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The State of the Art and Science of Coastal Engineering

Process Based Numerical Modeling and Laboratory Experiments on the Morphological Change Of Coastal Sand Dune

Sungwon Shin, Associate Professor
Hanyang University

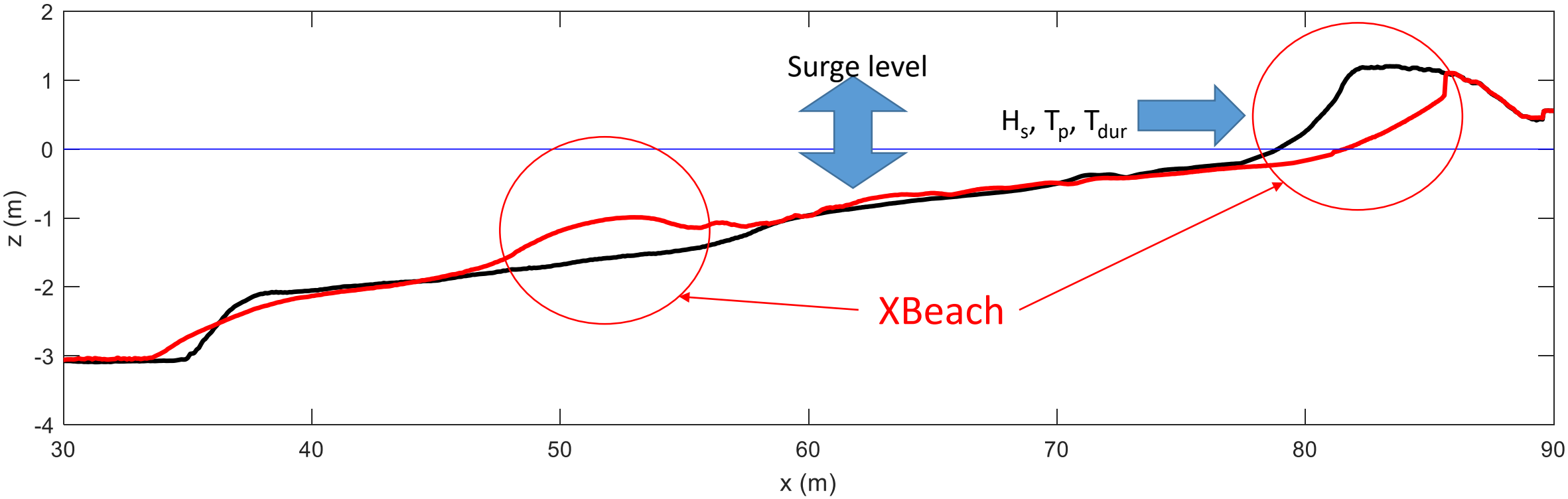
Kideok Do, Assistant Professor
Korea Maritime University

Daniel Cox, Professor
Oregon State University



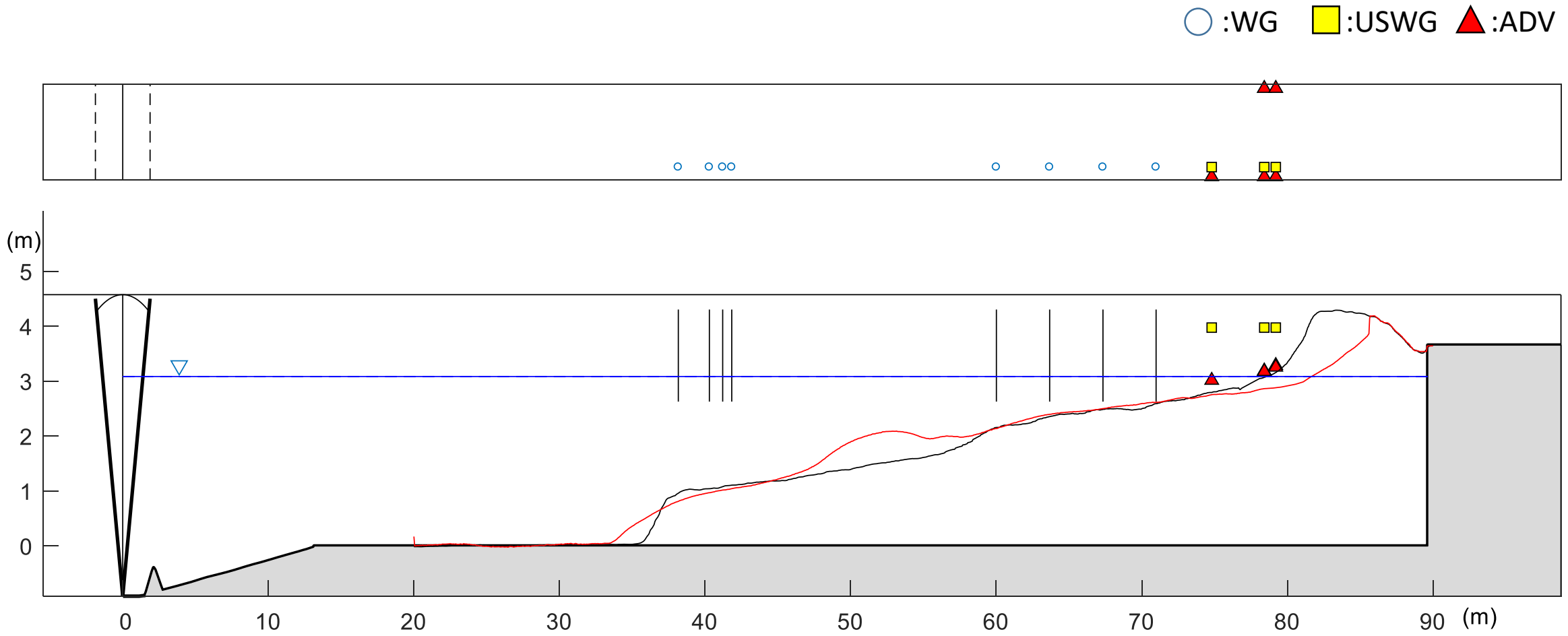

Objective

- Obtain the experimental data set of dune erosion for an entire storm event
- Investigate the main factor of dune erosion (wave height, period, surge level, and duration)
- Evaluate XBeach model performance by comparing with the large-scale experimental data
- Investigate the effect of sensitive parameters in the model for better prediction



