Modeling FRF Nearshore Processes and Morphology

CIRP Tech Discussion
13 Apr 2021

Project Team:

Brad Johnson
Nick Cohn
Spicer Bak
Kate Brodie
Pat Dickhudt

Nearshore Transport Models

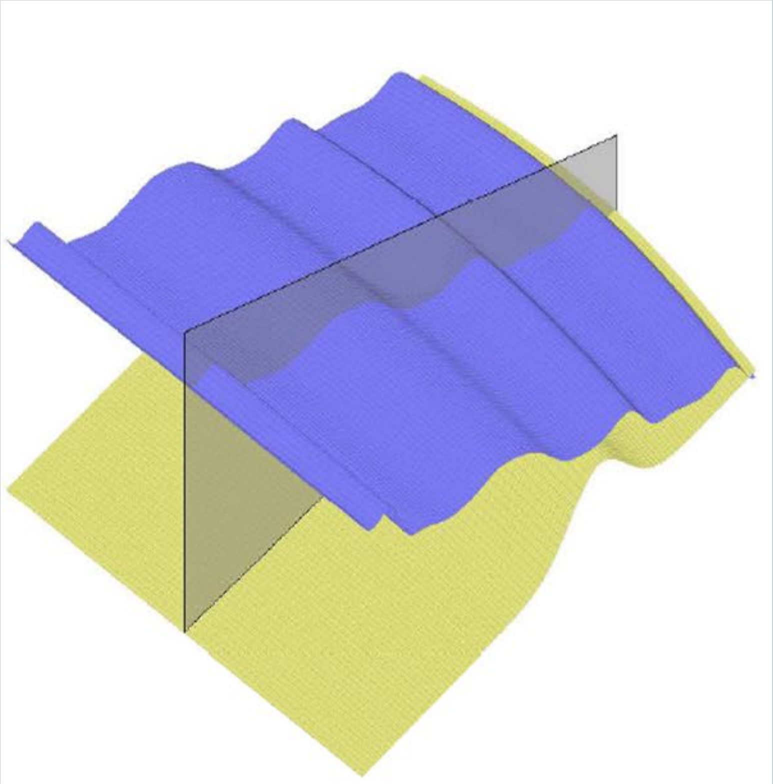
Less Complexity/ Computational Expense

More Complexity/ Computational Expense

- Scalar Parameter: e.g. Shields, Mobility, Dean.
- Data Driven: e.g. historical shoreline projections forced empirical models
- Phase-averaged steady models: SBEACH, Unibest , CSHORE.CMS/C2SHORE
- Phase-averaged, low-freq resolving steady model: XBEACH
- Phase-resolving models: FUNWAVE COULWAVE RANS, etc

CSHORE Hydrodynamics

- Assume local longshore uniformity
- Requires wave conditions at sea boundary
- Solve eqns for wave energy, momentum, mass for time-averaged hydrodynamics
- Predict cross-shore variation of



$\bar{\eta}$ = mean free surface elevation (wave setup)

$\sigma_\eta = H_{mo}/4$ = free surface standard deviation

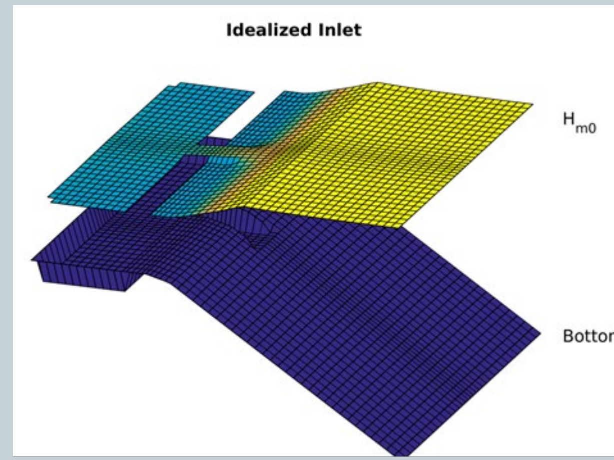
θ = wave angle

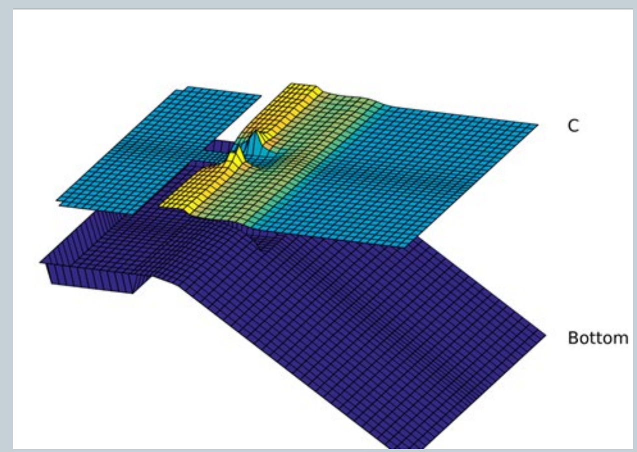
$\overline{U}$ = depth-averaged cross-shore current (undertow)

$\overline{V}$ = longshore current

CMS-C2SHORE

- C2SHORE sediment transport option
- Dependencies on waves, currents are satisfied with CMS wave, flow module solutions
- The computed concentration field and sediment transport has been verified with the theoretical CSHORE basis





CSHORE/C2SHORE

- In addition to obvious differences (1D vs 2DH) some important differences in hydro, computation of transport, and morphology change

- CSHORE Hydro
- Time-steady
- Tightly coupled
- Swash soln is integral

- CMS Hydro
- Time-dependent
- Modular waves/circulation
- Swash soln is a domain extension and simpler

CSHORE/C2SHORE

- CSHORE Sed Conc

$$V_s = \frac{e_B D_B + e_f D_f}{\rho g (s-1) w_f} P_s$$

- C2SHORE Sed Conc

$$C_{t*} = \frac{\rho_s V_s}{h}$$

$$\frac{\partial}{\partial t}\left\{\frac{hC_t}{\beta}\right\} + \frac{\partial}{\partial x_i} U_i h C_t = \frac{\partial}{\partial x_i}\left\{\nu_s h \frac{\partial C_t}{\partial x_i}\right\} + \alpha_t w_f (C_{t*} - C_t)$$

