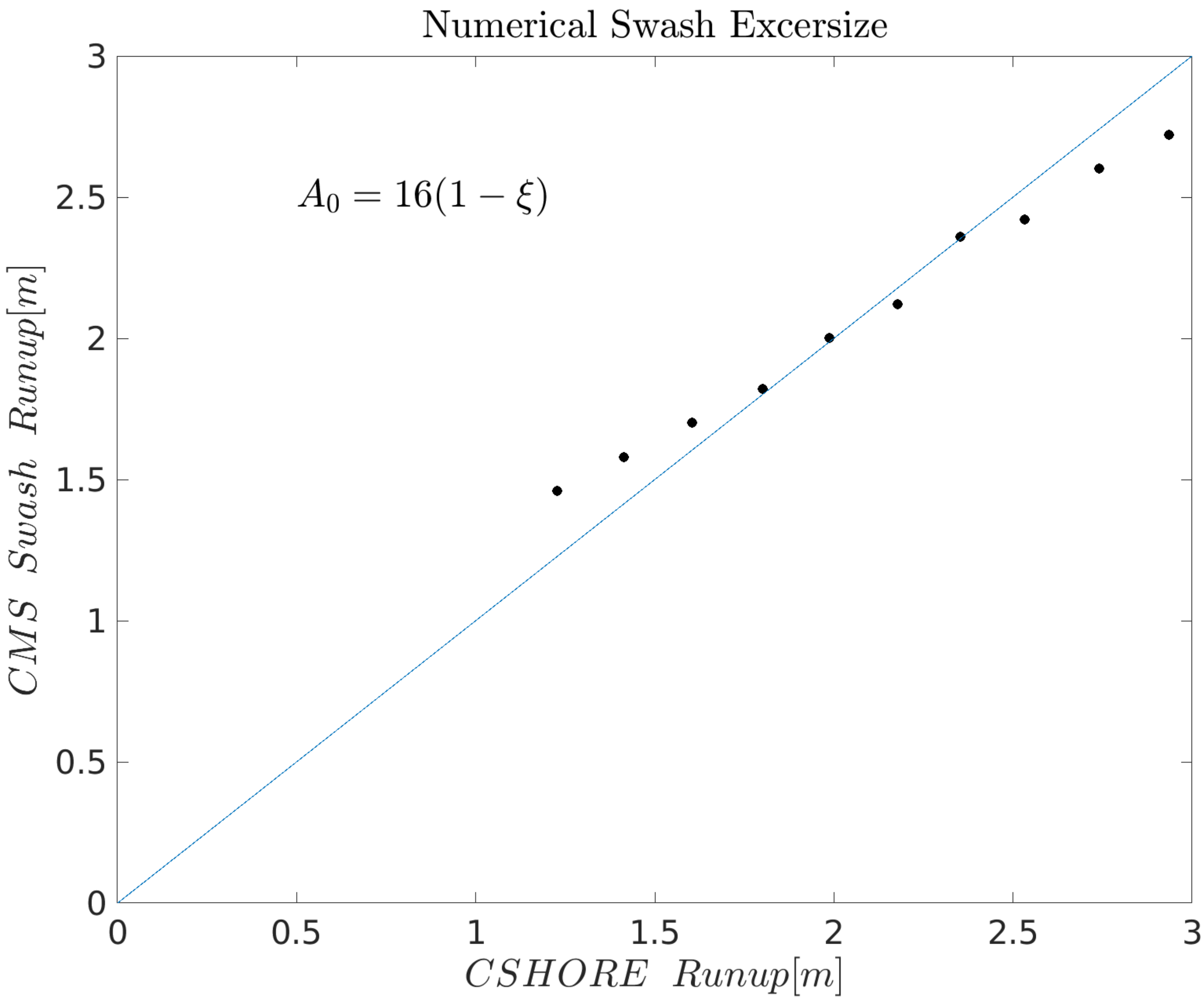
$$\frac{M_{i+i} - M_i}{\Delta x} = -g\overline{h_i}\frac{\partial z_b}{\partial x} - c'_f g\overline{h}$$



Swash Modeling



Swash Modeling

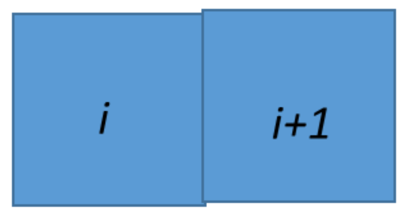


Swash Sediment Modeling

A general form for transport: $q = \overline{V_s U}$

But all parts are unknown, so rely on extrapolation from previously computed C2SHORE transport.