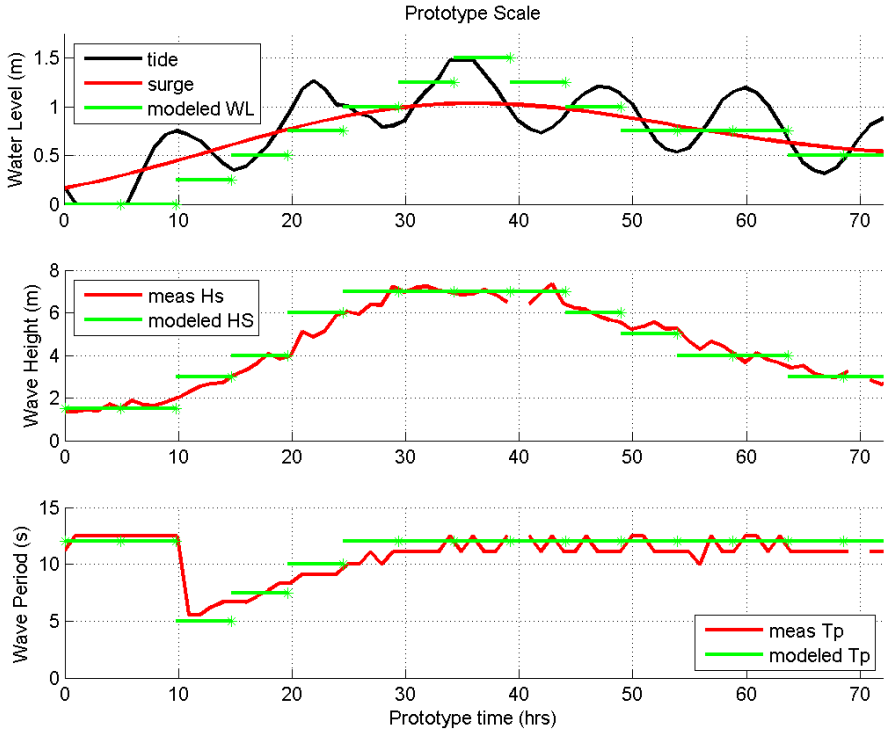
Physical modeling: experimental setup

- Large wave flume at Oregon State University, filled with 800m^3 of natural beach sand (d_{50} = 0.2mm)
- 8 resistance wave gages (WG), 3 ultrasonic wave gages (USWG) and 5 ADVs
- Survey by using MTA and laser range finder



