Development of 2DH Swash Model in CMS

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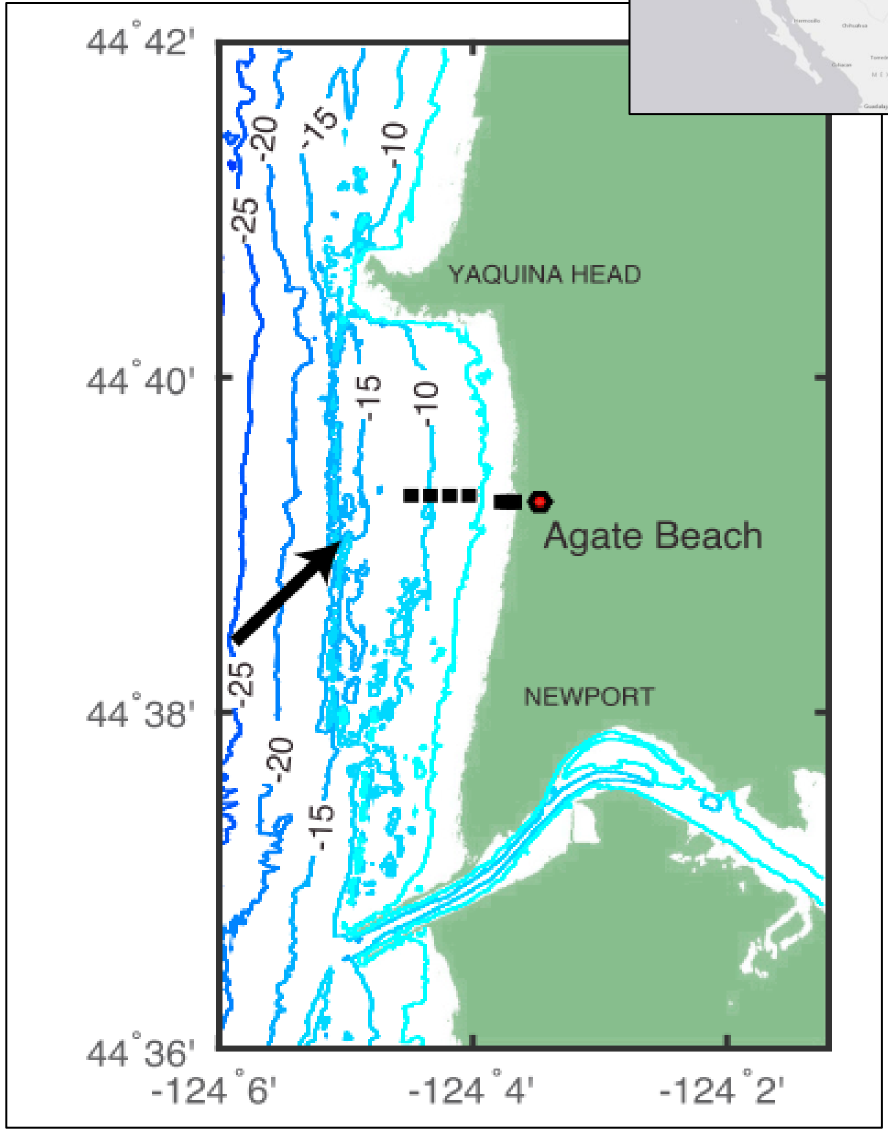
September 28, 2021

- Data introduction
- Surf zone data comparison
- Swash formulation
- Runup data/model
- Future work

Agate Beach Data set

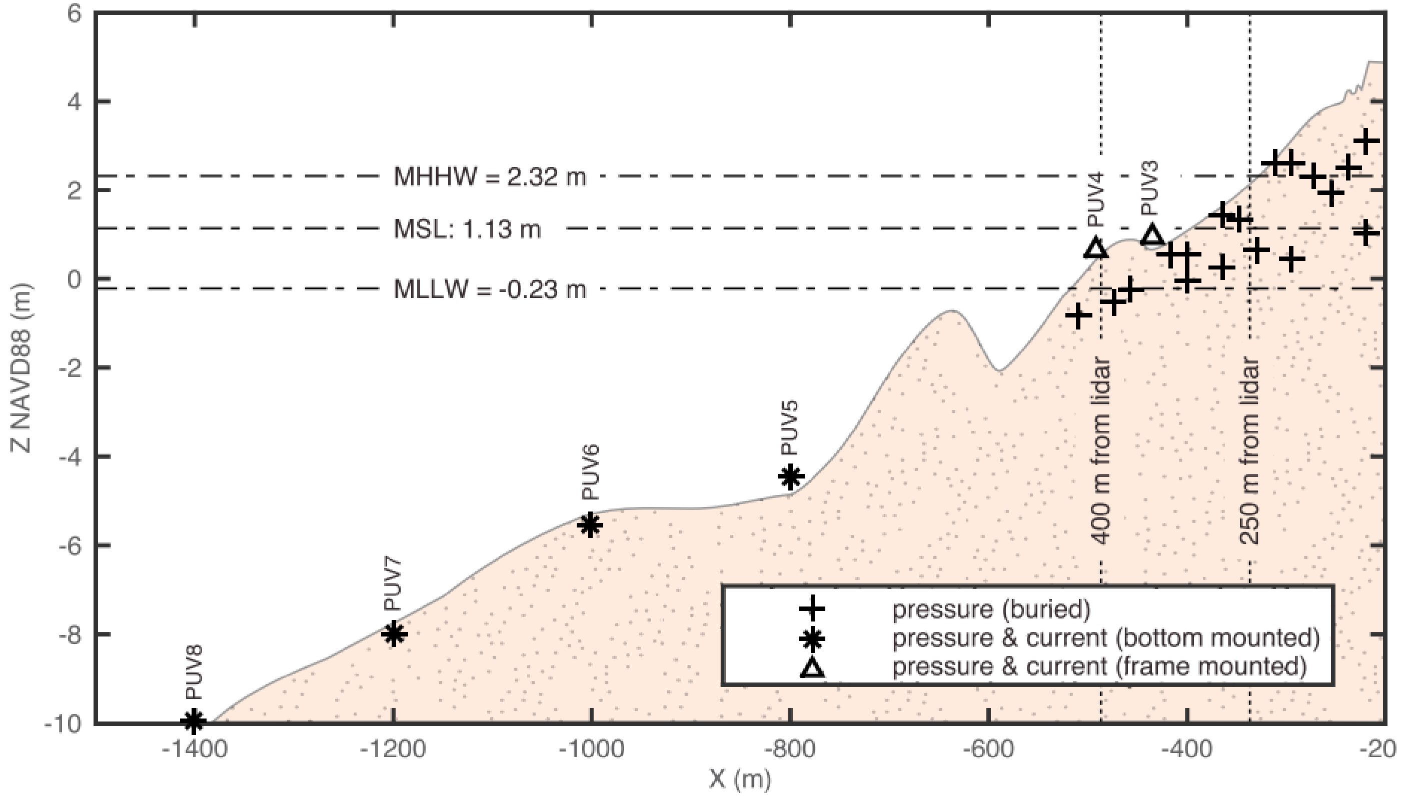
- Observations collected between 9/19 and 11/2, 2013
- Tidal range ~ 2 m
- Offshore wave heights ranged from 1.2 m – 4.7 m and peak period from 10 s -- 16.6 s
- Topobathymetry measured in cross-shore transects w/ GPS-equipped ATV, dolly, and jetski
- Mild slope (1/50 – 1/70)

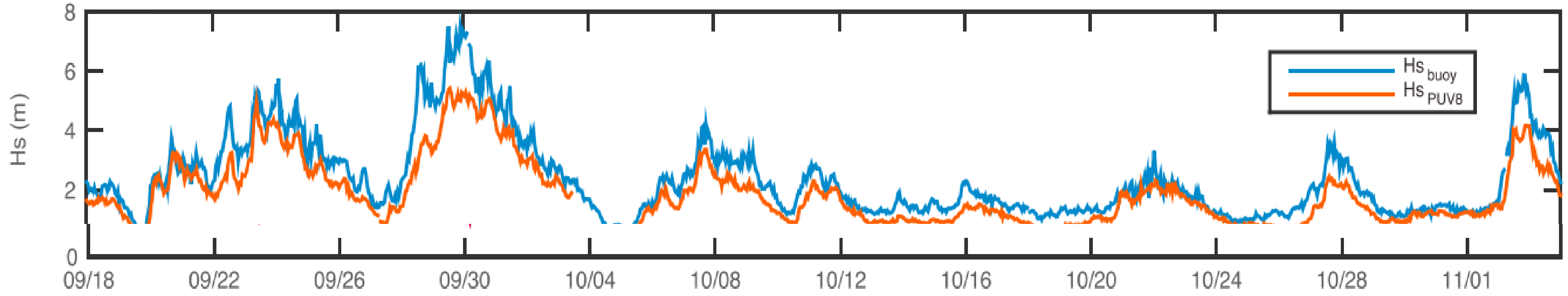


Fiedler, J. W., Brodie, K. L., McNinch, J. E., & Guza, R. T. (2015). **Observations of runup and energy flux on a low-slope beach with high-energy, long-period ocean swell**. Geophysical Research Letters, 42(22), 9933–9941.

Agate Beach data set

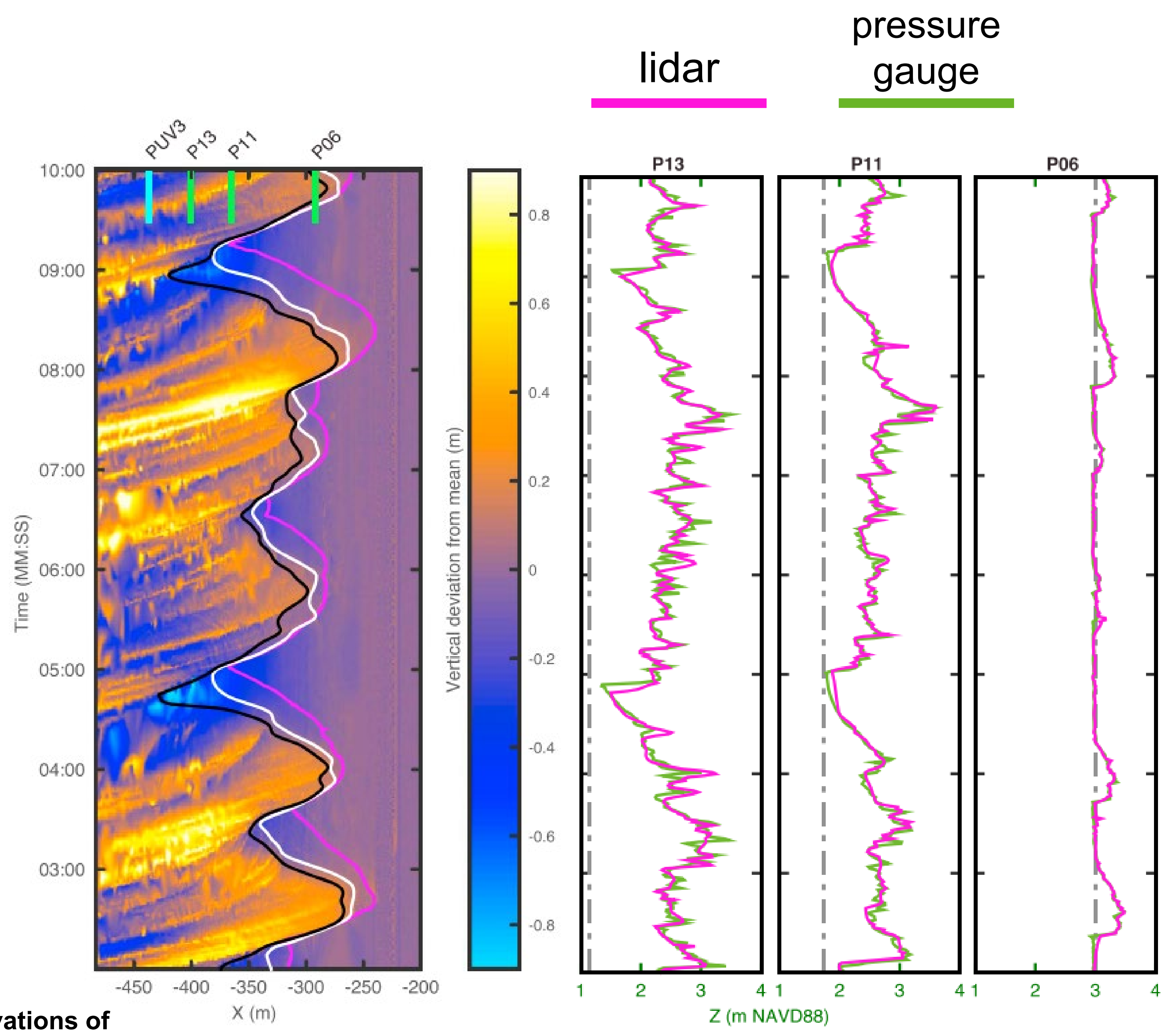
- 18 pressure sensors
  - Between -1 m and +3 m NAVD88
  - fs = 2 Hz
- 9 frame mounted PUV sensors
  - Between MSL and h=11 m
  - Controlled for shore normality
  - Deviated less that 30% from linear waves
  - Removed energetic nearshore eddy motions