CSHORE/C2SHORE

- CSHORE Transport
- and bed-change

$$q_x = aU_{RC}V_s + q_{bx}$$

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

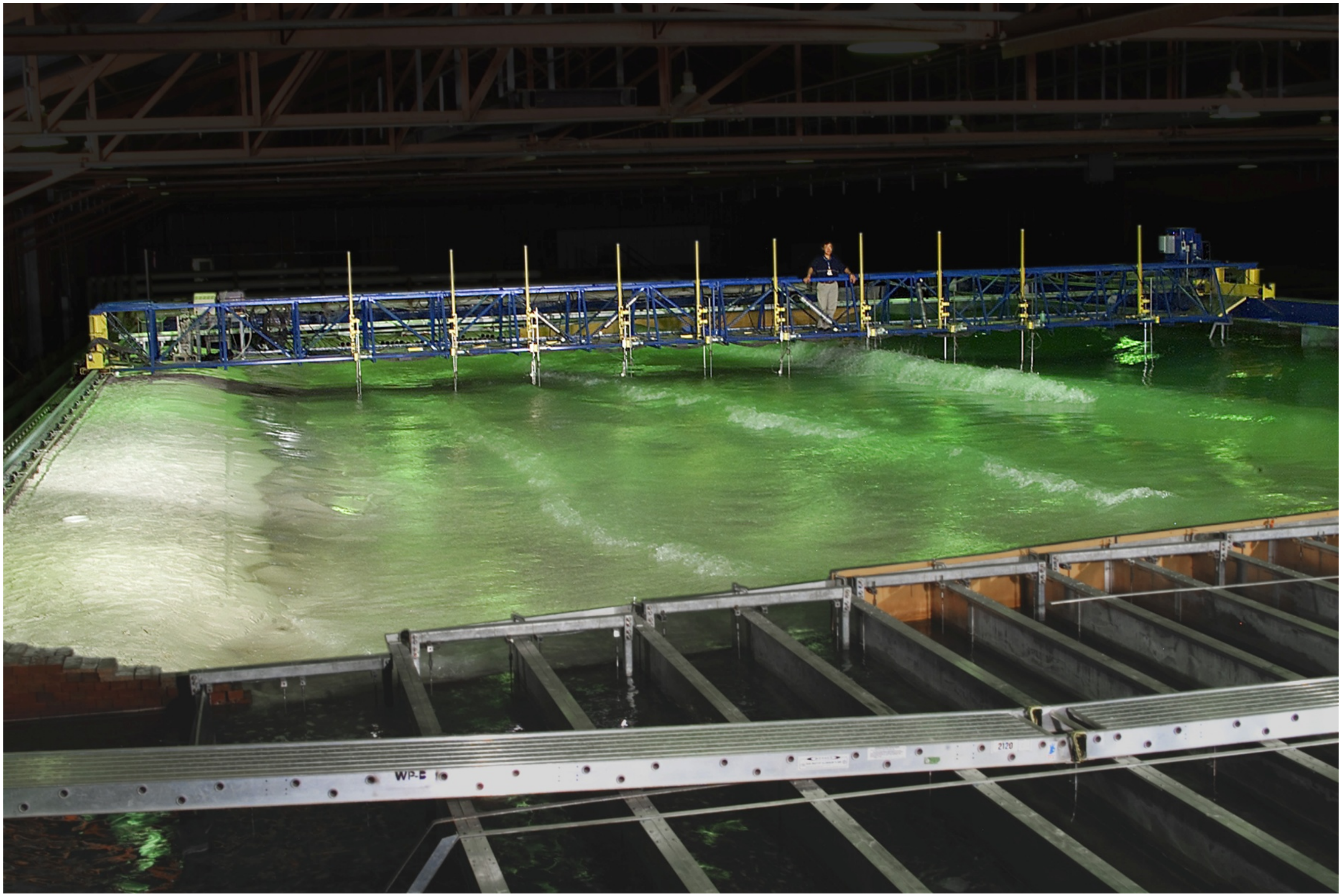
- C2SHORE bed change

$$\rho_s(1-n)\frac{\partial z_b}{\partial t} = \alpha_t w_f (C_{t*} - C_t)$$

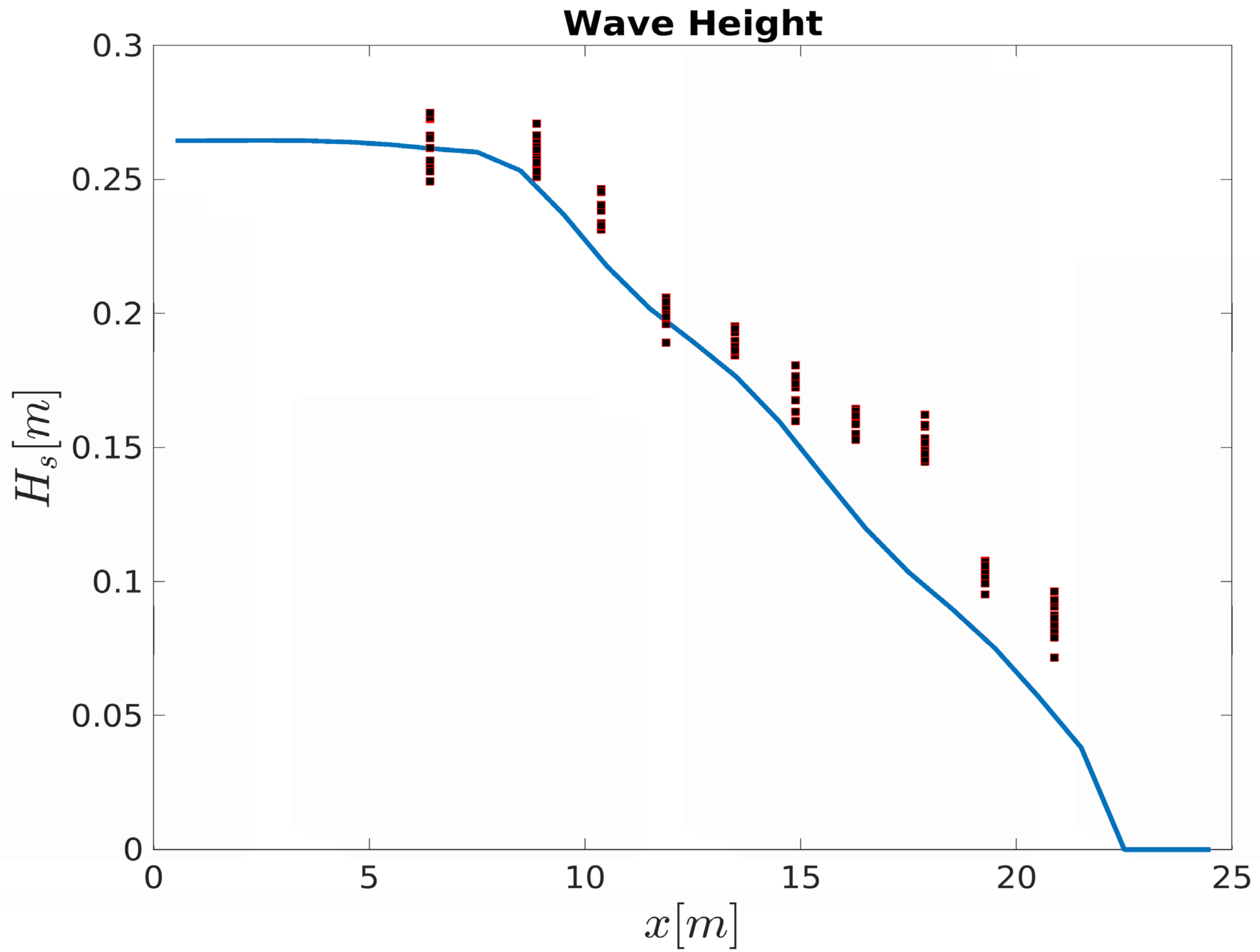
- Appropriate for sus load only with advection by currents only, but
- Bedload
- Wave-related transport

$$\rho_s(1-n)\frac{\partial z_b}{\partial t} = \alpha_t w_f (C_{t*} - C_t) - \frac{\partial \tilde{Q}_{x_i}}{\partial x_i}$$