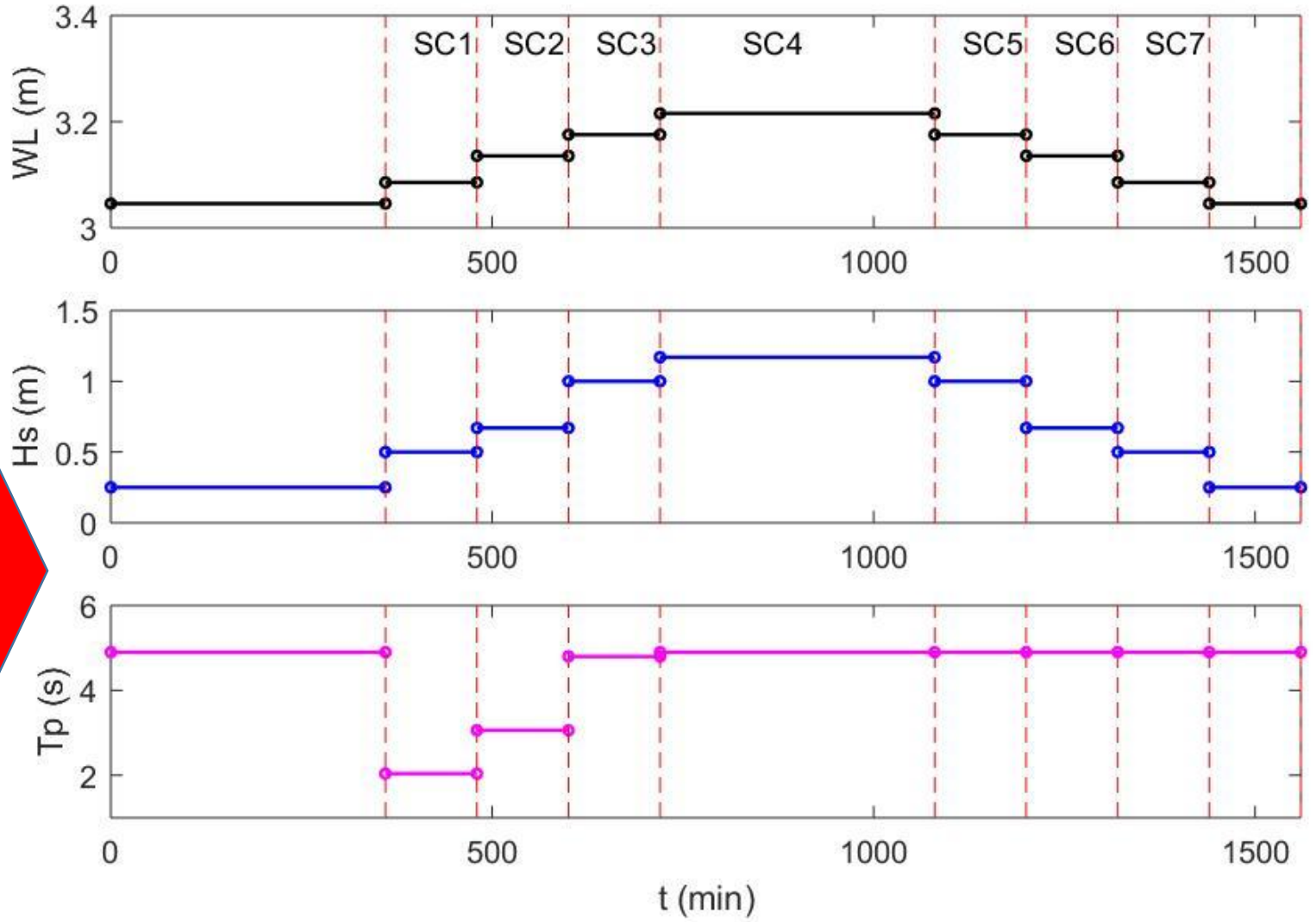
Experimental setup

- 7 different storm wave conditions for reproducing a single storm event
- Random wave time series using TMA spectrum (γ = 3.3)
- Waves were run in bursts of 15 minutes followed by resting periods, one hour.
- 8 runs for each storm except SC4 (24 runs)

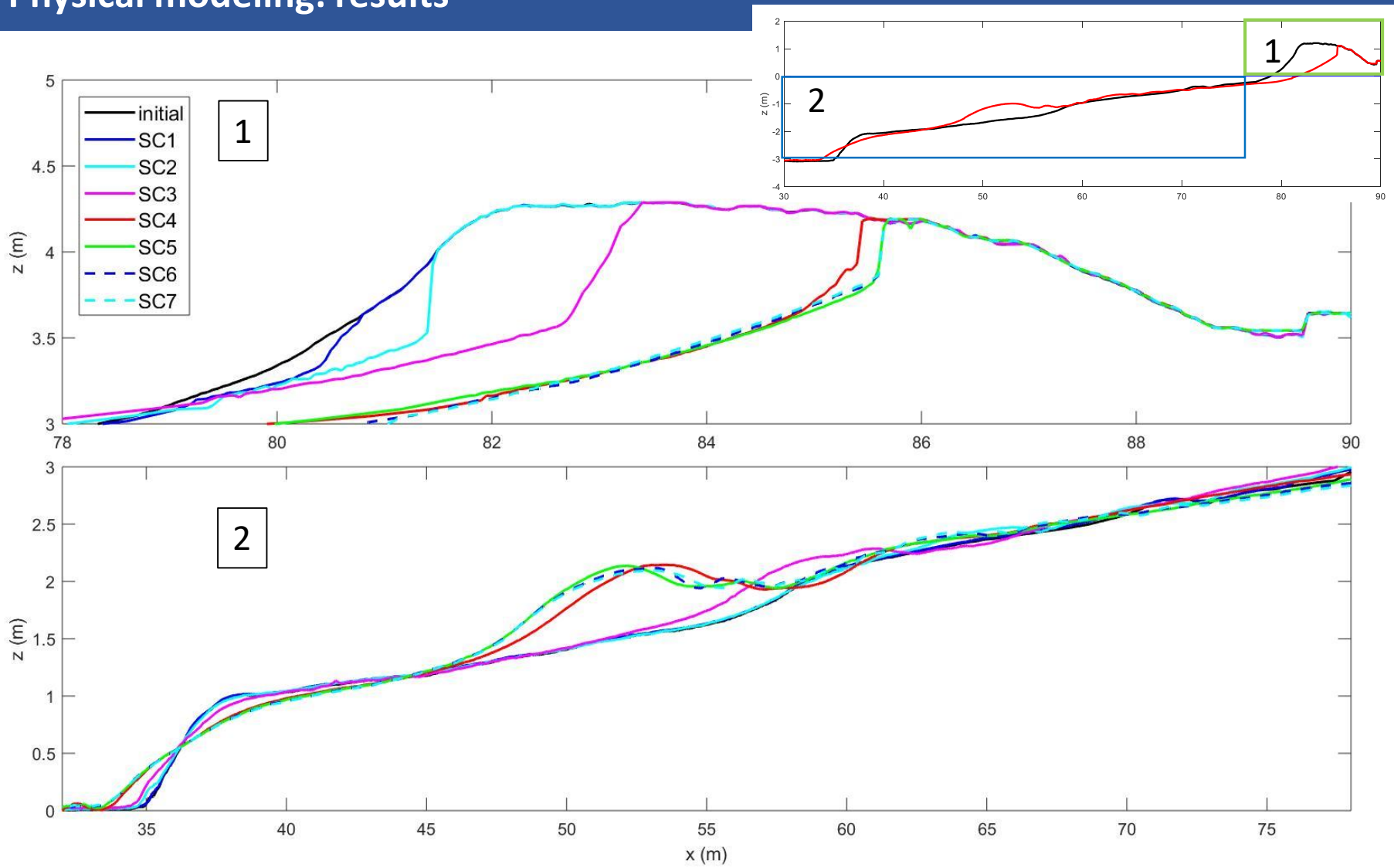


Maddux et al (2006)