Agate Lidar data

- Narrow beam, 1550 nm wavelength lidar
- fs = 7 Hz
- Lidar scans were rectified with independently surveyed targets
- Some noise due to long range (400 m)



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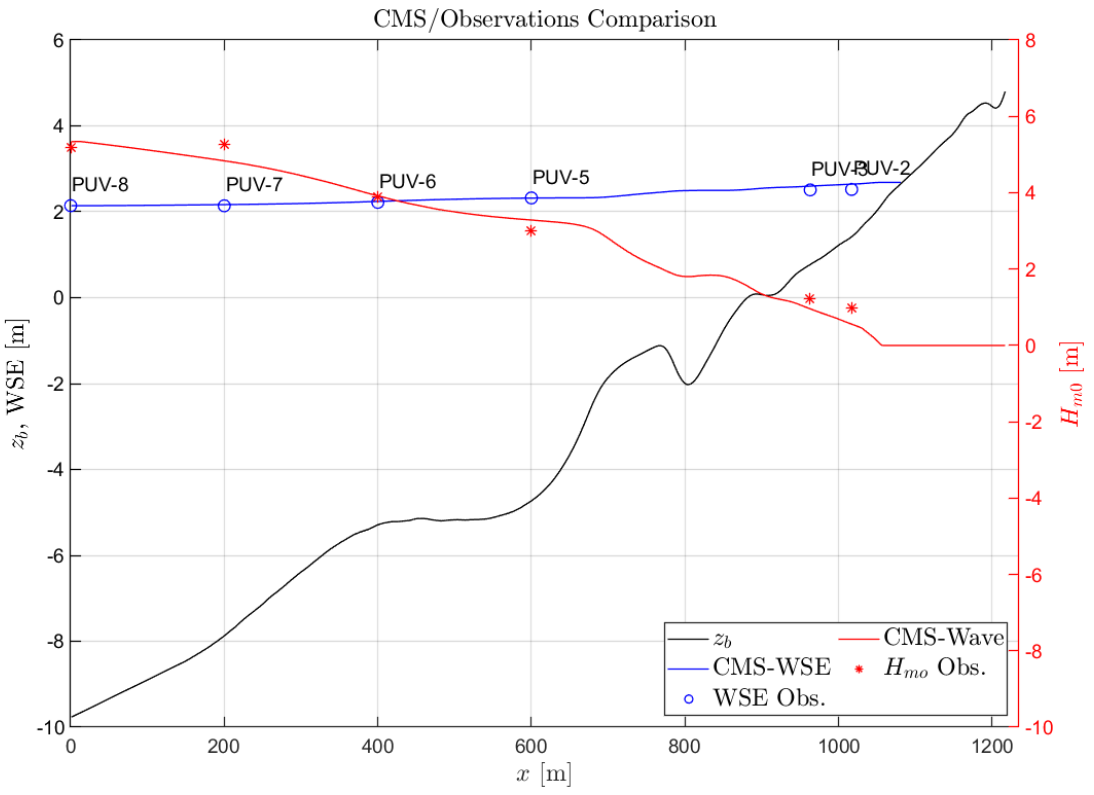
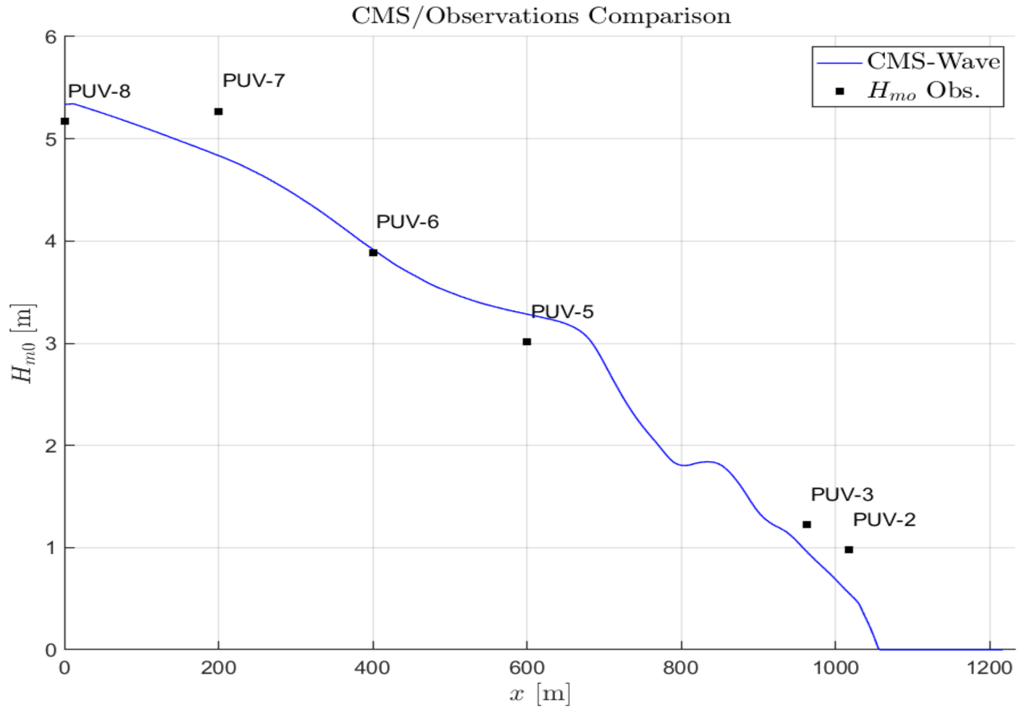
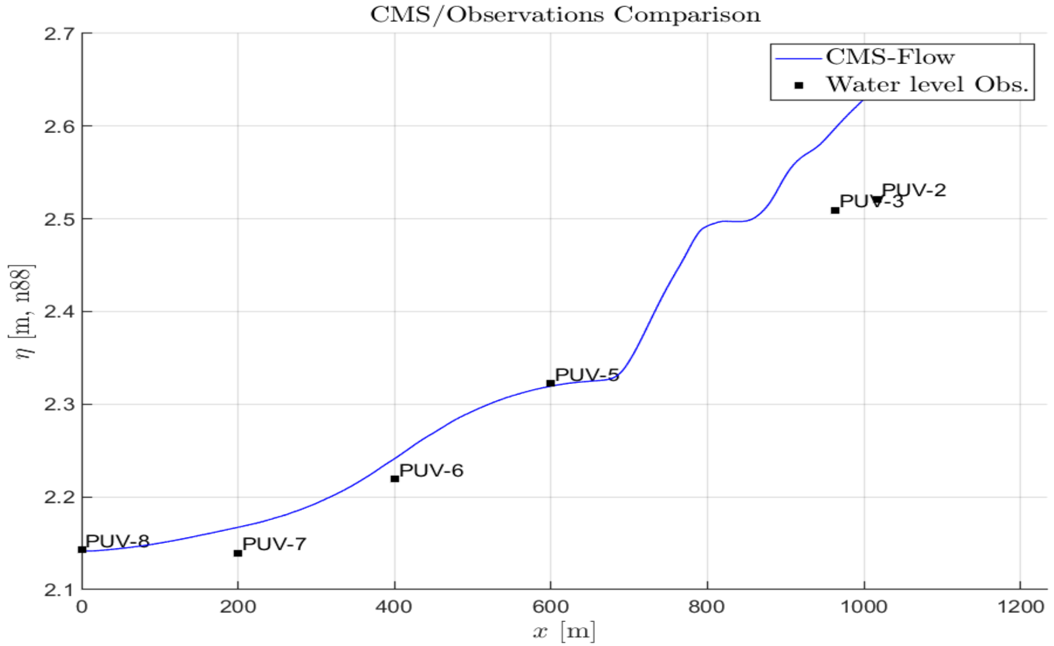
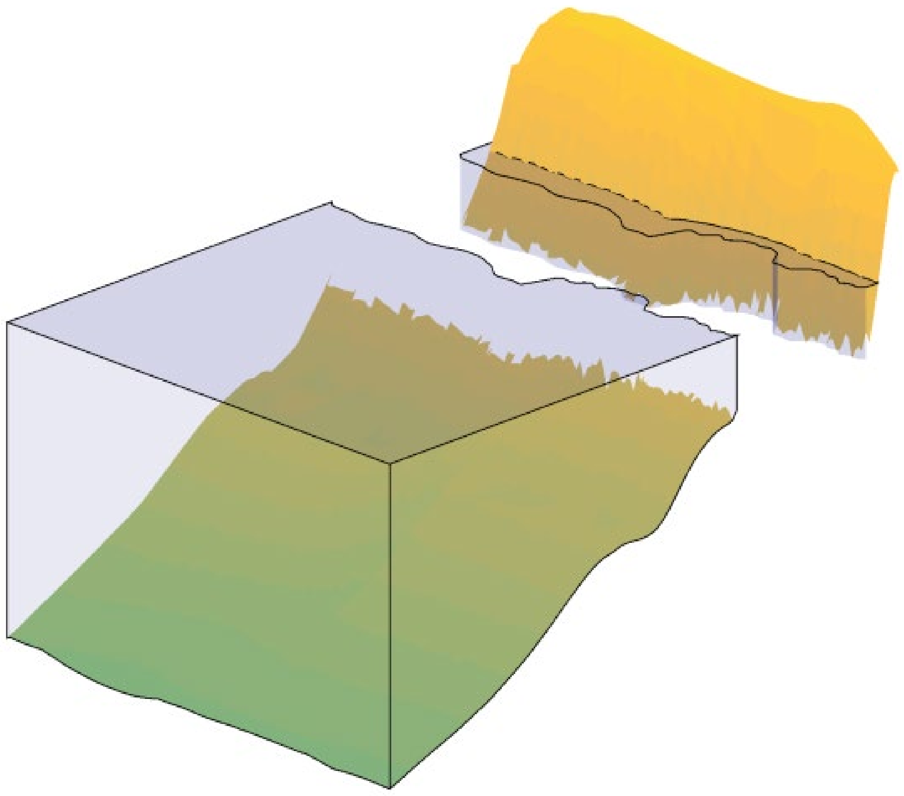
Results: Case A1