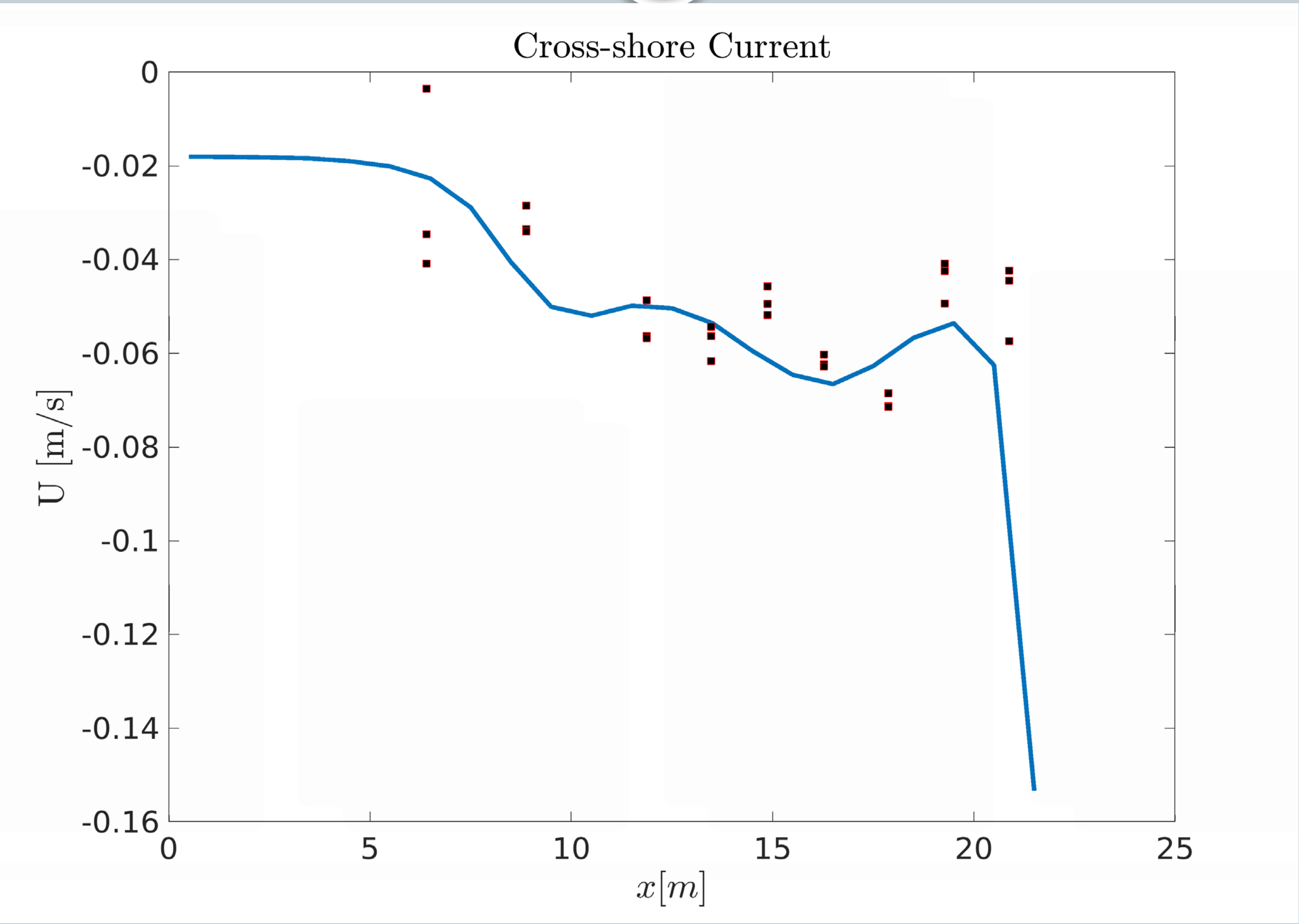
Laboratory Model Test



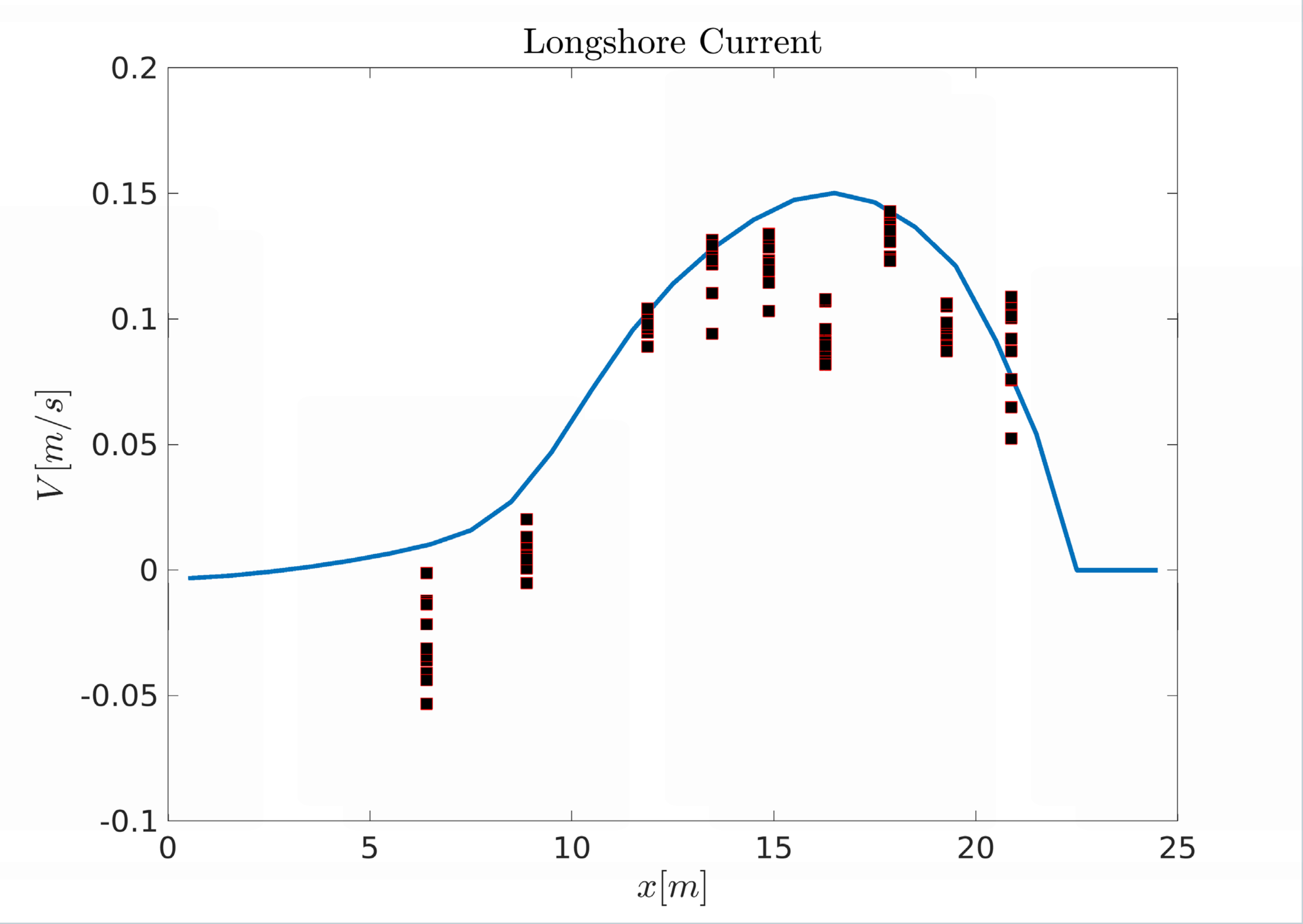
LSTF/C2SHORE



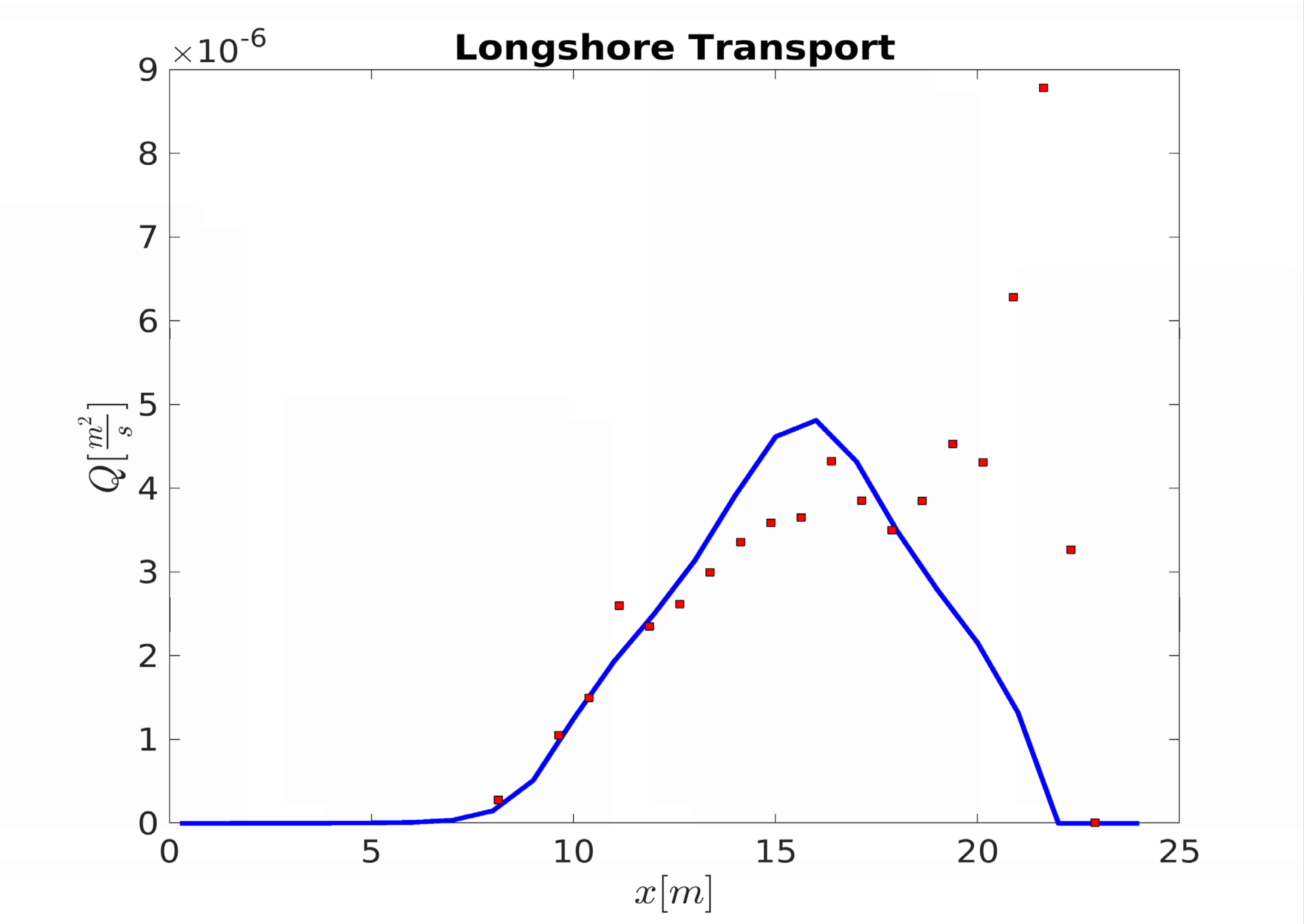
LSTF/C2SHORE



LSTF/C2SHORE



LSTF/C2SHORE



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

$$D'(z) \sim e^{kz}$$

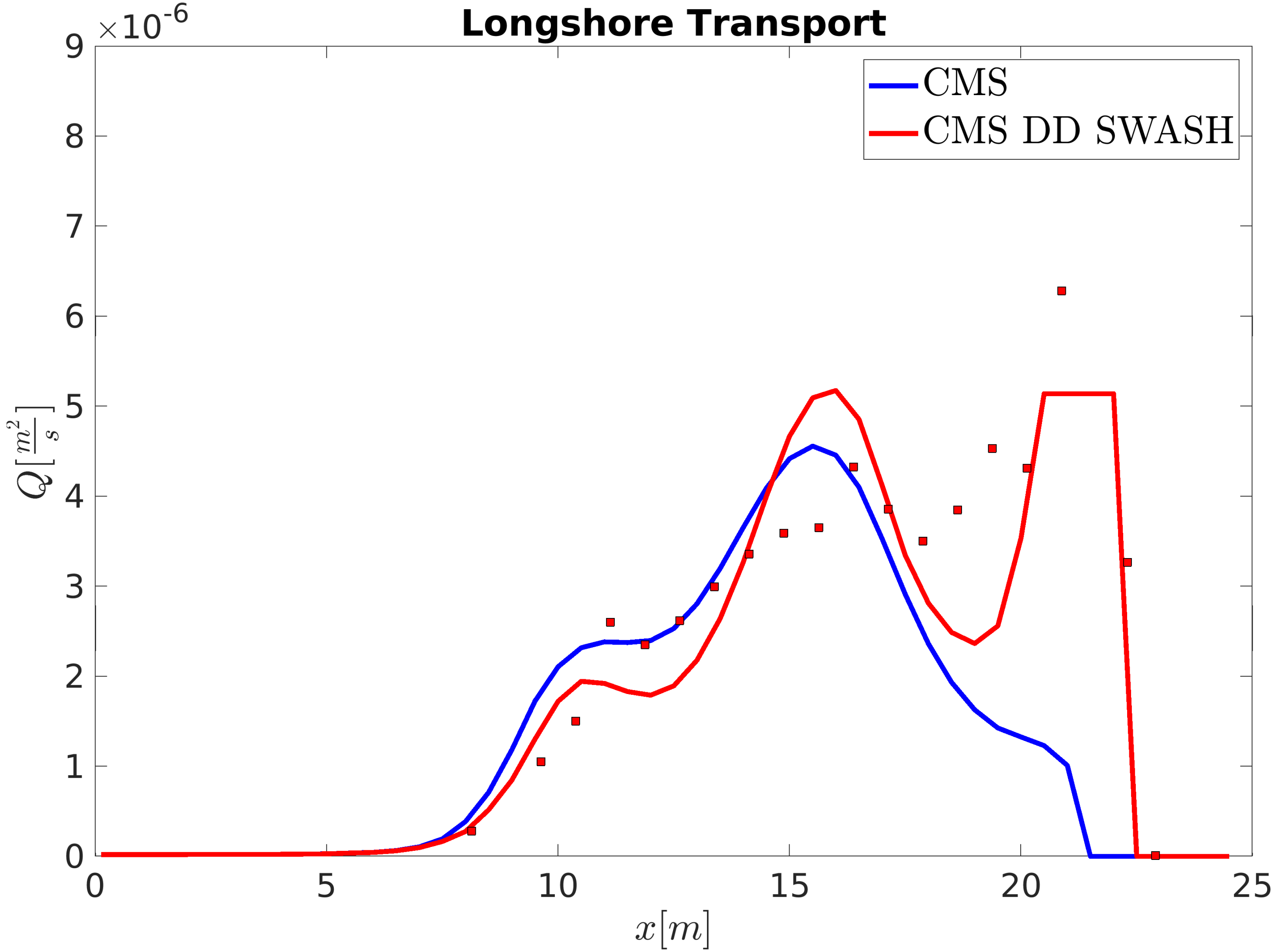
where

$$k = \frac{1}{l} = \frac{1}{\beta H_{rms}}$$

Results in

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

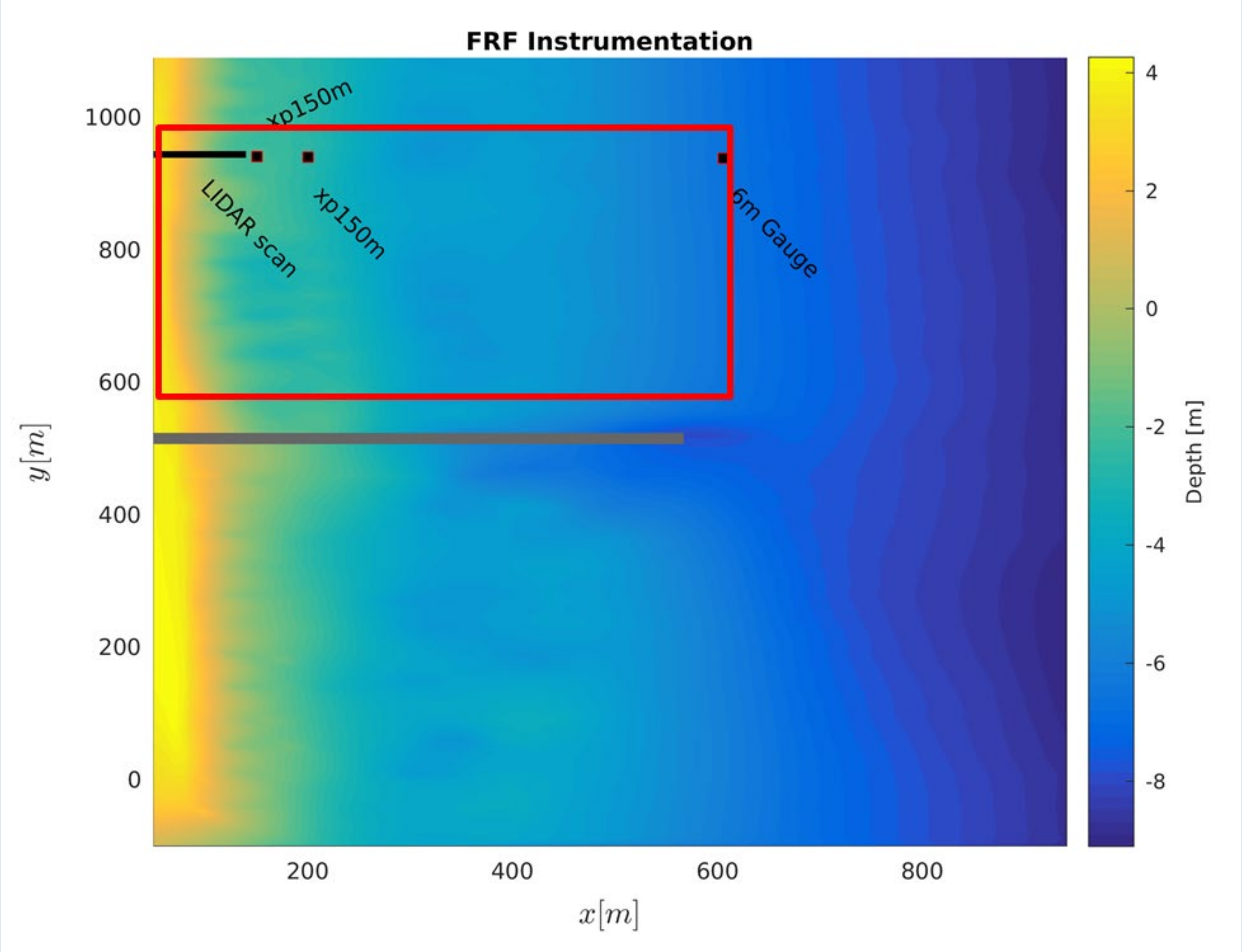