Previously computed



New Swash Cell

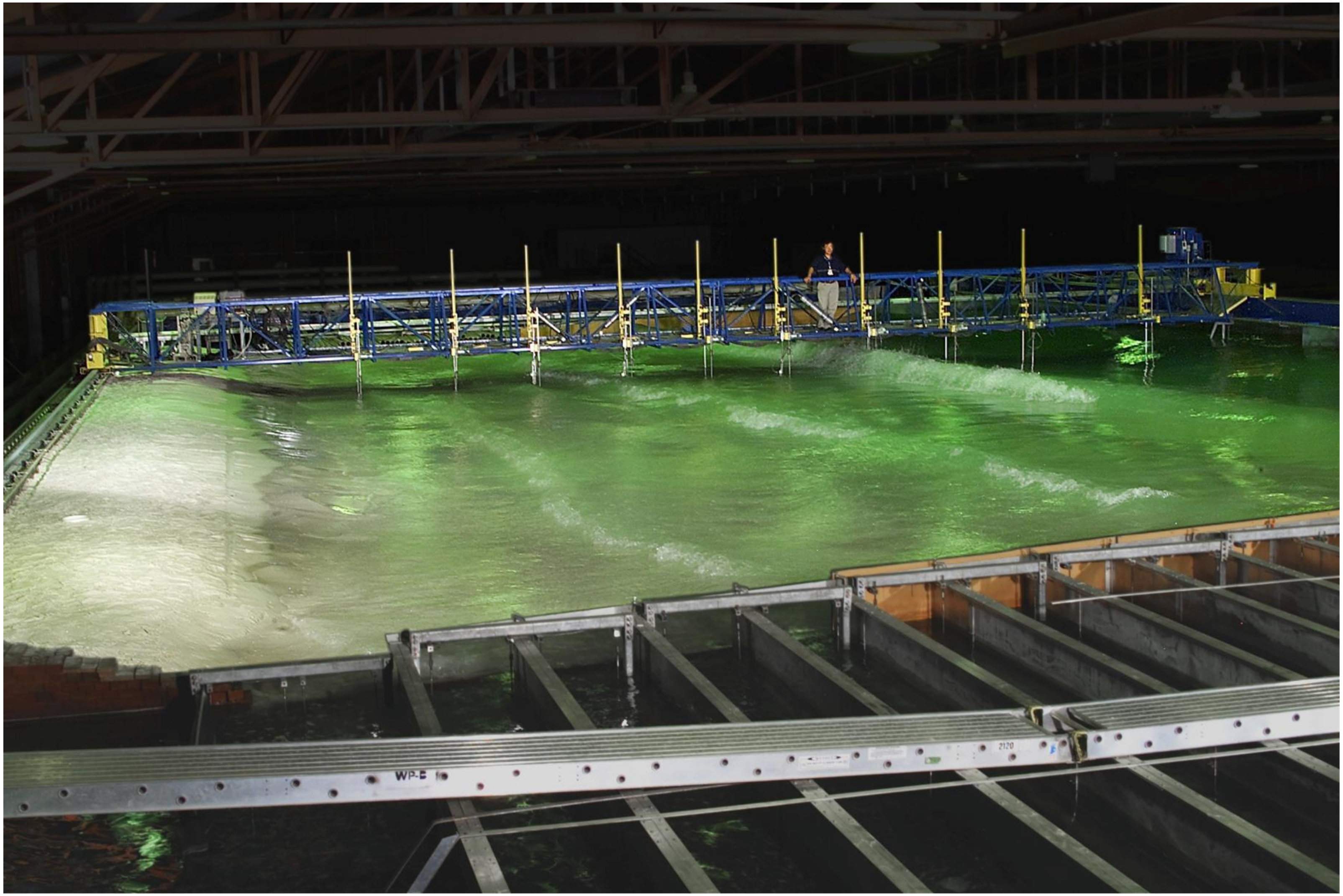
$$q_{x_{i+1}} = \frac{\overline{h}_{i+1}}{\overline{h}_i} q_{x_i} \quad ; \quad q_{y_{i+1}} = \hat{q}_{y_i} \frac{\tan\phi}{\tan\phi + \frac{\partial z_b}{\partial y}}$$

Swash Model, Numerical Recipe

- Execute CMS Wave, CMS Flow
- Initialize all wet cells with scalar *M* and direction
- Find all dry cells with wetted neighbors
- If momentum flux is towards dry cell, compute new *h*
- Check that *M>0, h>0, set cell to wet*
- Iterate to find swash cells, stop when momentum is exhausted or no dry cells.
- Compute bottom position change

$$(1-n)\frac{\partial z_b}{\partial t} = -\frac{\partial q_x}{\partial x} - \frac{\partial q_y}{\partial y}$$