Swash Modeling



CMS SWASH Extension:

- Instantaneous
- Wave and currents are combined
- Demarcation is a minimum depth (under revision at present)
- Hydrodynamics are one-way coupled, appropriate for simulations with low current at interface.
- Transport is two-way coupled
- Bed conservation is rigid
- Simplified propagation model:

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

- Necessarily dependent on empirical data

Swash Modeling

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

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

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

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

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

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: $$U \sim \sqrt{g\overline{h}} \qquad M \sim g\overline{h}^2 \sim gH_{rms}^2$$

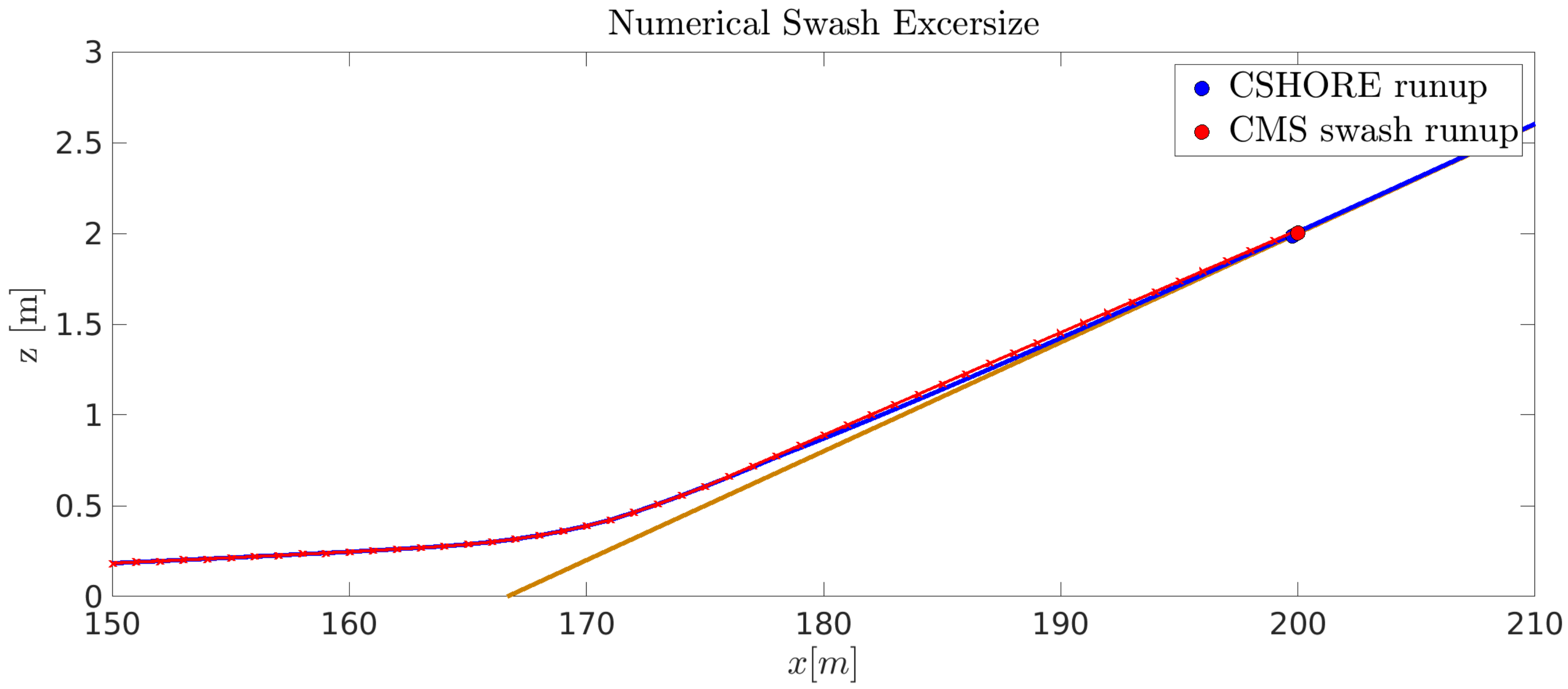
$$M \simeq A_0 g\overline{h}^2 \qquad c_f' g\overline{h} \simeq c_f\overline{|U_s|U_s}$$