Laboratory Model Test



FRF/C2SHORE

FRF X-Shore Array

Study Focus Area: Make use of surveys, and cross-shore array



FRF Transport

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

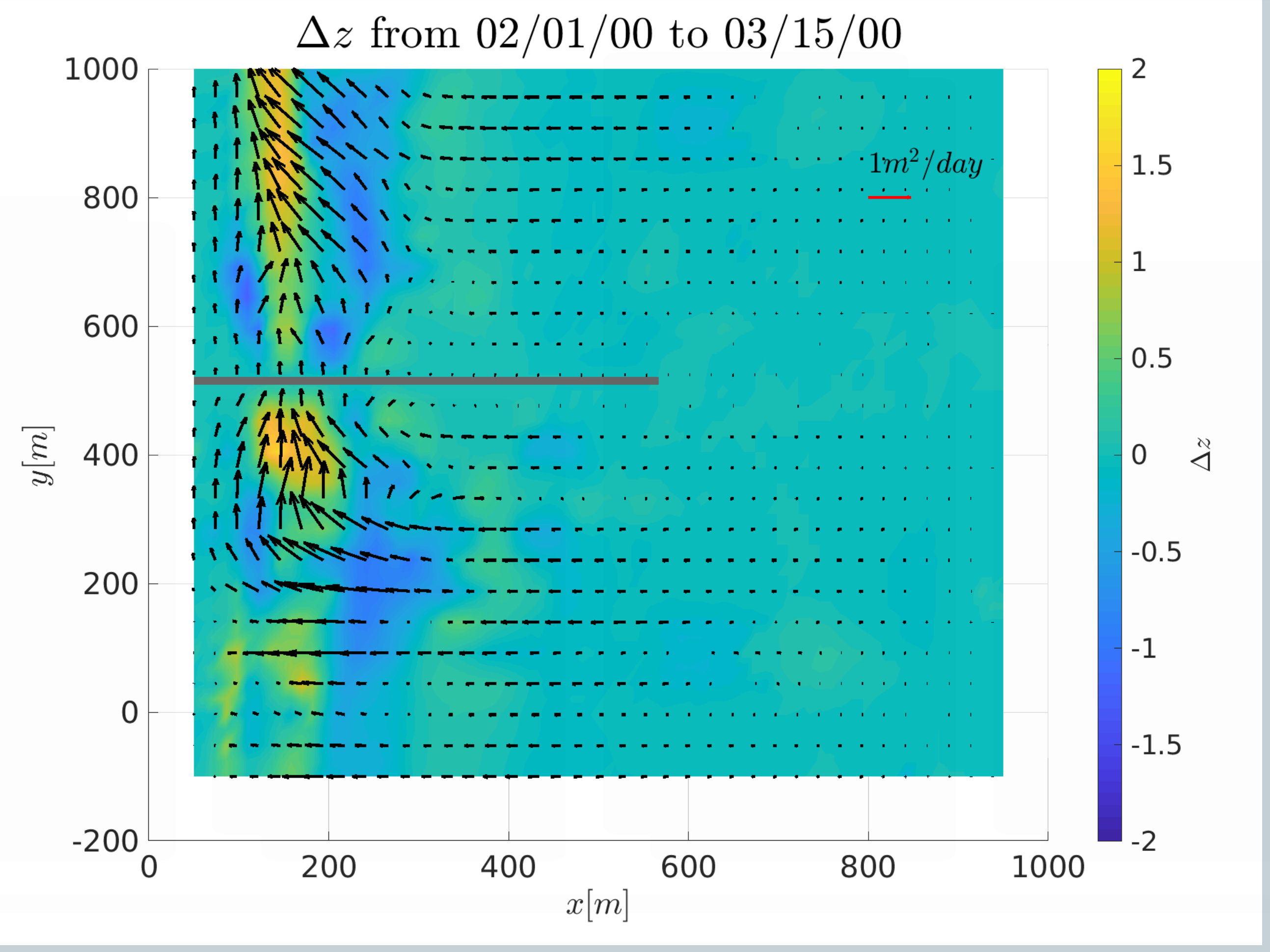
$$\int_{dry}^{deep} (1-n)\frac{\partial z_b}{\partial t} dx = -\frac{\partial Q_y}{\partial y}$$

$$Q_y = \int_{dry}^{deep} q_y dx$$

$$Q_y = Q_{y0} - \int_0^y \int_{dry}^{deep} (1-n)\frac{\partial z_b}{\partial t} dx dy$$