Model scale

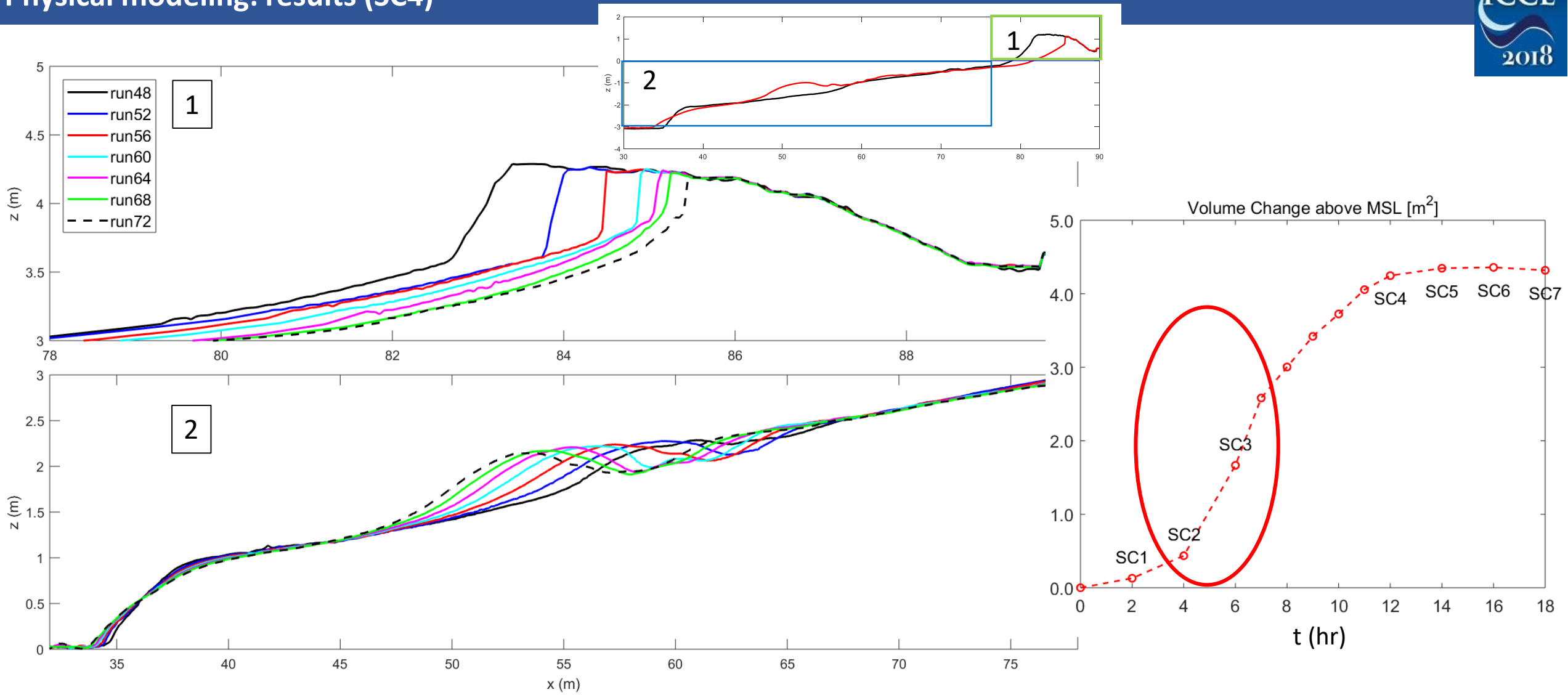


Physical modeling: results



- Dune erosion mainly occurred between SC3 and SC4 due to strong wave condition with water level increase.
- Sand bar was clearly formed after SC4.

Physical modeling: results (SC4)



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Numerical modeling: XBeach

- Process-based, open-source, freeware numerical model for simulating bed level changes.
- Simulates the 2D-horizontal nearshore hydrodynamics of waves on the time scale of wave-groups, including surfbeat (long waves, infragravity waves)
- Solves both short waves (energy balance) and long waves (Nonlinear Shallow Water Wave Equations)
- Avalanching of dune fronts and morphological change on the time scale of storm events.