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

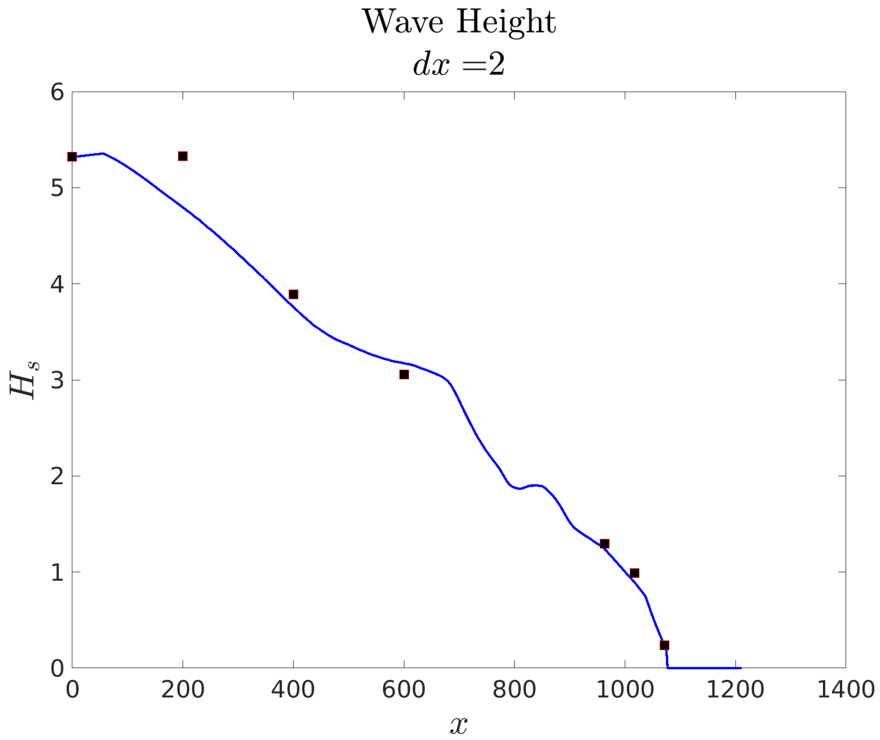
$$S_{xx} \sim g\overline{h}^2$$

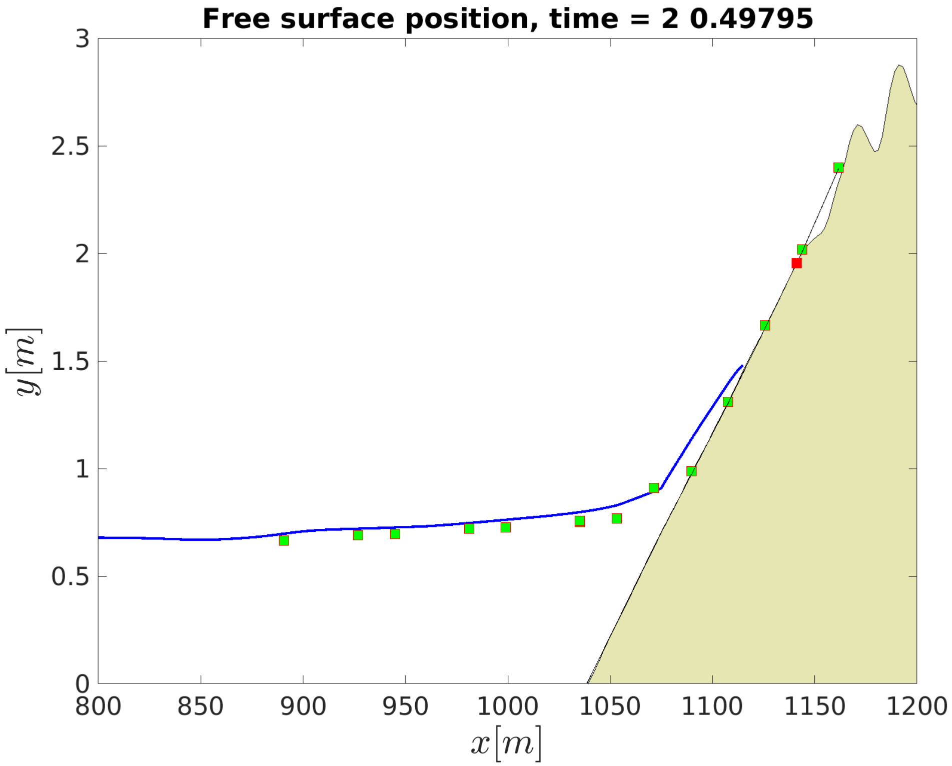
Swash Modeling

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

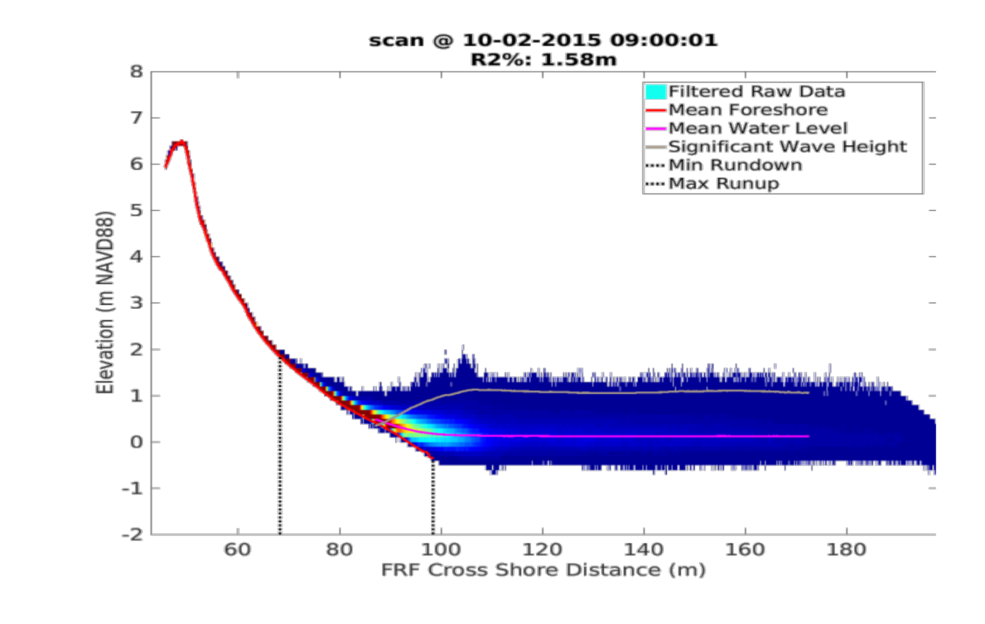


Agate Modeling





Continuous Dune Lidar Tower, used at Agate and FRF

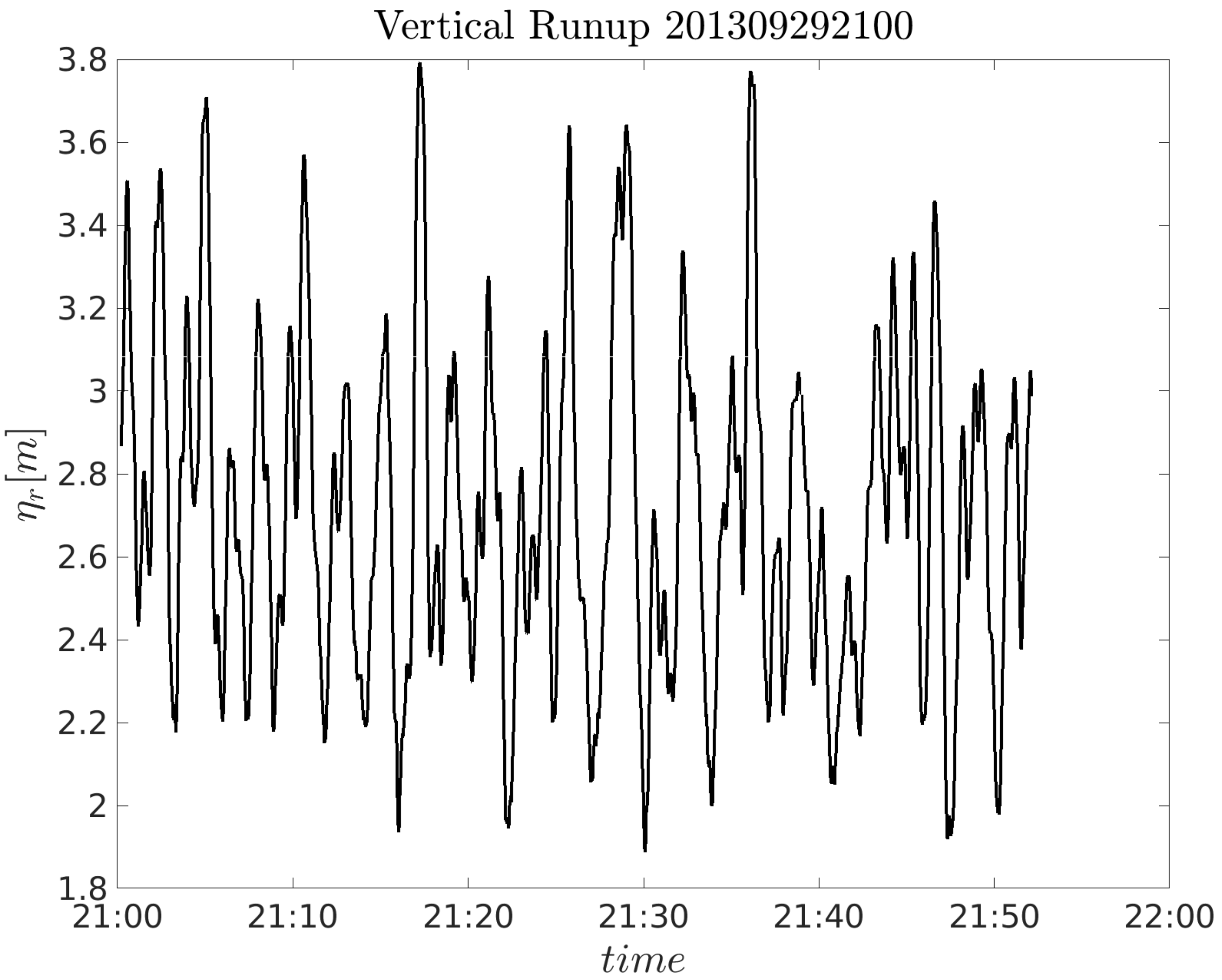


Simultaneous observations of Wave Runup, Swash Hydrodynamics, Morphology Change

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

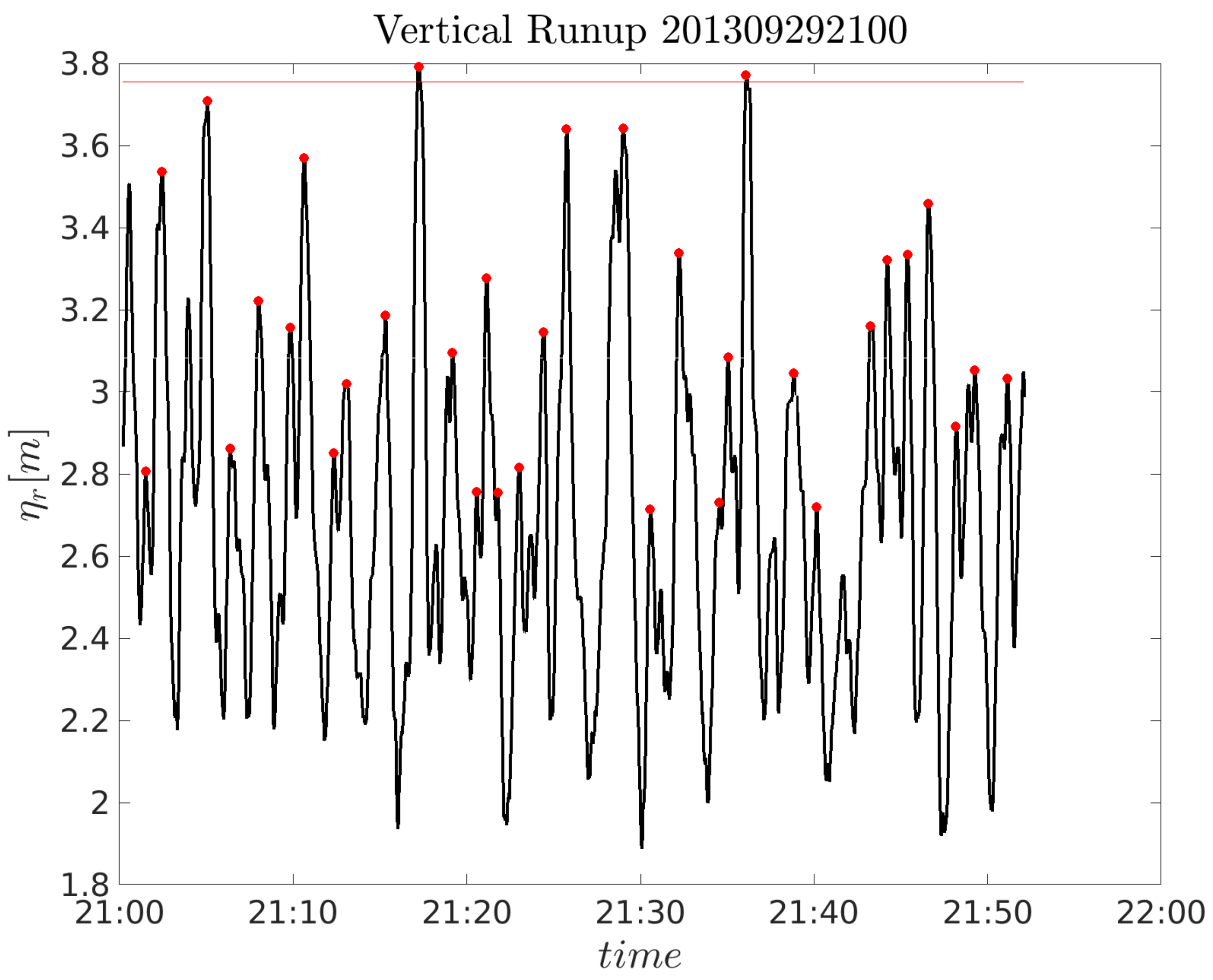
Swash Modeling

- Phase-averaged hydrodynamics are only part of the answer—and it not what the users are asking
- Time-series of instantaneous wet/dry interface
- LF: about T~90s



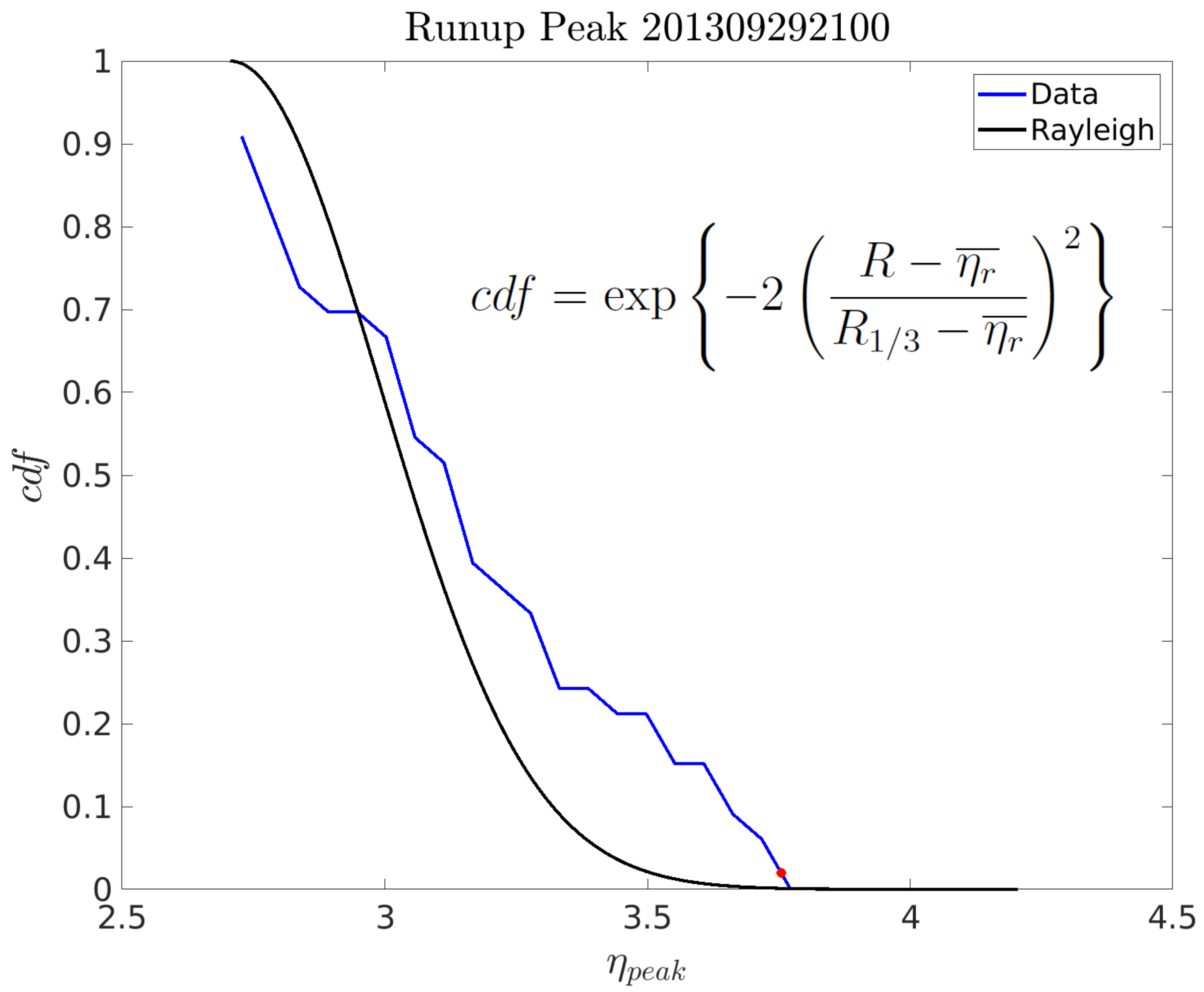
Swash Modeling

- No user asks me for distributions of h but are looking for for $R_{2\%}$ or R_s
- Despite an hour of data here, only 33 waves, so stats are less robust
- $R_{2\%}$ shown and based on a continuous cdf from data