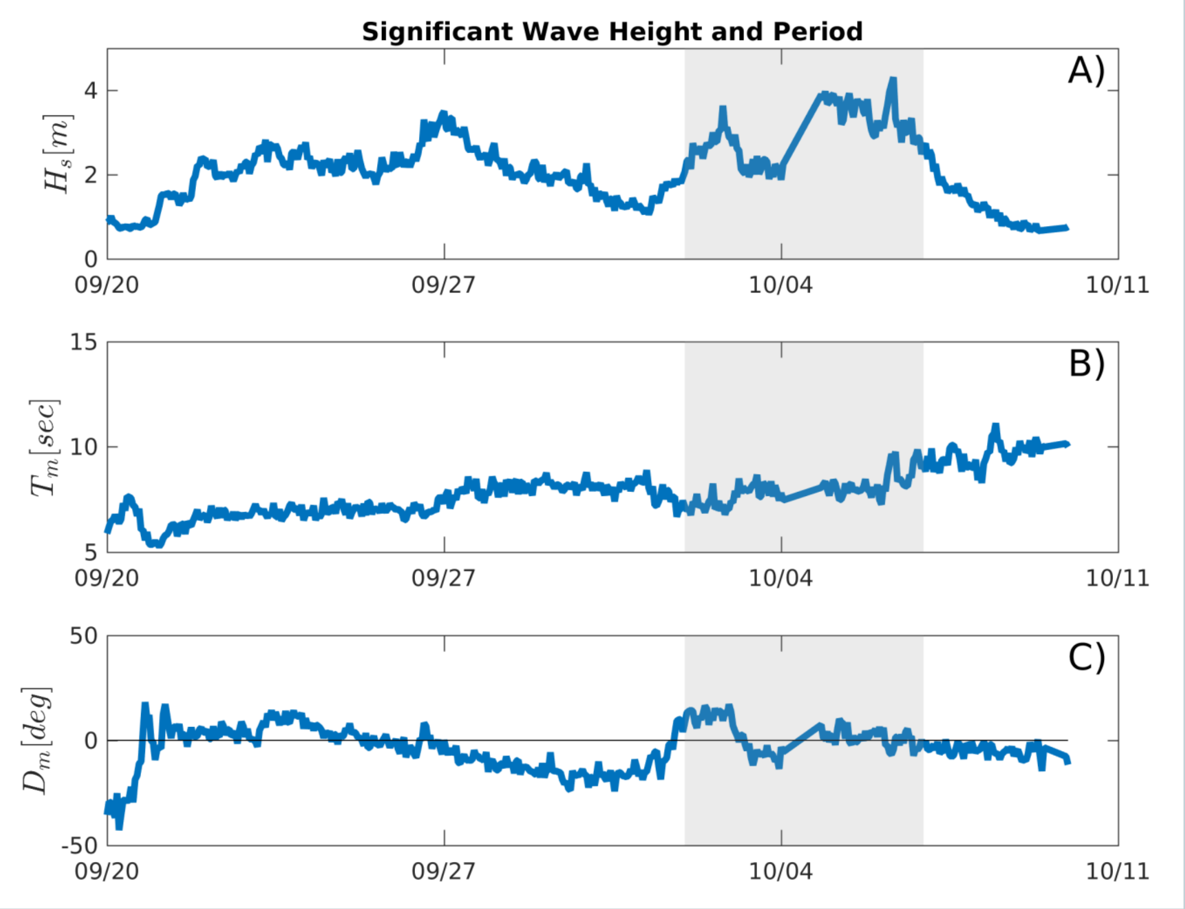
Requires a boundary condition and then estimates of the distribution of Q_y results in uniquely determined average transport fields.

FRF Transport

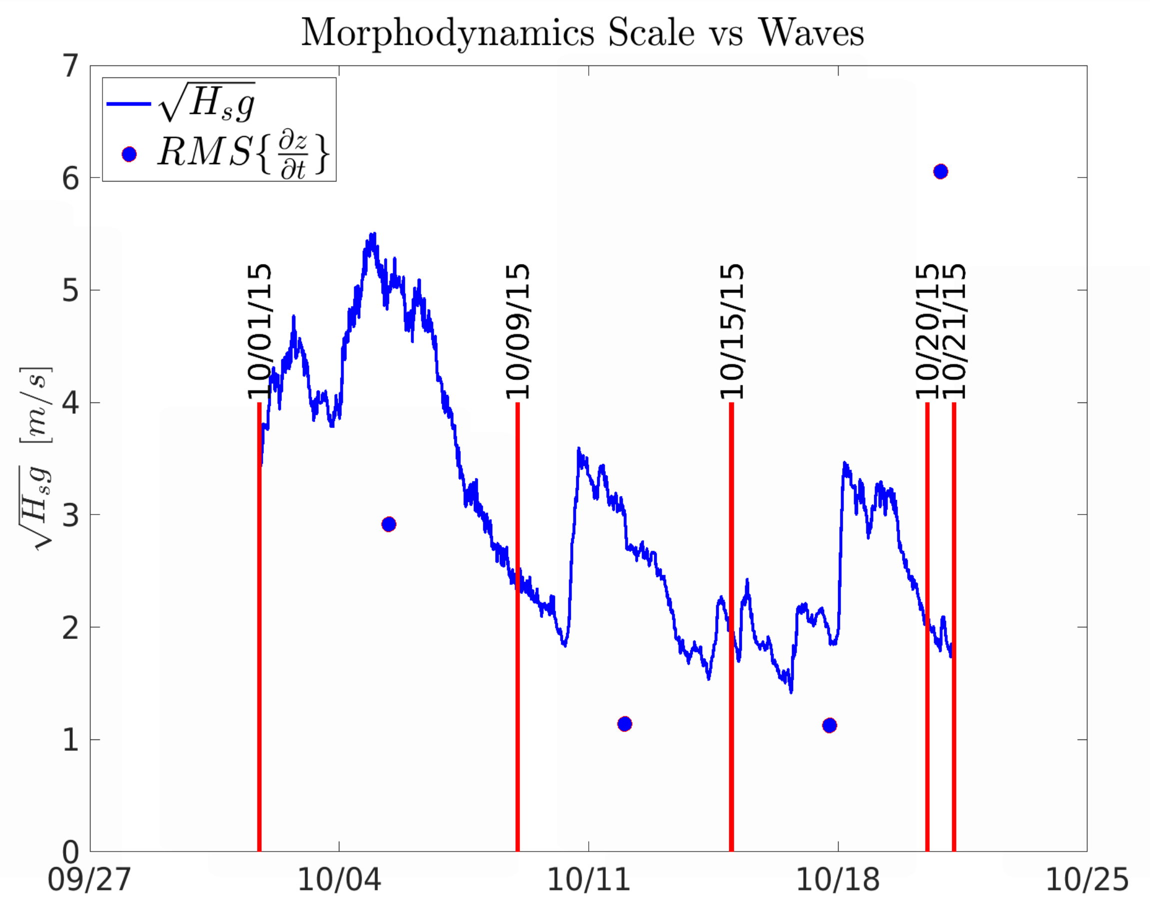


Nor'easter storm and hurricane Joaquin

- Sustained energetic conditions for 15 days
- Peak Hs of 4 m
- Storm surge < 1 m