Laboratory Model Test



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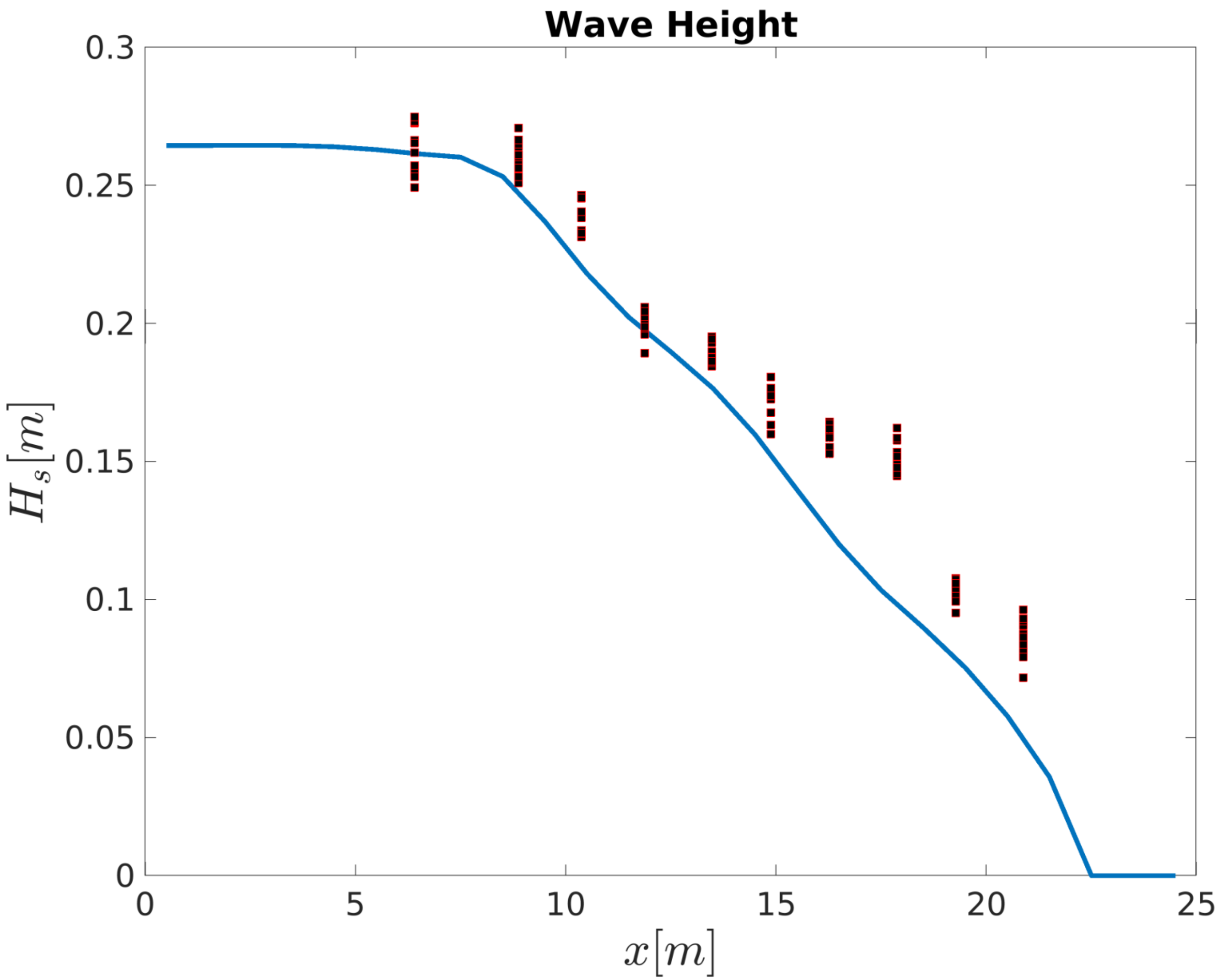

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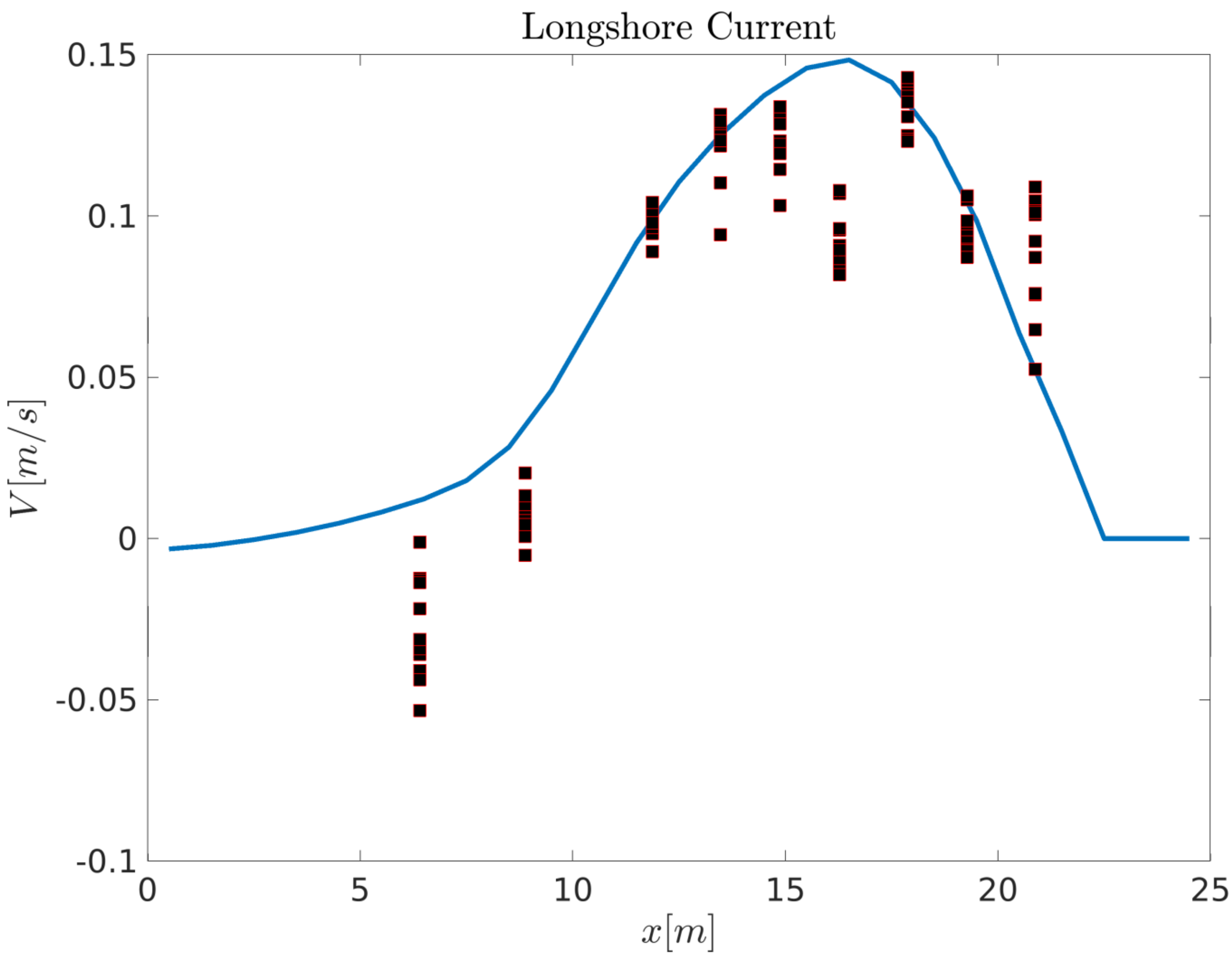