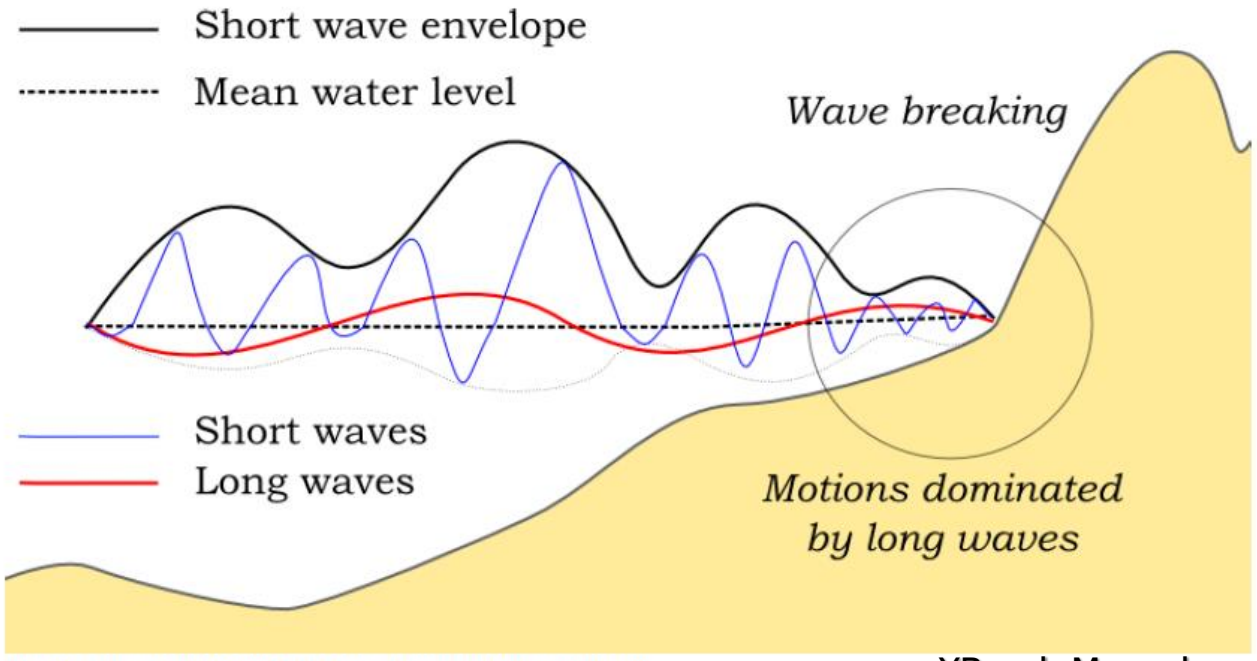


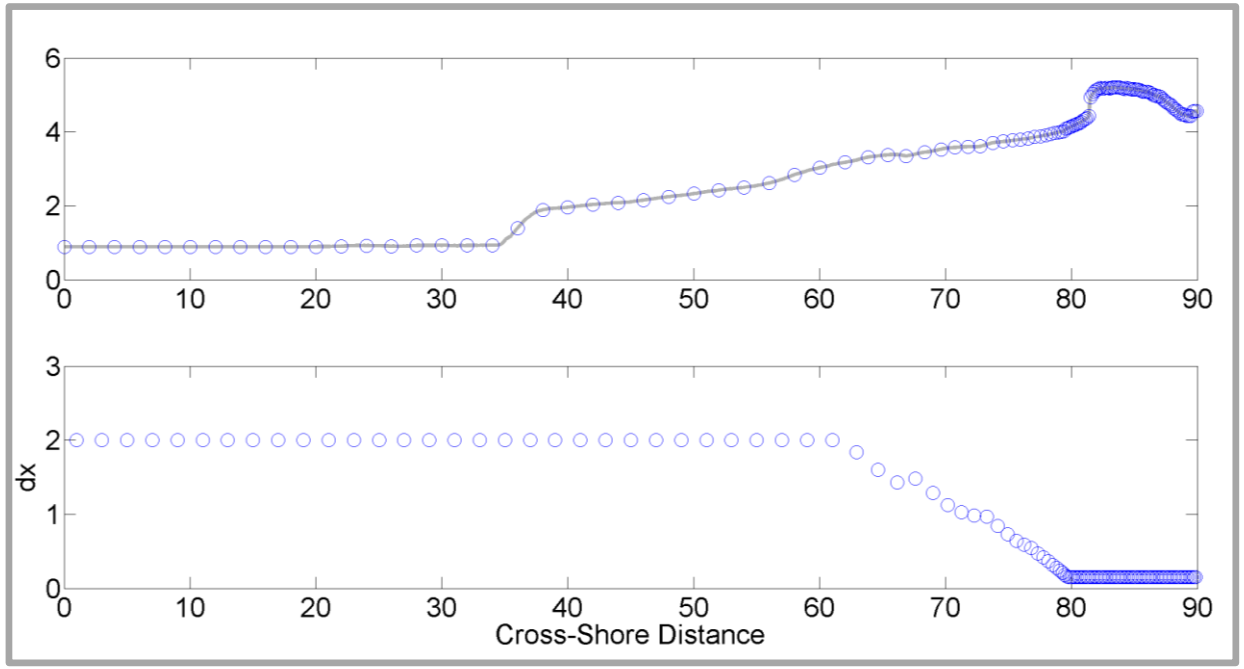
Figure 2.3 Principle sketch of the relevant wave processes

XBeach Manual

- Wave action balance
- Shallow water wave equations
- Advection-diffusion equation
- Bed load transport
- Bed updating including avalanching

Numerical modeling: XBeach setup

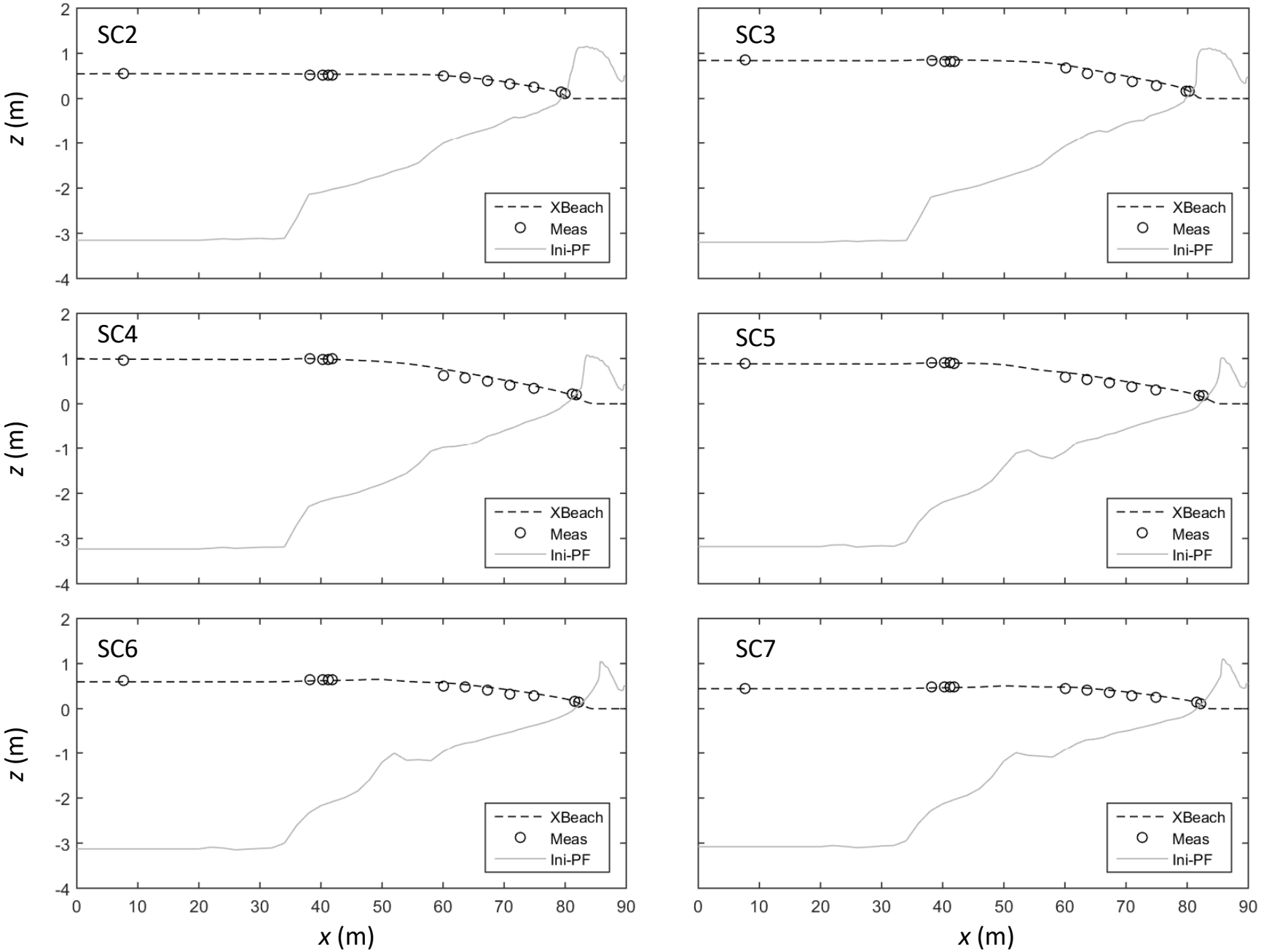
- Surfbeat mode
- Numerical Grid
  - vardx = 1 (varying grid)
  - dx_{min} = 0.15m (in the dry zone)
  - dx_{max} = 2.0 m (offshore area)
- Bed composition parameters
  - D_{50} = 0.20 mm