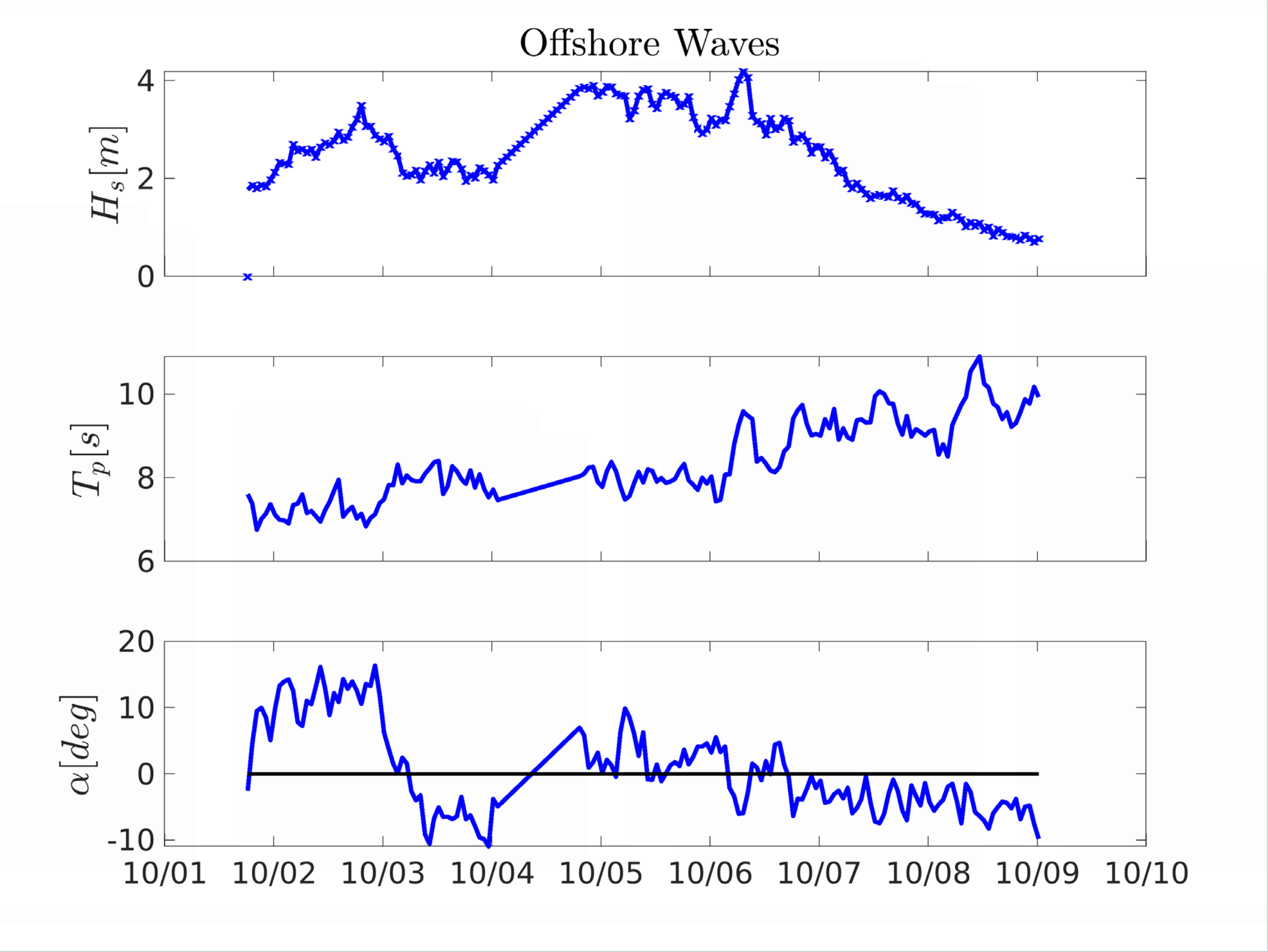


FRF/C2SHORE



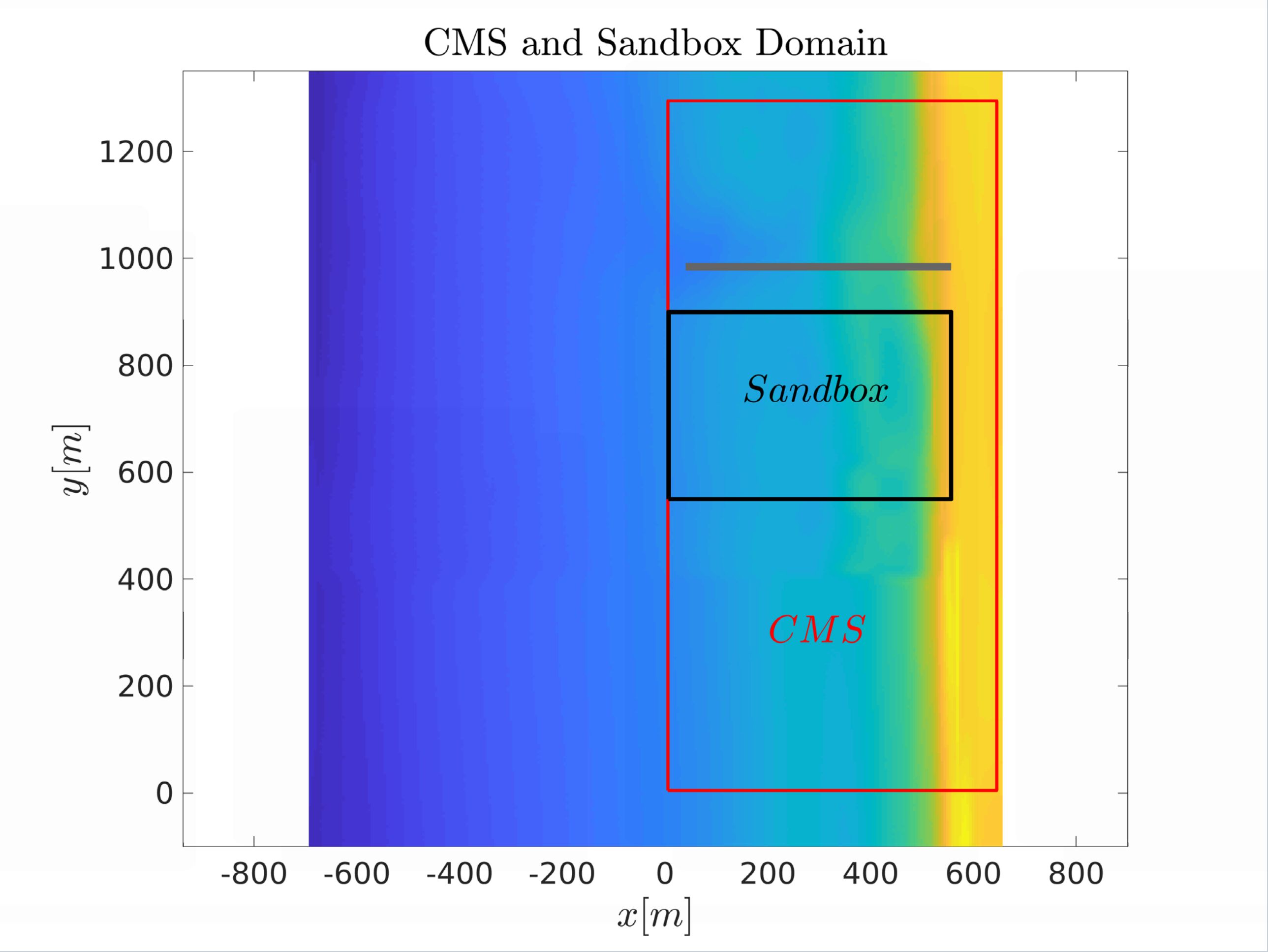
Morphodynamics Scale vs Waves
$\sqrt{H_s g}$
$RMS\{\frac{\partial z}{\partial t}\}$
$\sqrt{H_s g}$ $[m/s]$
0
1
2
3
4
5
6
7
09/27
10/04
10/11
10/18
10/25
10/01/15
10/09/15
10/15/15
10/20/15
10/21/15

FRF/C2SHORE



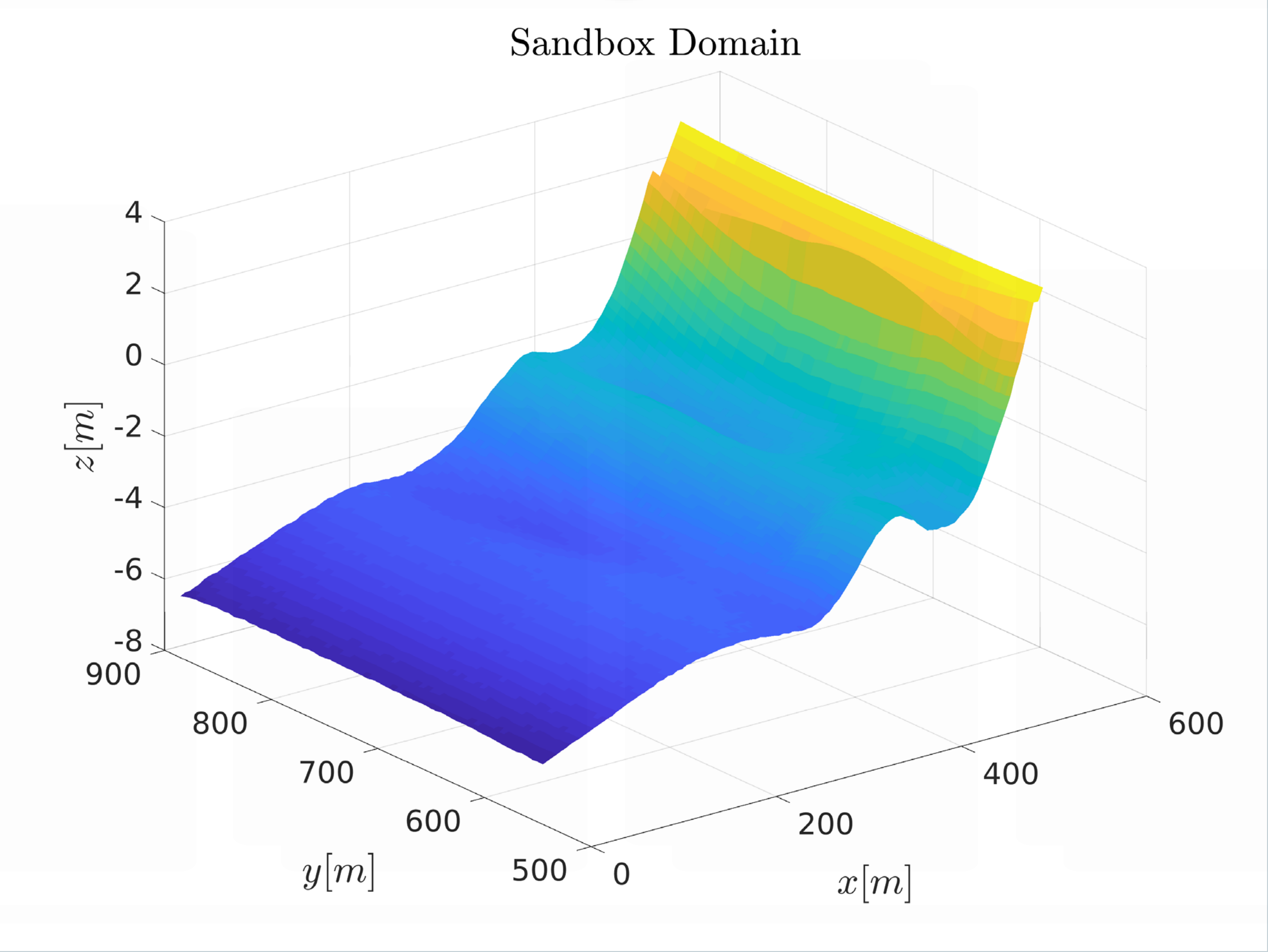
Offshore Waves
$H_s [m]$
4
2
0
$T_p [s]$
10
8
6
$\alpha [deg]$
20
10
0
-10
10/01
10/02
10/03
10/04
10/05
10/06
10/07
10/08
10/09
10/10