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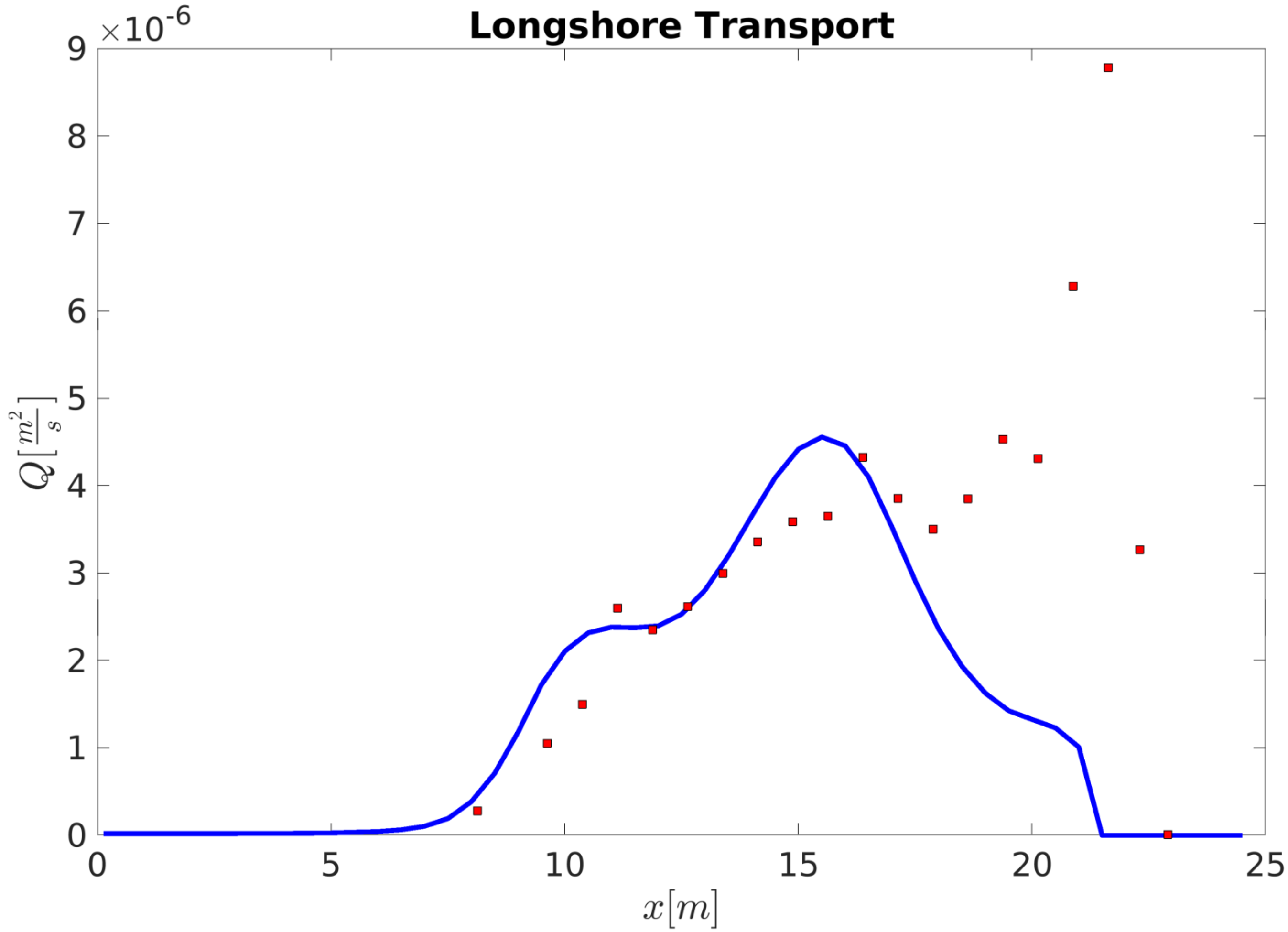