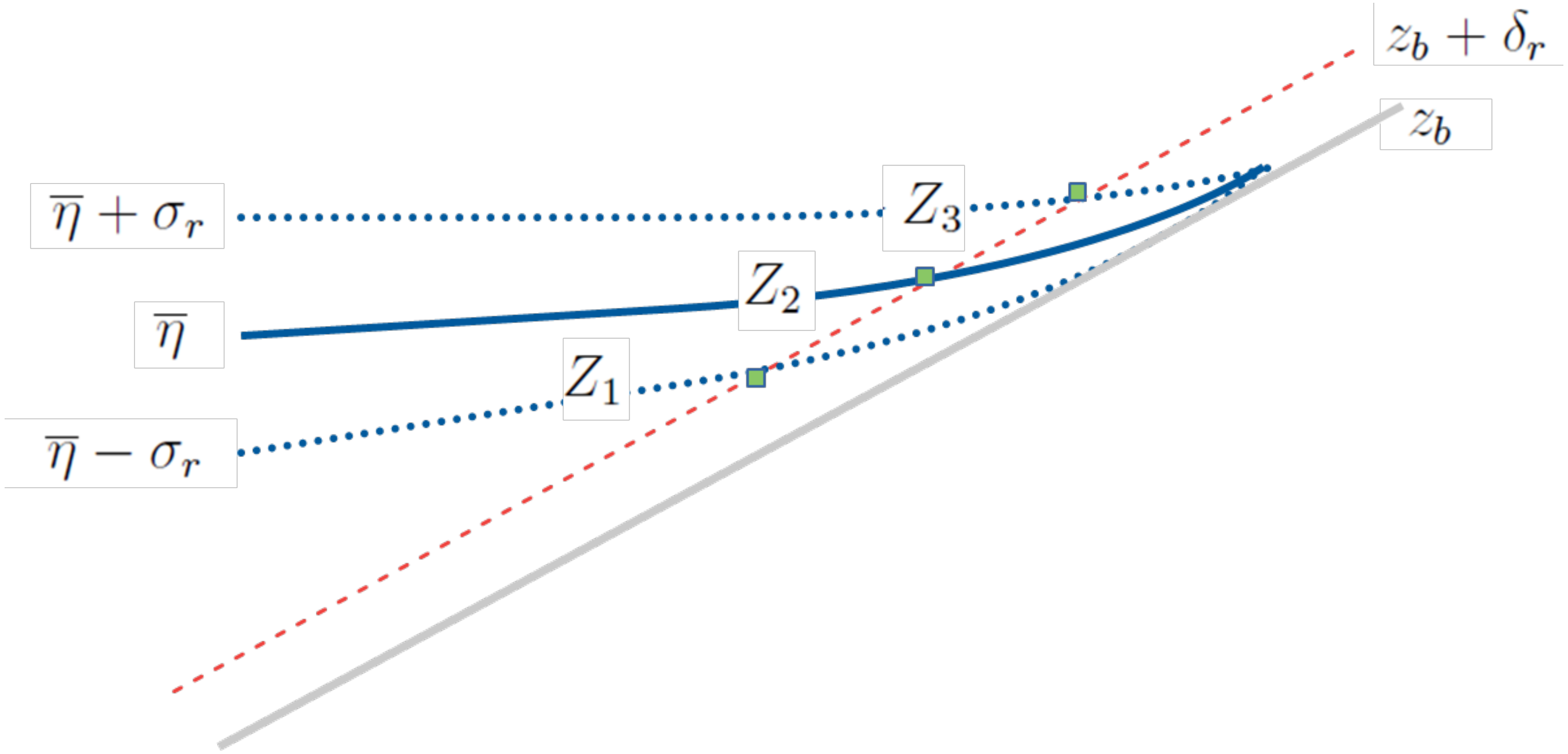
Swash Modeling

- We require some theoretical description of the peak runup distribution order to generalize results
- We use geometric trick to get parameters and then rely on Rayleigh dist to complete the suite
- data/model differences are significant, particularly in the larger runup peak tail
- Data pdf is more uniform leading to cdf that is nearly linear.



Swash Hydro to Runup Stats

- Runup stats from hydro field is based on CSHORE method
- A geometric argument based on intersection points of numerical runup wire and hydro curves
- Runup height of 10cm corresponds to the value used in analyzing the lidar data



Swash Hydro to Runup Stats

$$\overline{\eta_r} = (Z_1 + Z_2 + Z_3)/3$$

where

$$R_{1/3} = \overline{\eta_r} + (2 + \frac{\partial\, z_b}{\partial x})\sigma_r$$

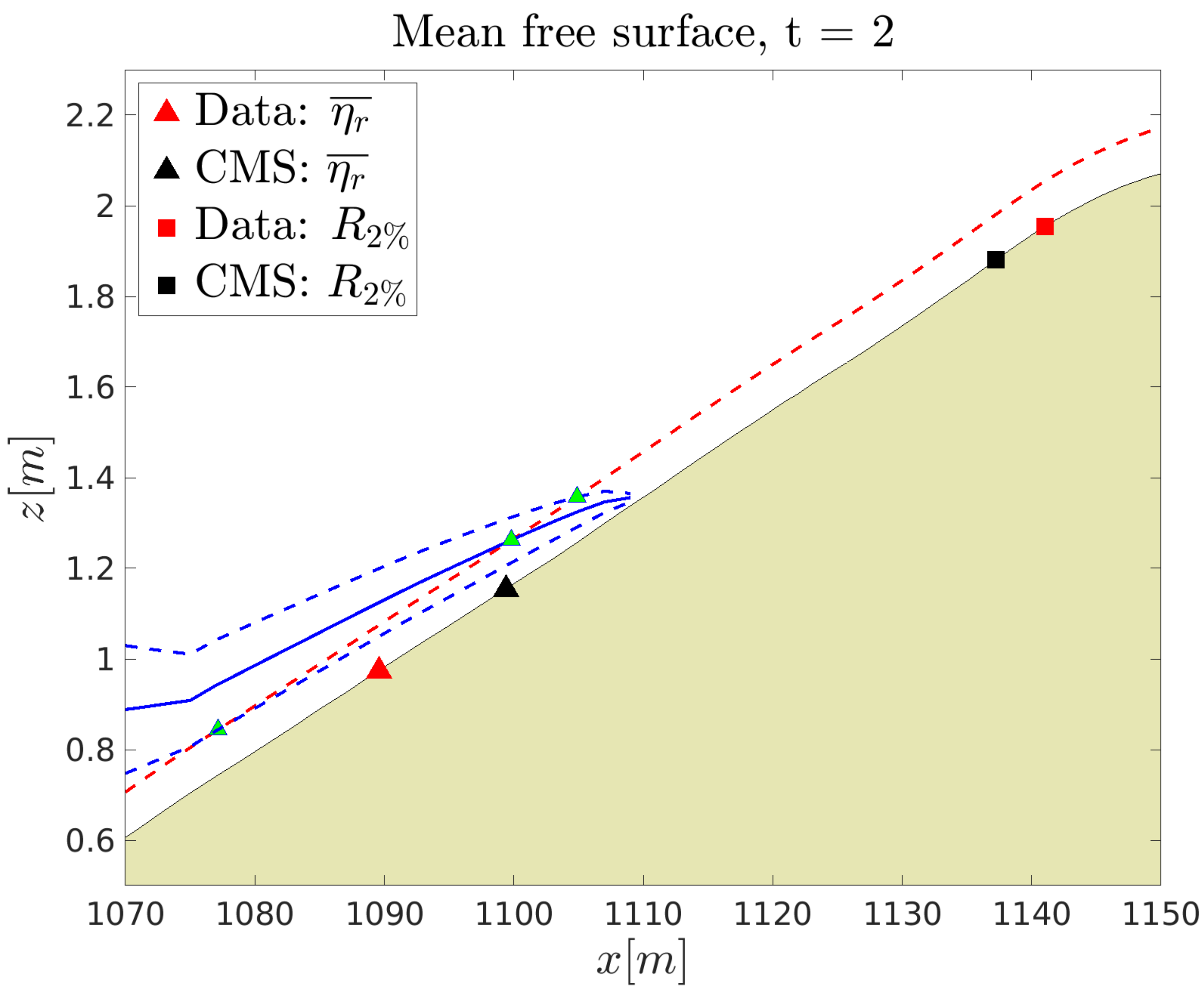
and

$$\sigma_r = (Z_1 - Z_3)/2$$

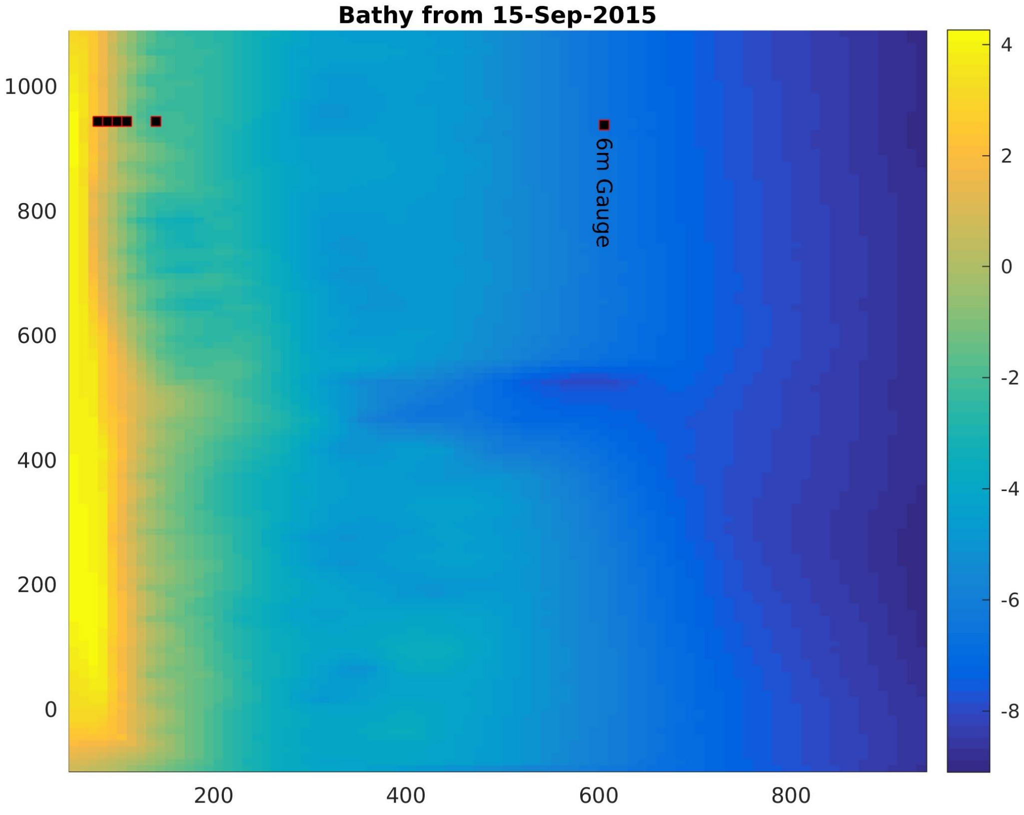
Making use of the Rayleigh-distributed runup peaks:

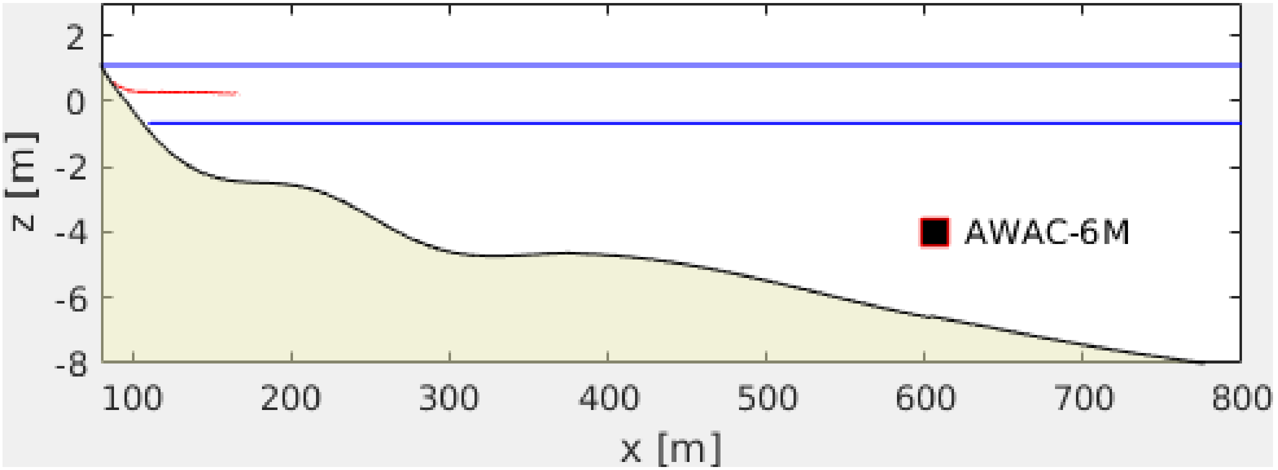
$$R_{2\%} = \overline{\eta_r} + 1.4(R_{1/3} - \overline{\eta_r})$$

Swash Hydro to Runup Stats



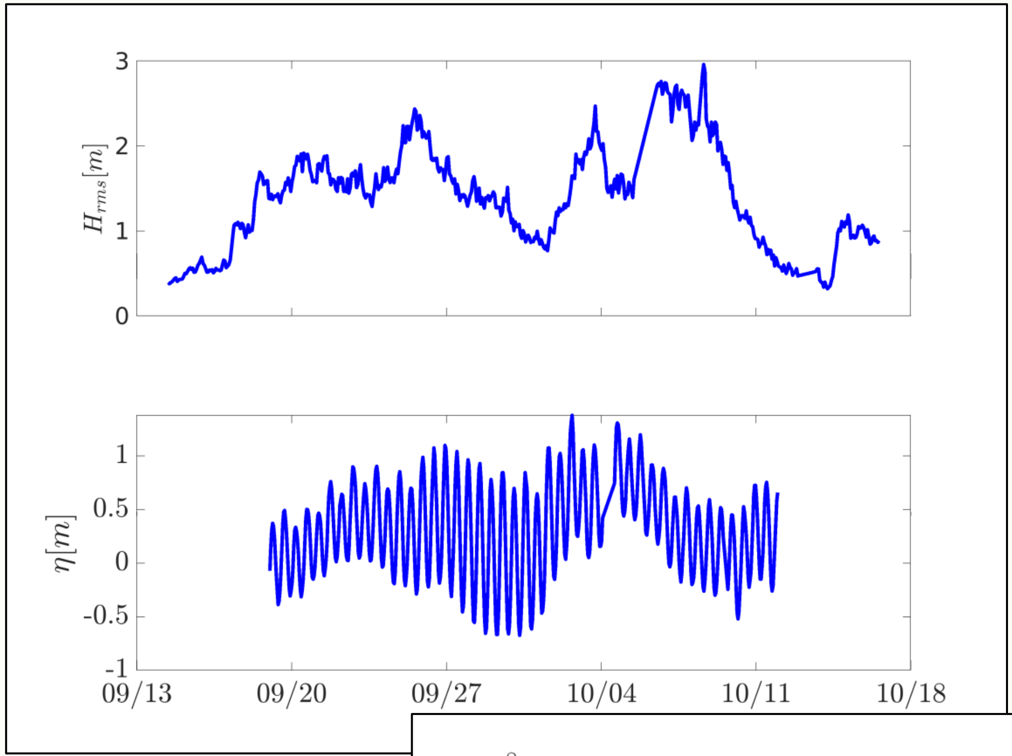
FRF Runup Predictions

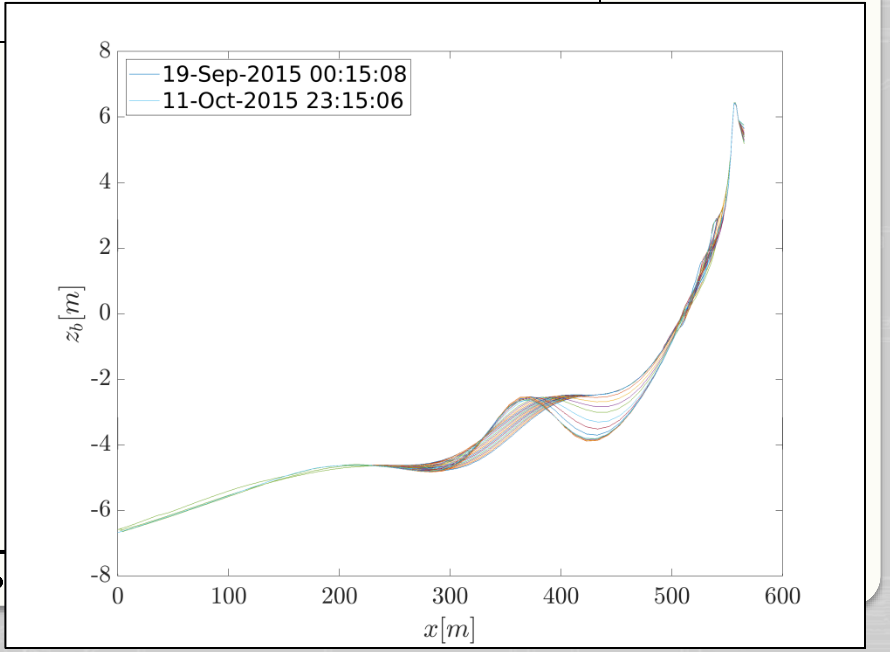




FRF Runup Predictions

- Using three weeks of well-curated data for BC, swash
- Decouple errors due to bottom position inaccuracy by running hourly cases (533 cases) in one dimension with interpolated bathy.
- 2DH swash data are not yet available



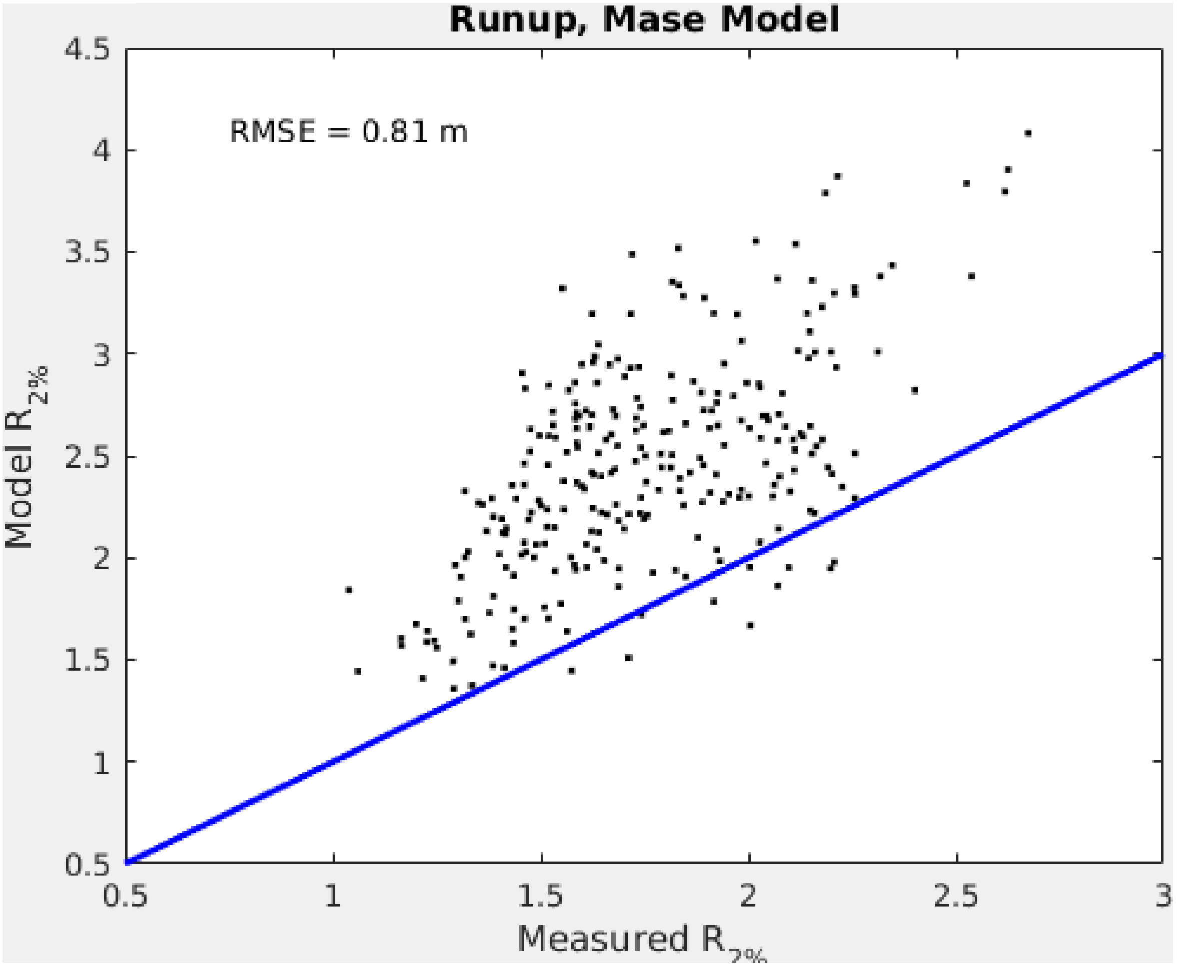


FRF Runup Predictions

$$\frac{R_{2\%}}{H_{mo}} = 1.86\zeta^{0.71}$$

Mase (1989)

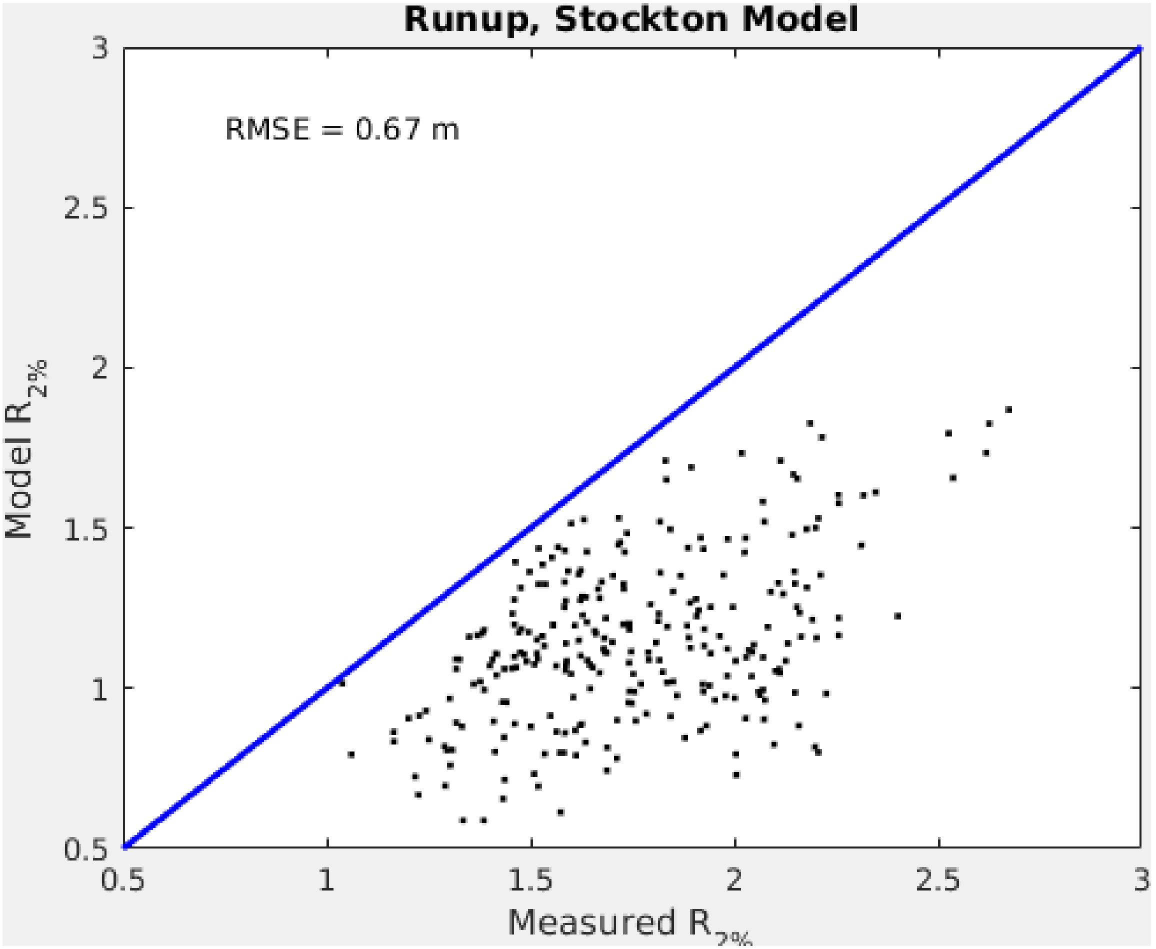
- Just because 'we can' is not a compelling reason to use a complex numerical model