FRF/C2SHORE

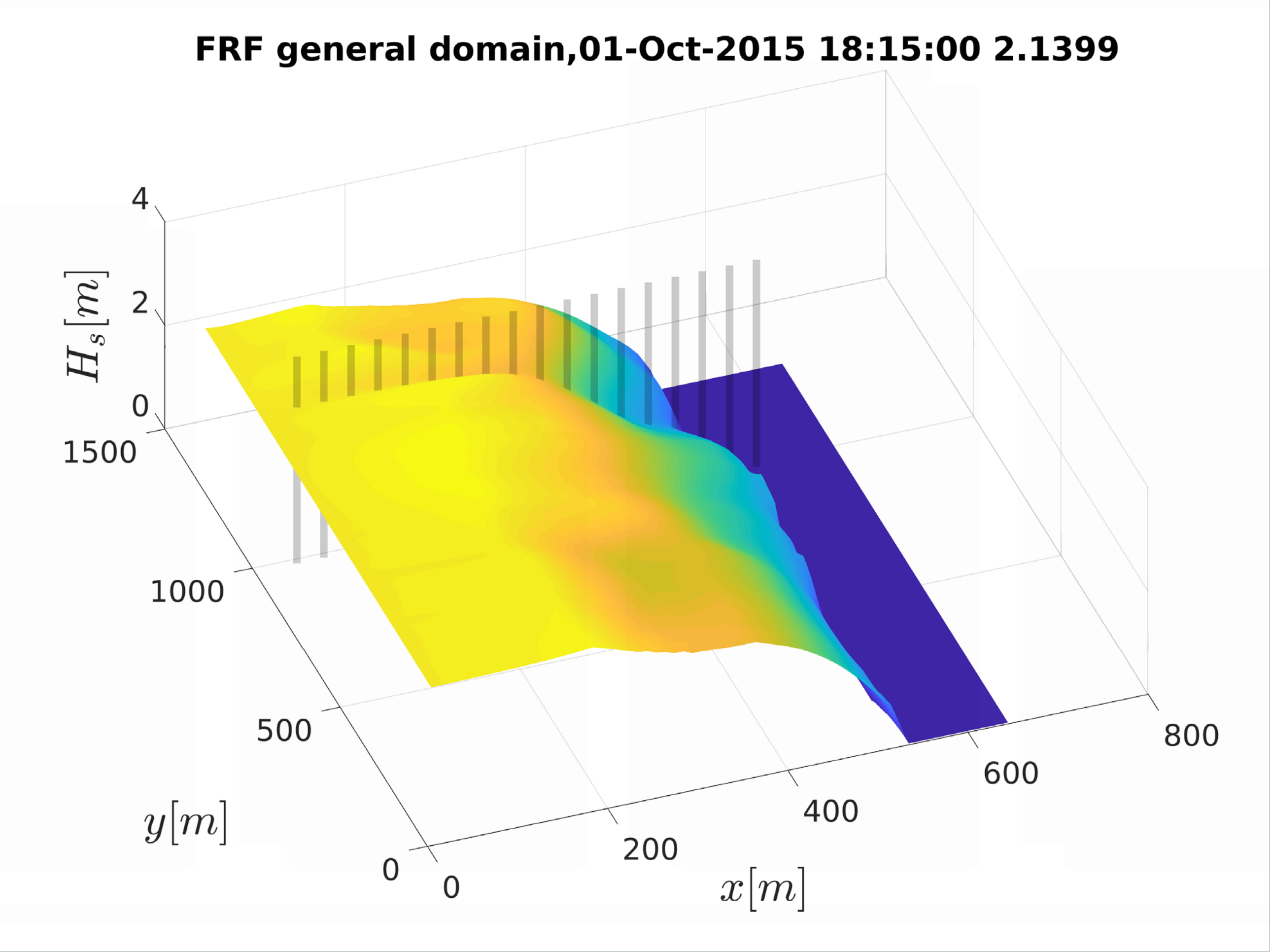


CMS and Sandbox Domain
1200
1000
800
600
400
200
0
y[m]
-800
-600
-400
-200
0
200
400
600
800
x[m]
Sandbox
CMS

FRF/C2SHORE

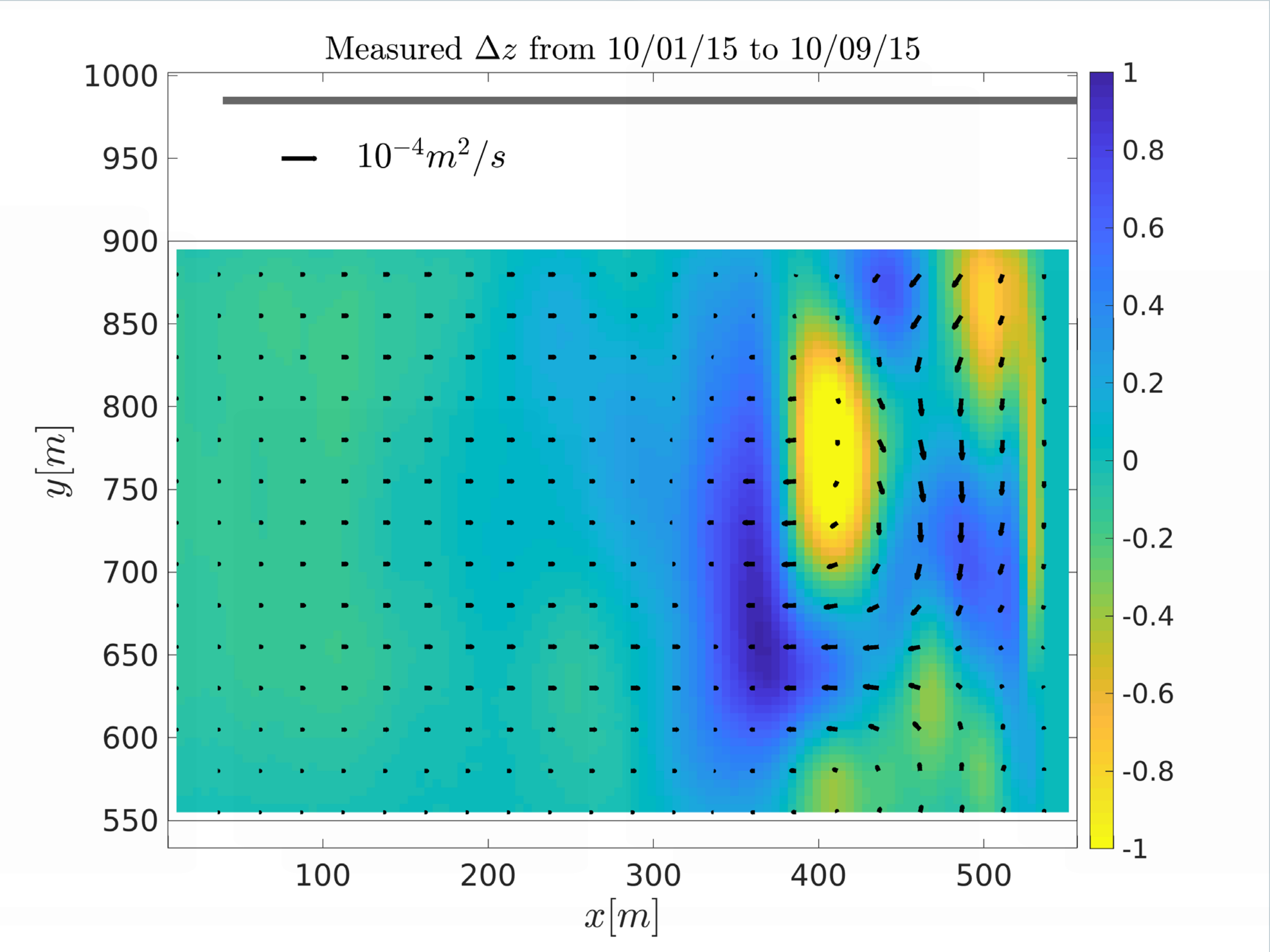

Sandbox Domain
4
2
0
-2
-4
-6
-8
$z[m]$
900
800
700
600
500
$y[m]$
0
200
400
600
$x[m]$

FRF/C2SHORE



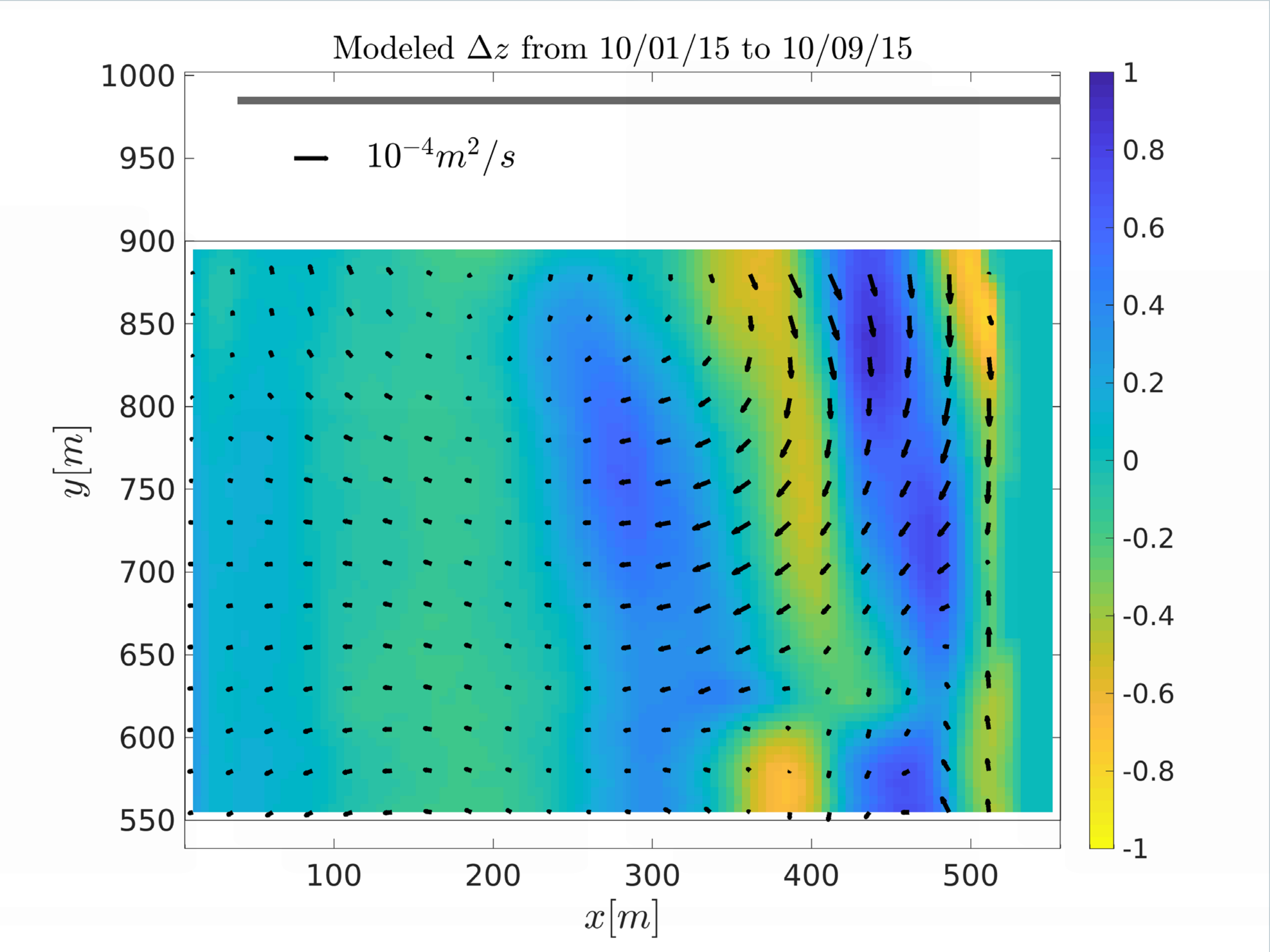
FRF general domain,01-Oct-2015 18:15:00 2.1399
$H_s[m]$
4
2
0
1500
1000
500
0
$y[m]$
0
200
400
600
800
$x[m]$