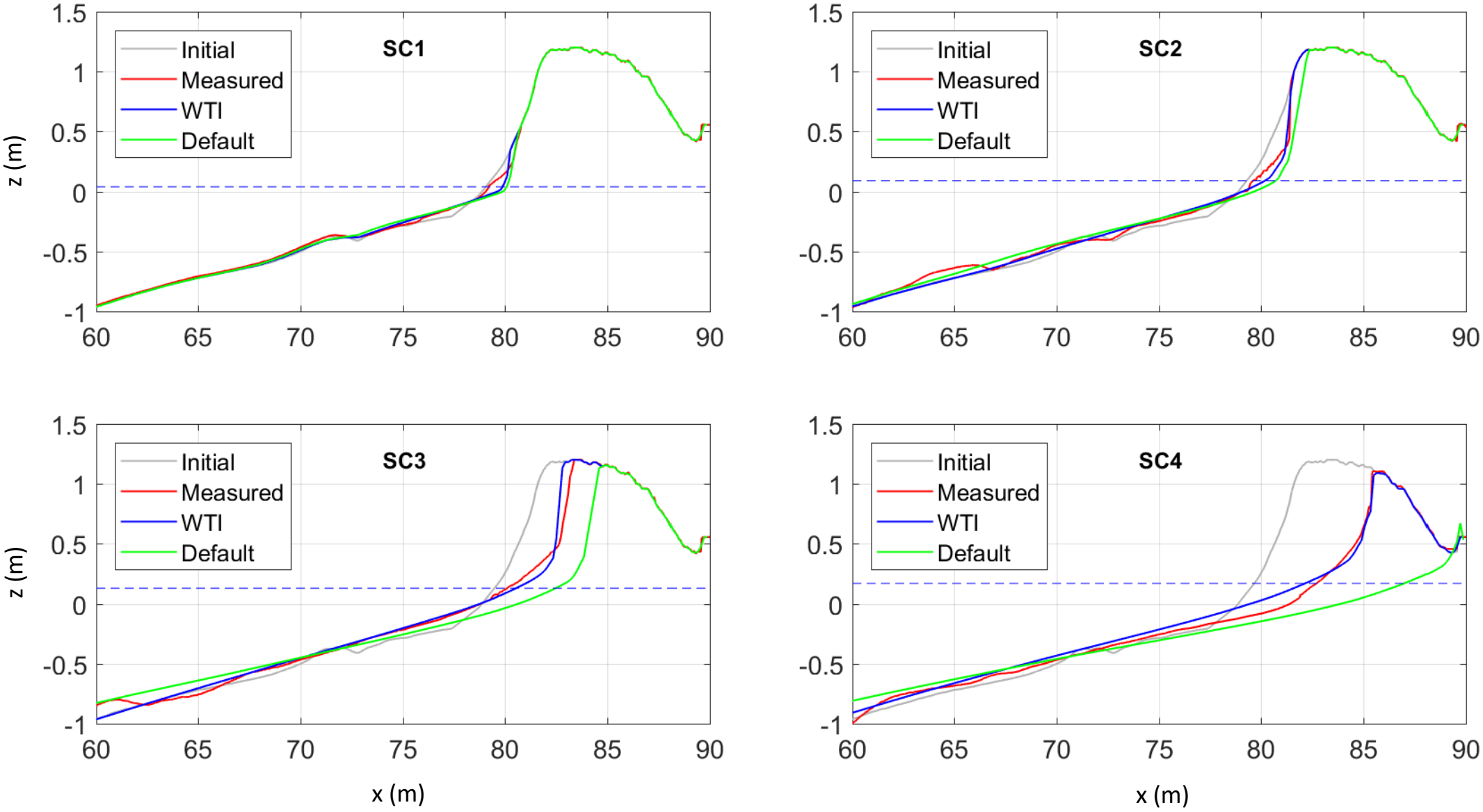
- Morphology Setting : WTI setting (van Geer et al., 2015)

Parameter	WTI setting	Default	
facSK	0.375	0.100	Calibration factor time averaged flows due to wave skewness
facAs	0.123	0.100	Calibration factor time averaged flows due to wave asymmetry
gammax	2.364	2.000	Maximum ratio wave height to water depth
gamma	0.541	0.550	Breaker parameter in Baldock or Roelvink formulation
beta	0.138	0.100	Breaker slope coefficient in roller model
wetslp	0.260	0.300	Critical avalanching slope under water (dz/dx and dz/dy)
alpha	1.262	1.000	Wave dissipation coefficient in Roelvink formulation