FRF Runup Predictions

$$R_{2\%} = 1.1\left\{0.35\beta_f(H_{mo}L_o)^{1/2} + \frac{1}{2}\left(H_{mo}L_o\left[0.563\beta_f^2 + .004\right]^{1/2}\right\}$$

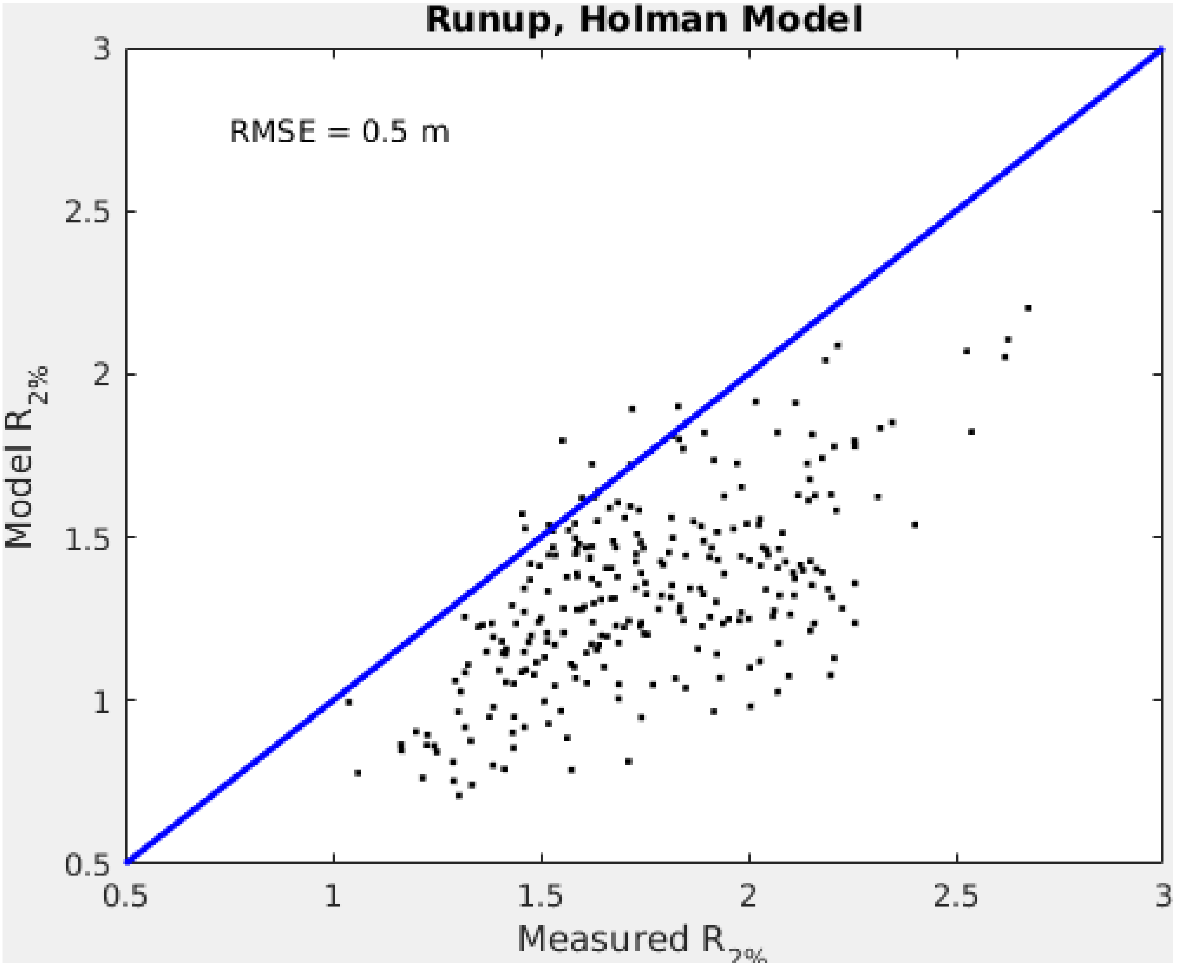
Stockton (2006)



FRF Runup Predictions

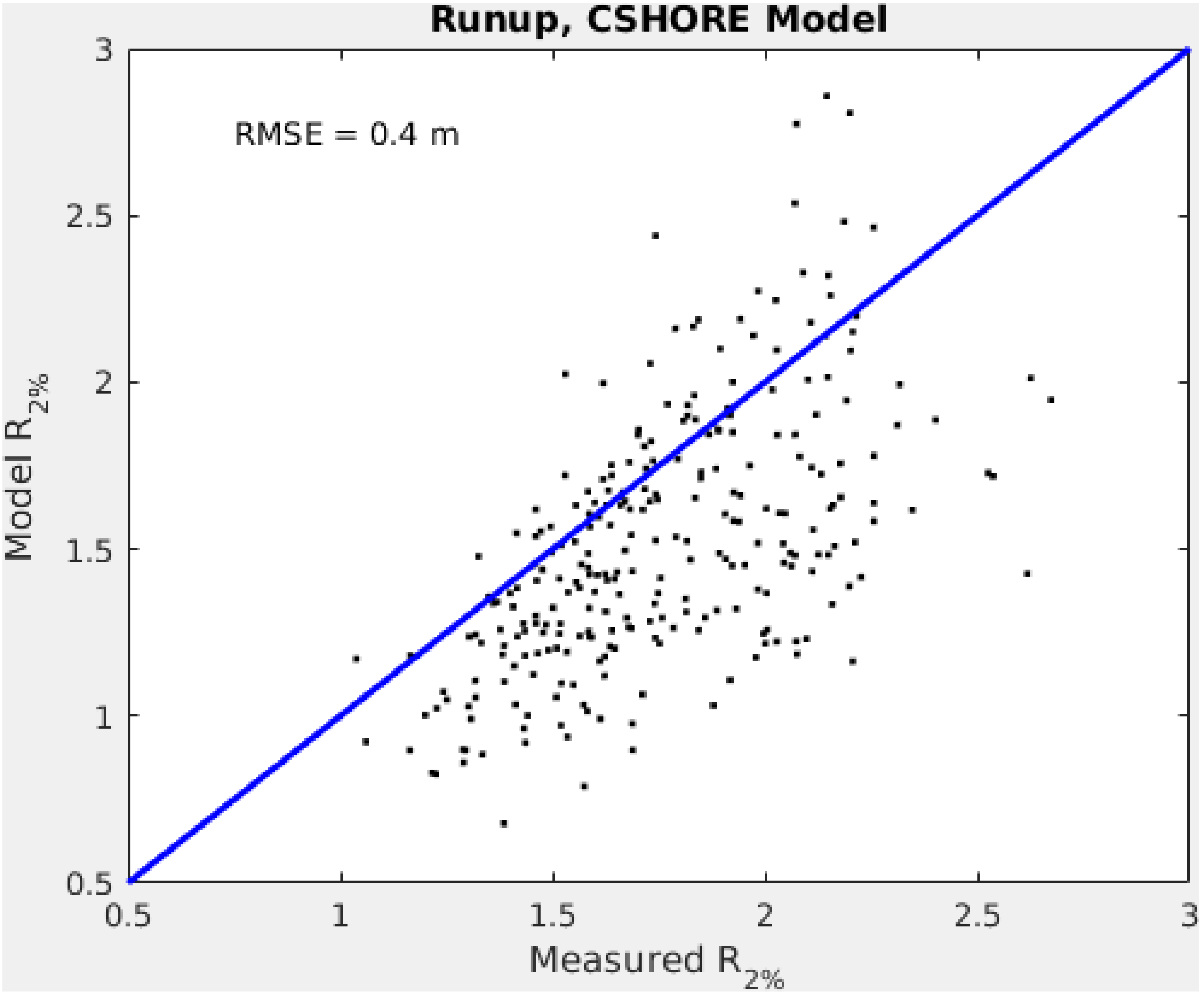
Holman (1986)