Depth-Dependent Suspension

Growing evidence that suspension slightly over predicted in outer surf/ under predicted in inner surf

$$V_s = \int_0^h c\,dz = \frac{e_f D_f + e_B D_B}{\rho g(s-1)w_f} P_s \sqrt{1 + S_x^2 + S_y^2}$$

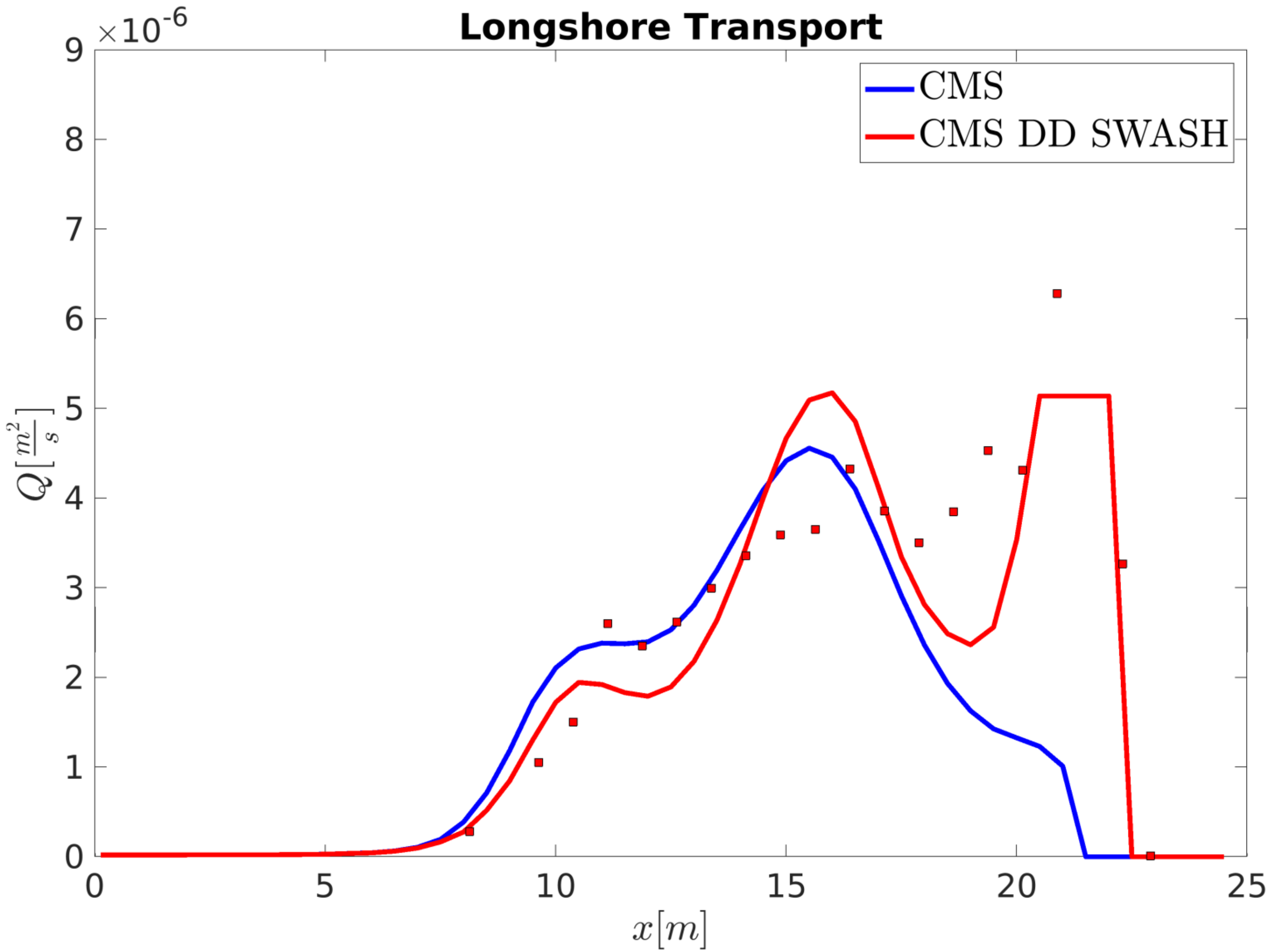
A new corrective factor is implemented

$$D'(z) \sim e^{kz}$$ where $$k = \frac{1}{l} = \frac{1}{\beta H_{rms}}$$

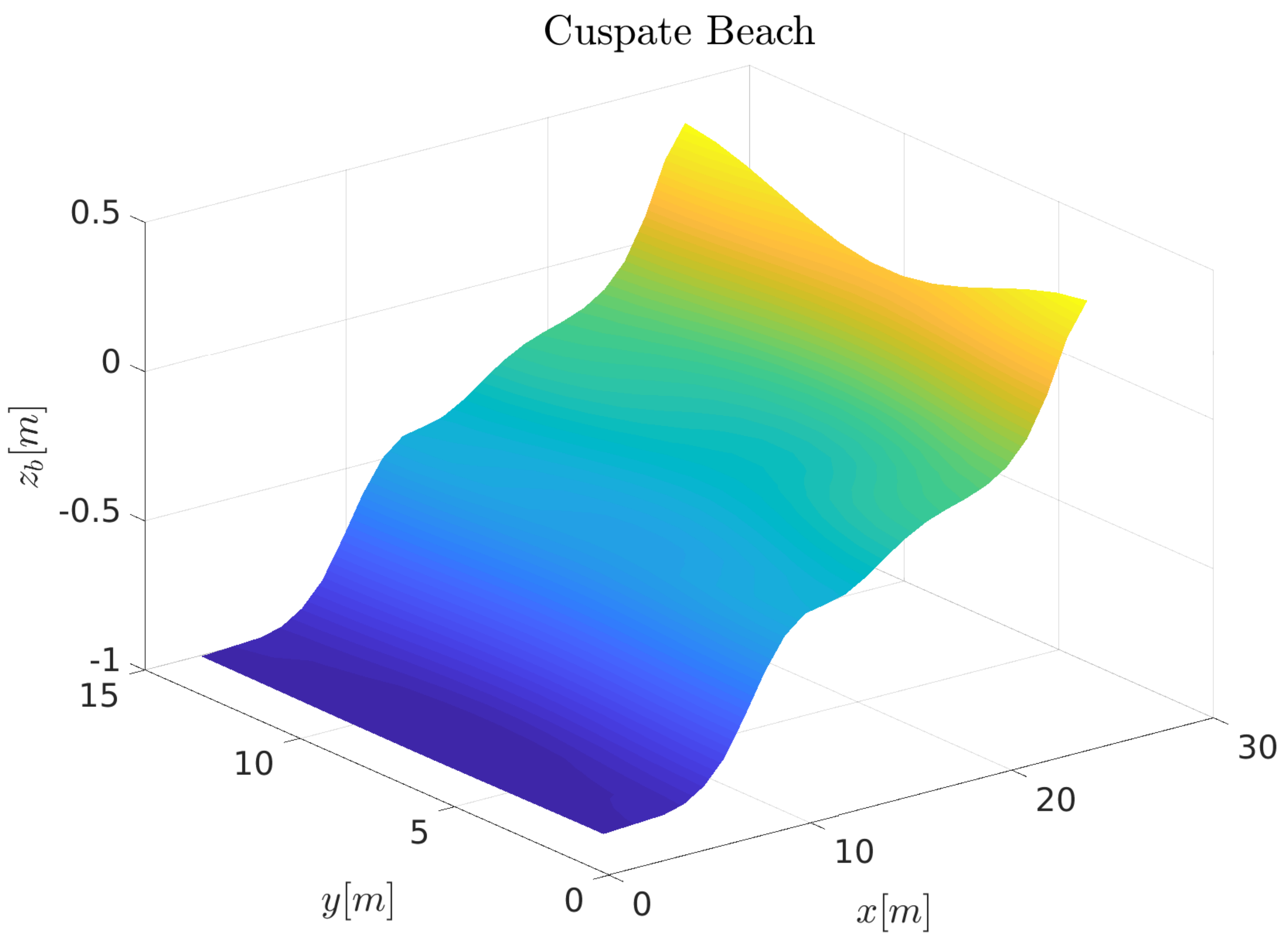
Results in