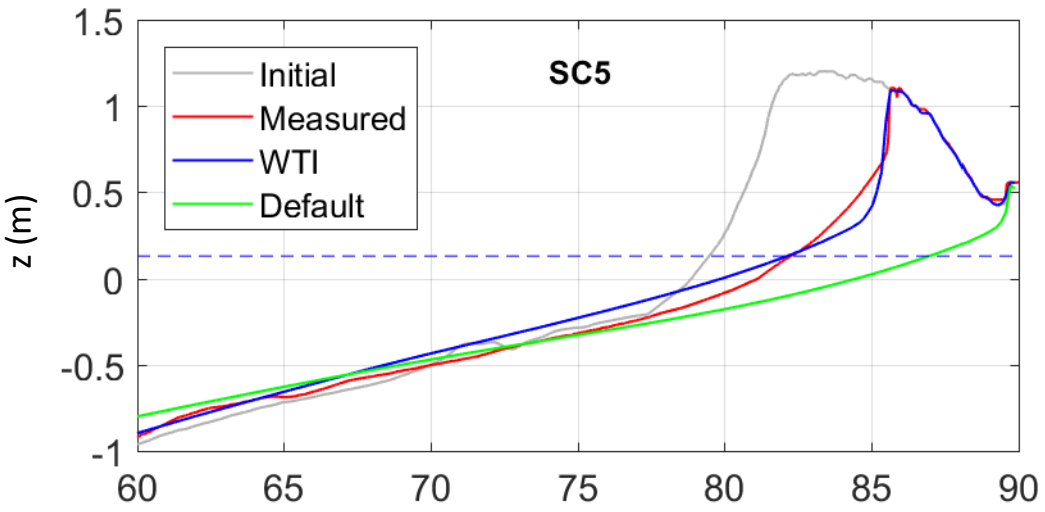
Results: wave height variation

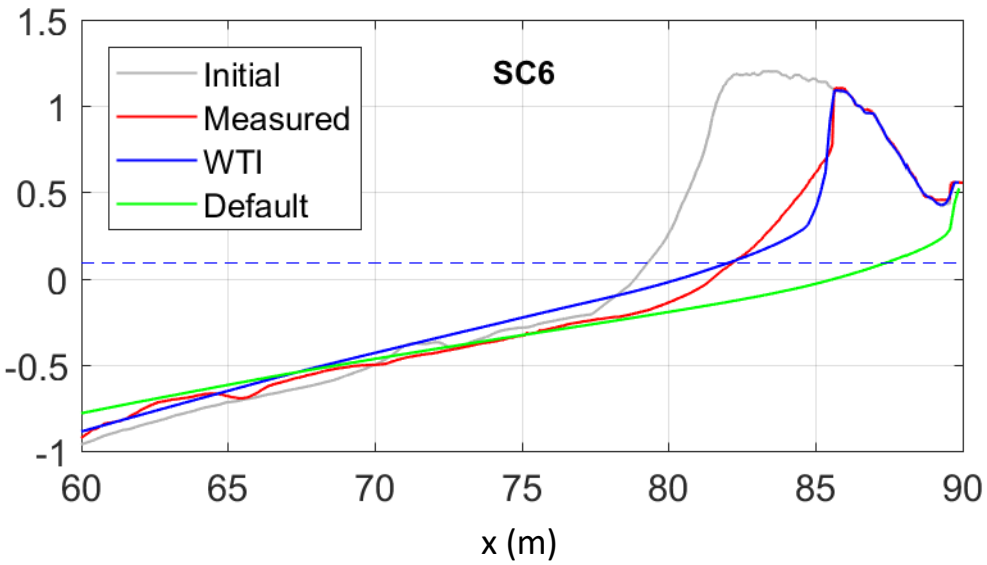


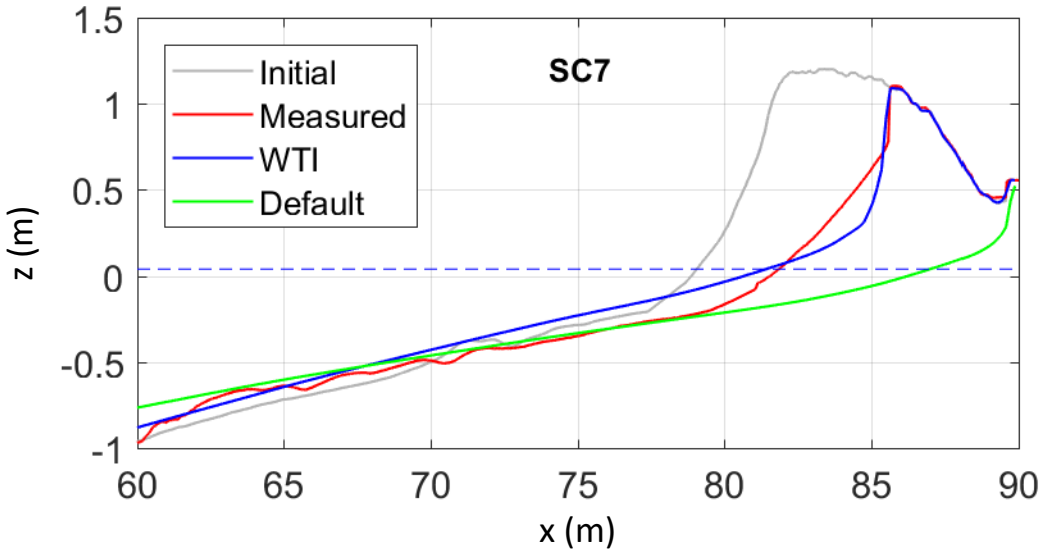
Results: profile change



Results: profile change



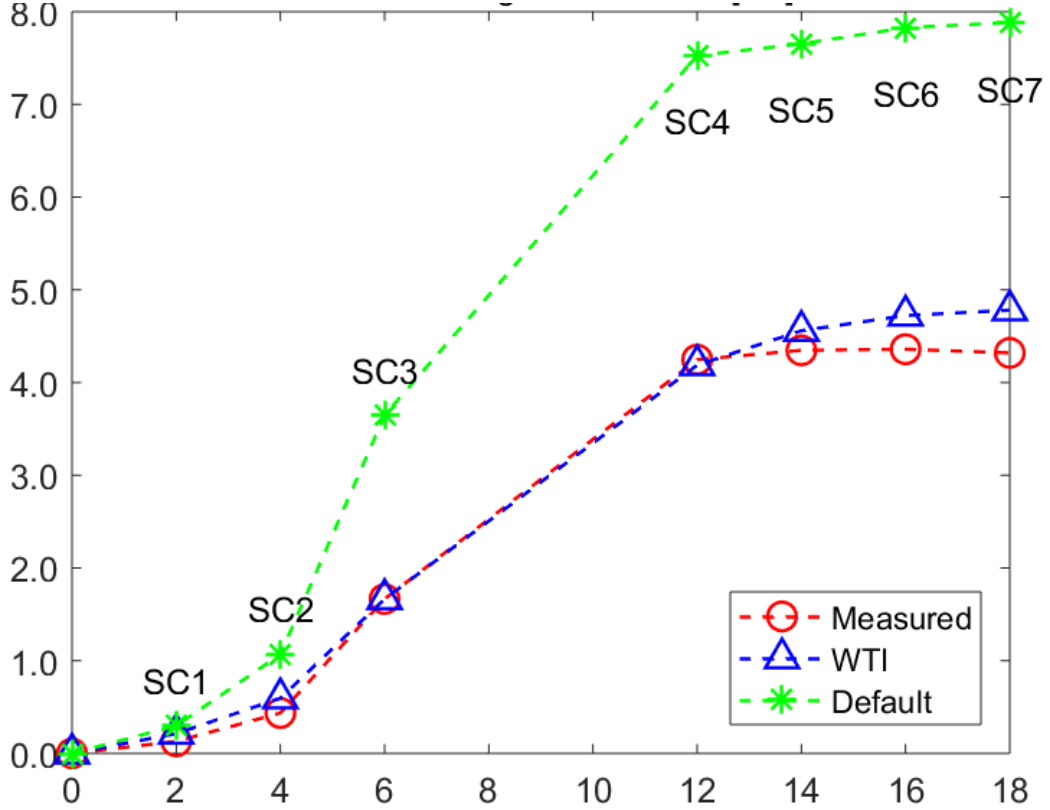