FRF/C2SHORE



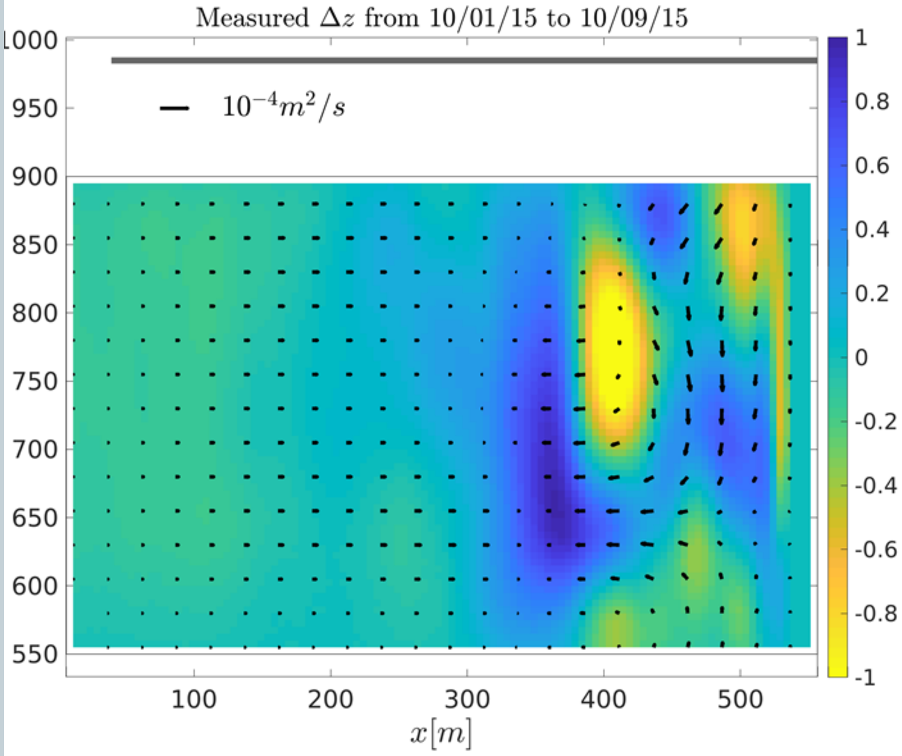
Measured Δz from 10/01/15 to 10/09/15
10^-4 m^2/s
1000
950
900
850
800
750
700
650
600
550
y[m]
100
200
300
400
500
x[m]
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

FRF/C2SHORE

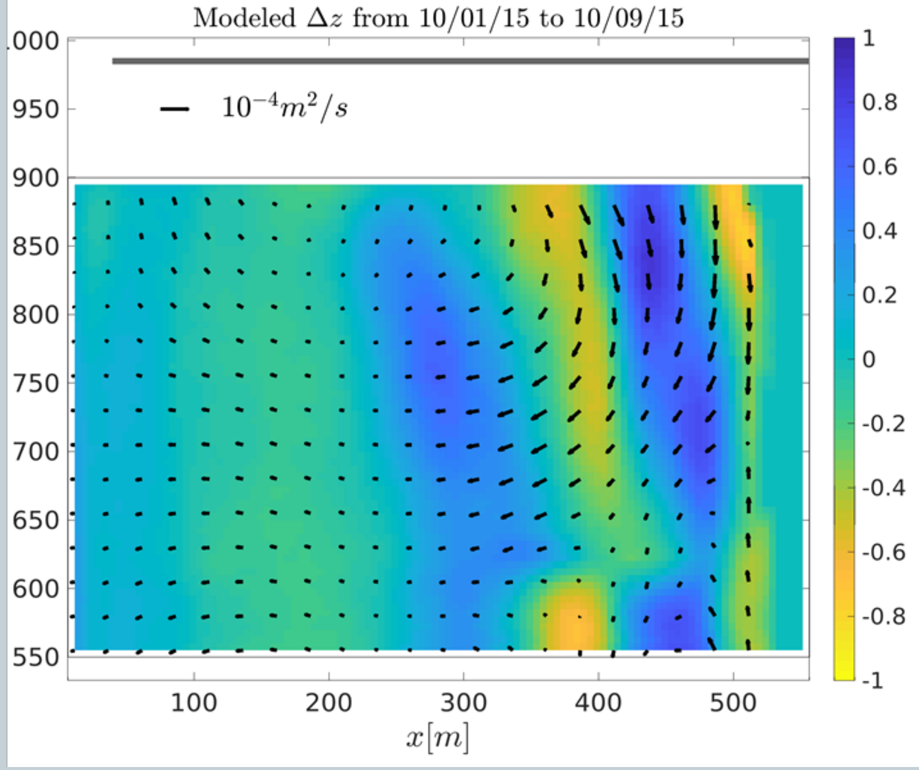


Modeled Δz from 10/01/15 to 10/09/15
1000
950
900
850
800
750
700
650
600
550
y[m]
100
200
300
400
500
x[m]
10^-4 m^2/s
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

FRF/C2SHORE

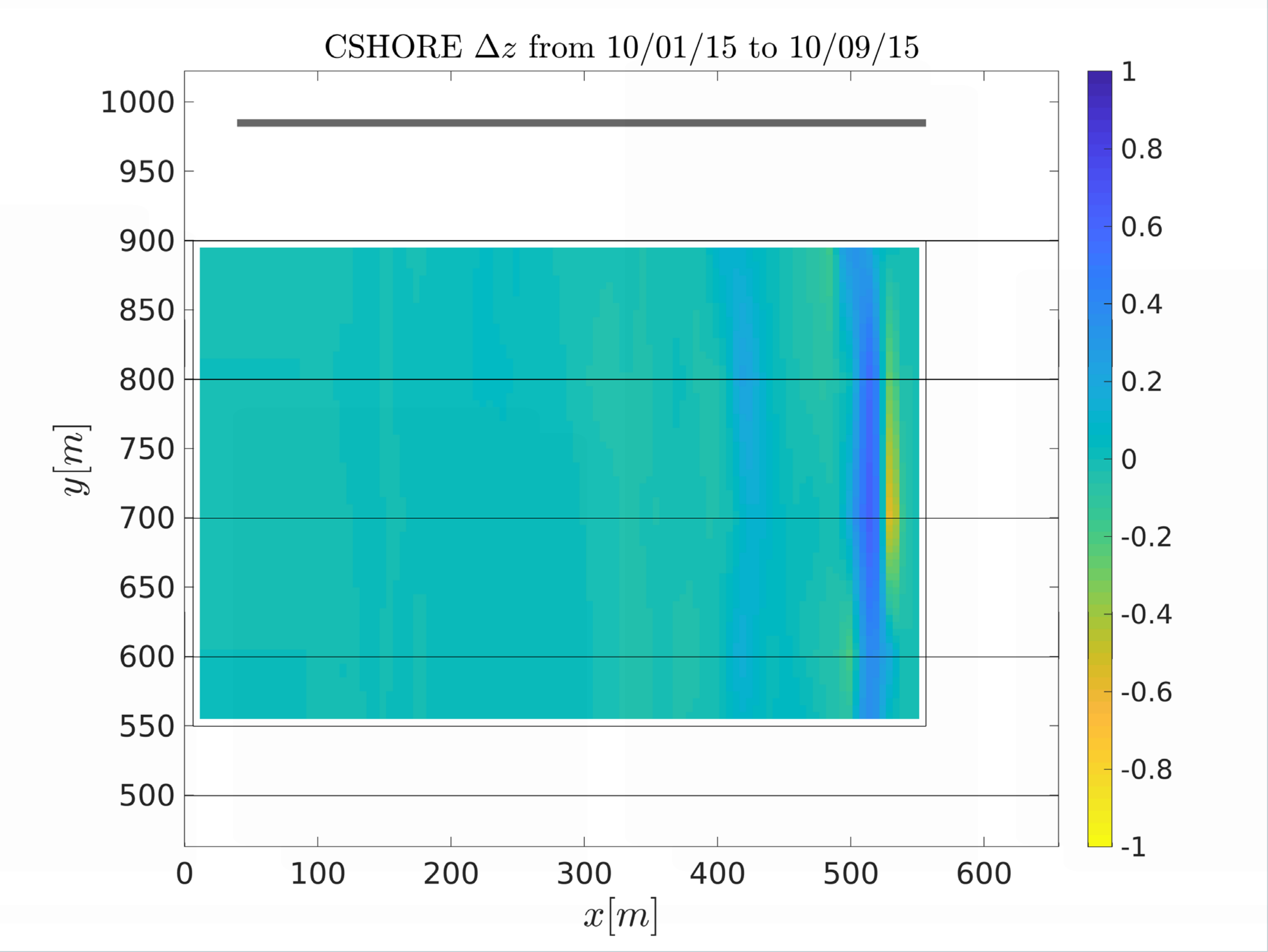


Measured Δz from 10/01/15 to 10/09/15
$10^{-4}m^2/s$
1000
950
900
850
800
750
700
650
600
550
100
200
300
400
500
x[m]
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1



Modeled Δz from 10/01/15 to 10/09/15
$10^{-4}m^2/s$
1000
950
900
850
800
750
700
650
600
550
100
200
300
400
500
x[m]
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

FRF/C2SHORE



CSHORE Δz from 10/01/15 to 10/09/15
1000
950
900
850
800
750
700
650
600
550
500
y[m]
0
100
200
300
400
500
600
x[m]
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

Conclusions

- CMS-C2SHORE is settling to stable version
- High-quality lab data provides opportunity to fix free params
- No guarantee of generality
- FRF data provide another comparison
- With some assumptions, a field of transport can be calculated
- 1D model shows some skill in dune erosion
- CMS/C2SHORE predicts fabulously complex transport patterns (current advection and wave-related part important)
- The divergence(wave-transport)+pickup+fallout results in accurate bed-level changes
- Cross-shore model has no skill in bathy changes
- Working with FRF on data needs