$$\frac{R_{2\%}}{H_{mo}} = 0.83\zeta + 0.2$$



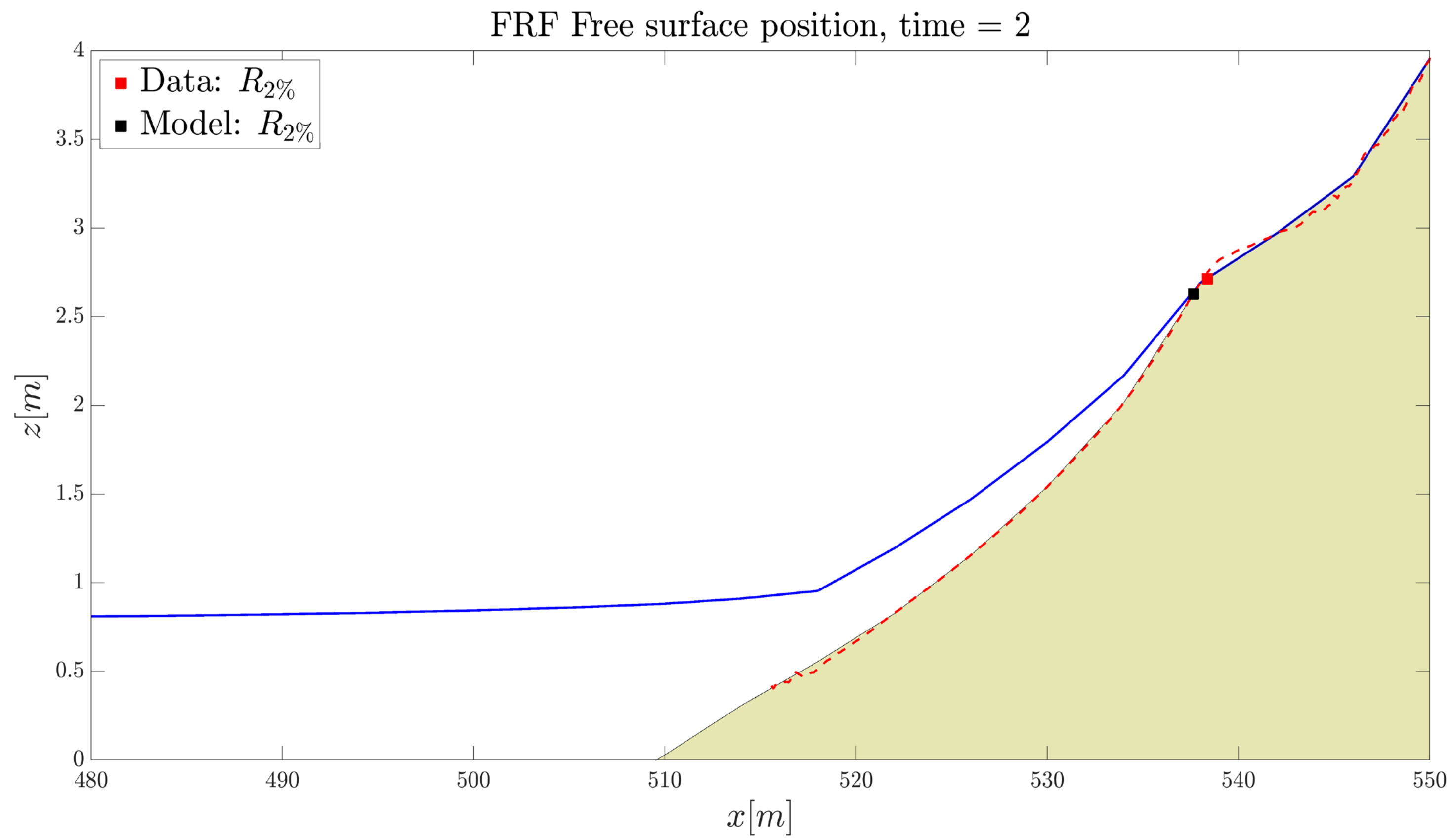
FRF Runup Predictions CSHORE

CSHORE Model



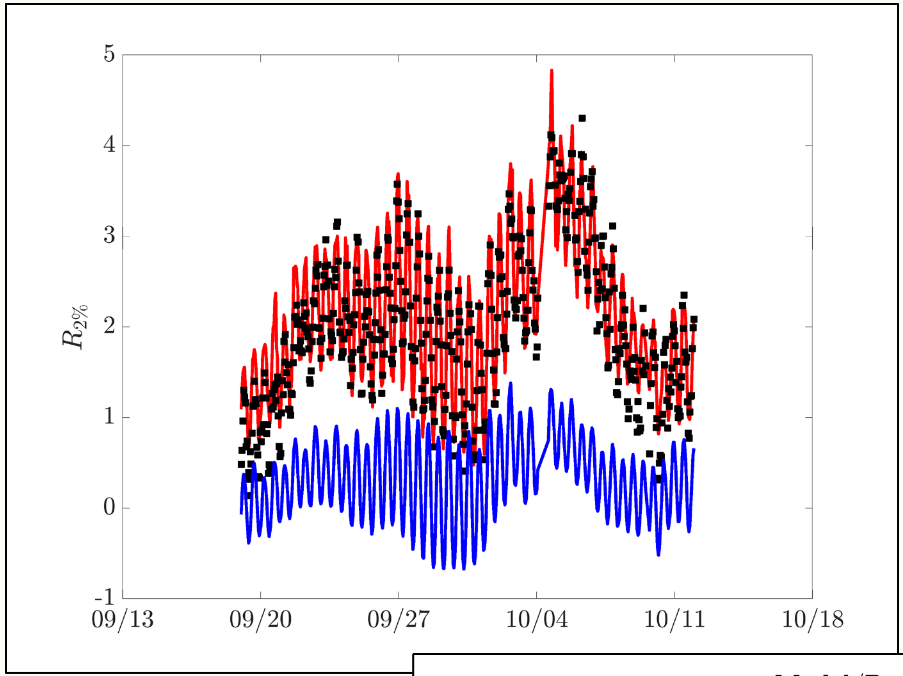
FRF Runup Predictions CMS

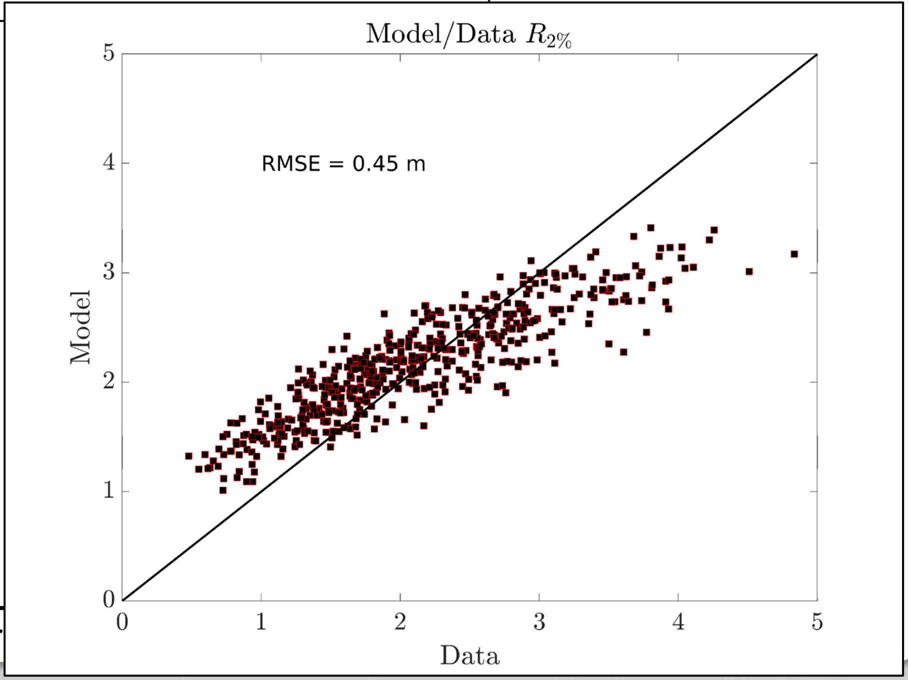
- Using A0 = 5.2
- 533 CMS runs is computationally expensive due to 2DH and transients
- R2% well-predicted
- Some dependence on full/swash boundary



FRF Runup Predictions CMS

- Boundary at $h=h_{min}$
- Runup has water level variation and wind-wave modulation
- Use is made of A0 = 5.2, minimizing error in subsequent model application
- Simple swash propagation method is more efficient, stable, and with similar accuracy when compared with CSHORE.

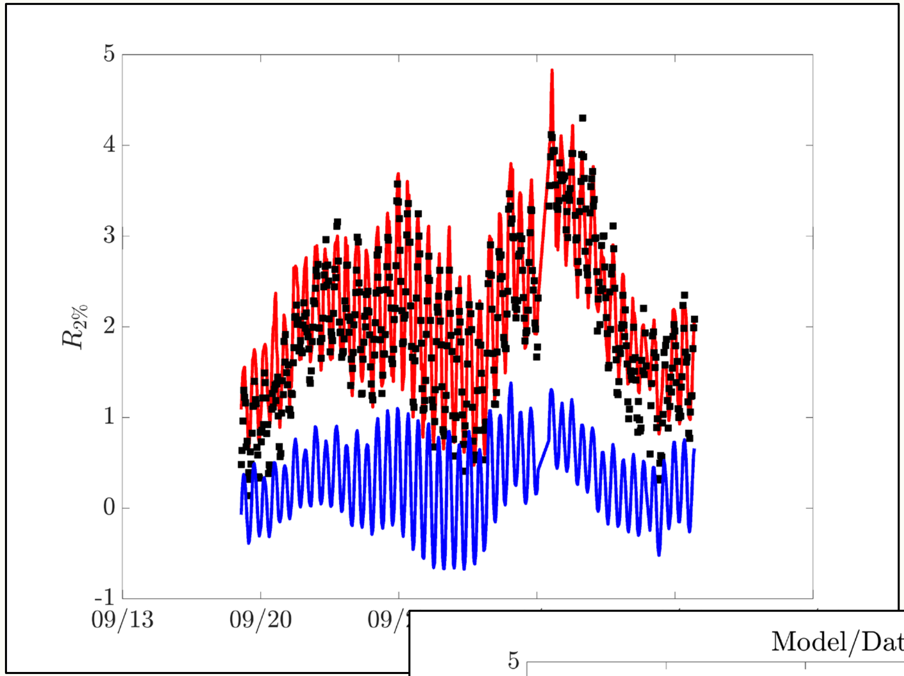


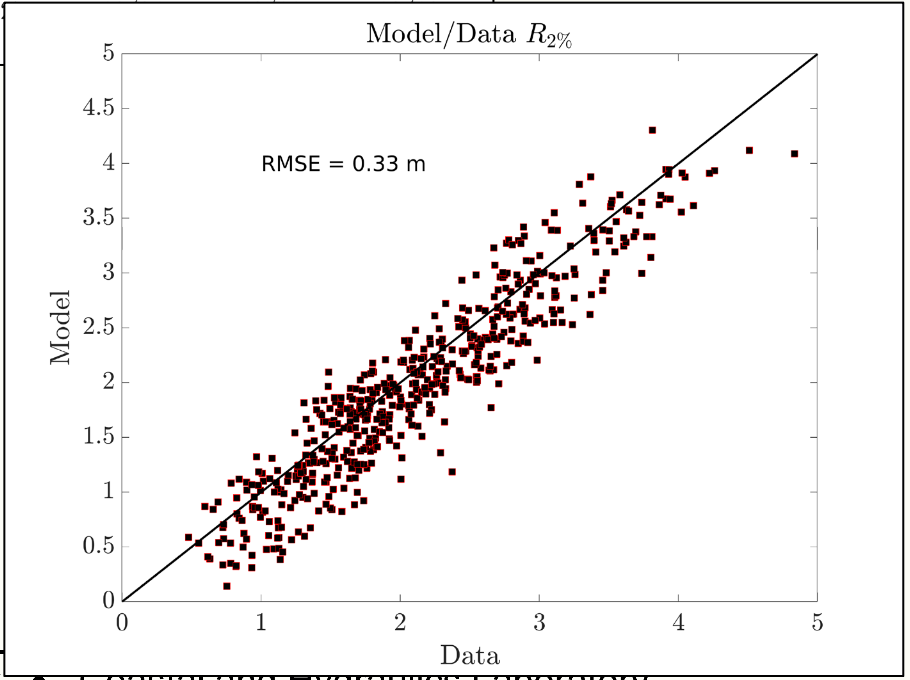


FRF DUNUEX Swash Data

- Brittany Bruder overseeing the most comprehensive swash data collection campaign ever
- Extensive coverage for several weeks
- Both in-situ instrumentation and remote sensing
- hydro+morpho

FRF Runup Predictions CMS





- $h_{bnd} = h_{(x=sws)}$
- Tricky to define where SWS is located for time-dependent CMS domain
- Simple swash propagation method is more efficient, stable, and accurate when compared with CSHORE computation in this case.

Conclusions

- Phase-averaged CMS predictions in wet domain for Agate beach and FRF are suitably accurate to constitute boundary conditions
- Swash predictions are based on a aggressively-simplified set of momentum eqns
- In simple cases, CMS/CSHORE can provide similar hydro fields
- Details of the measured/modeled runup peak distribution open to skepticism
- Mean runup slightly over-predicted, while $R_{2\%}$ slightly under-predicted
- Generality is always an open question, but growing confidence
- Method is more accurate than algebraic predictors
- FRF lidar data comparison are encouraging, some scatter, no bias
- Bruder’s 2DH detailed runup data campaign (DUNEX) is underway