$$D_{B_b} = \frac{khD_B}{e^{kh} - 1}$$

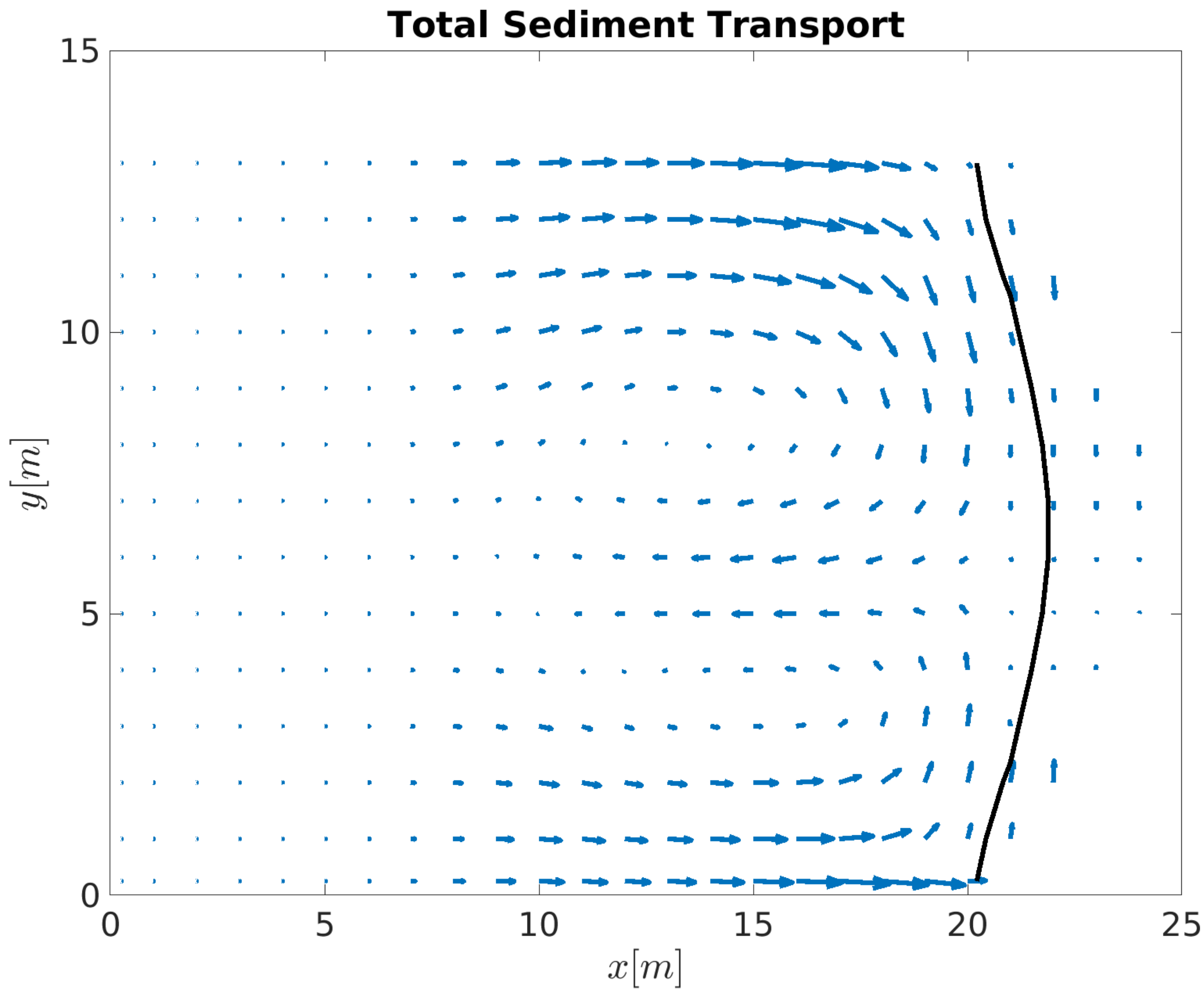
Laboratory Model Test



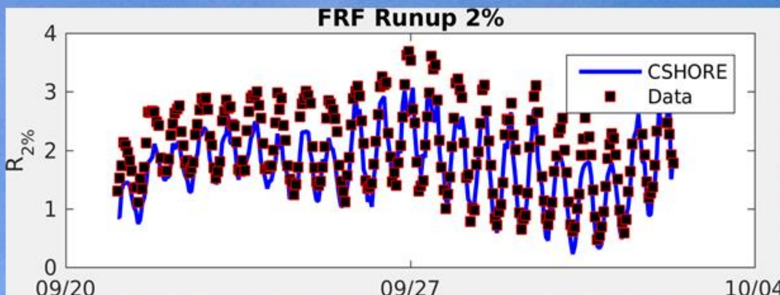
Cuspate Model Test

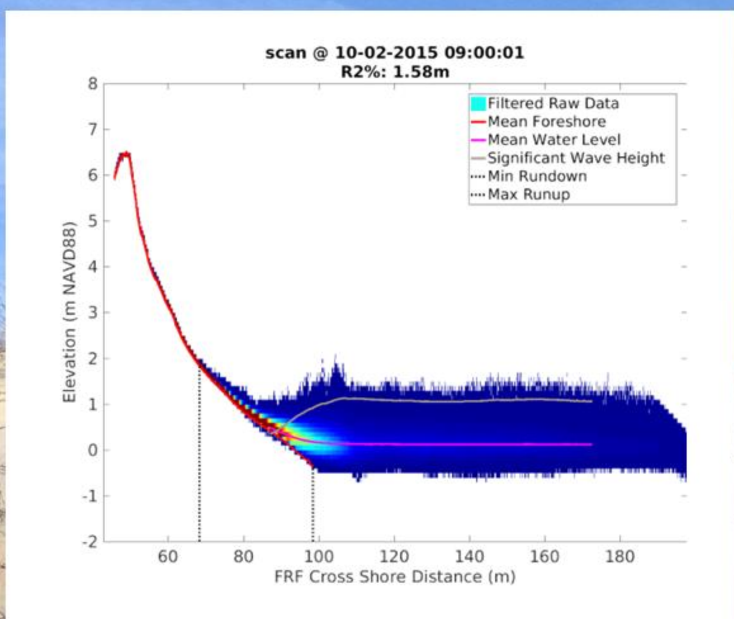


Cuspate Model Test



Next steps: FRF data:Continuous Dune Lidar Tower





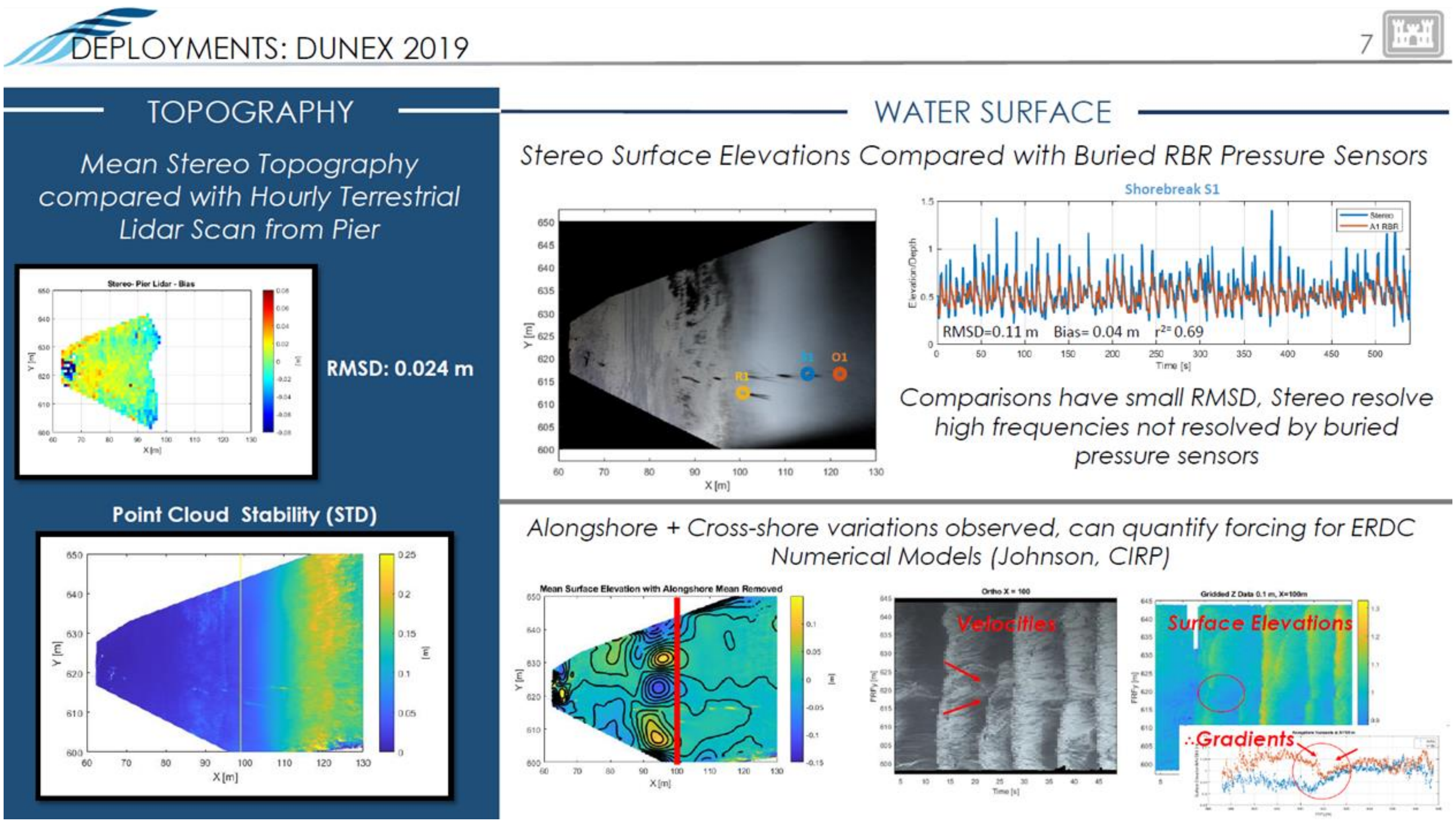
Simultaneous observations of Wave Runup, Swash Hydrodynamics, Morphology Change

- **Inner surf zone wave height & spectra**
- **Mean water level**
- **Runup elevations**
- **Foreshore beach profile (hourly & wave by wave) & 3D morphology**

Next steps

Recall: $$M = \overline{U_s^2 h} + \frac{g}{2}\overline{h^2}$$

Bruder 6.1:



Conclusions

•Swash is (almost) always neglected – in spite of importance
•Challenge in making physically realistic numerical model when system is underspecified
•A simple evolution scheme is introduced where momentum propagates into previously dry cells
•Scaling is provided to 'close' the time-averaged terms
•Simple model provides similar results with CSHORE
•Sediment transport is an extrapolation from C2SHORE results
•Comparison with lab data indicates deficiency in suspension model
•Model with altered breaking suspension + swash transport compares reasonably well with data
•Plans include effort to compare model to FRF data, justify alter formulation