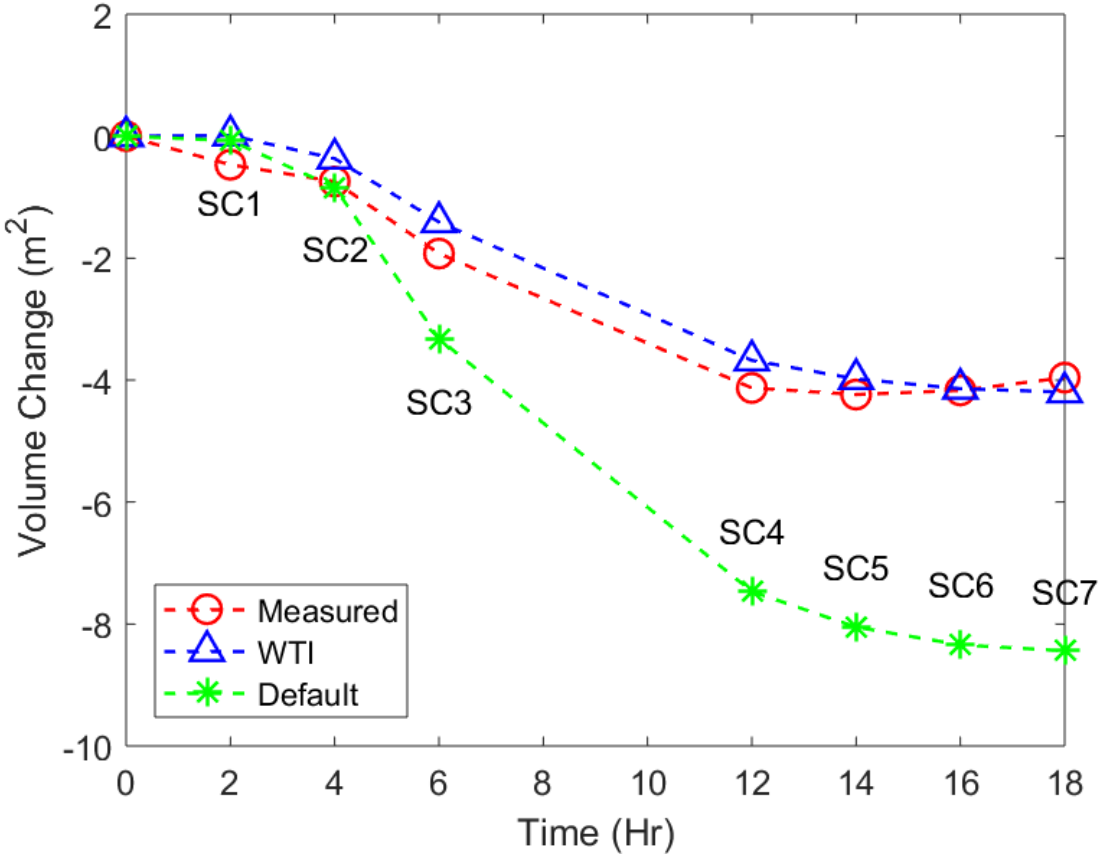
- Default setting: over-predicts dune erosion
- WTI setting:
  - Good for top location and face of the dune
  - Under-predicts swash zone beach slope

Results: erosion volume

Erosion volume change (Z > 0 m)

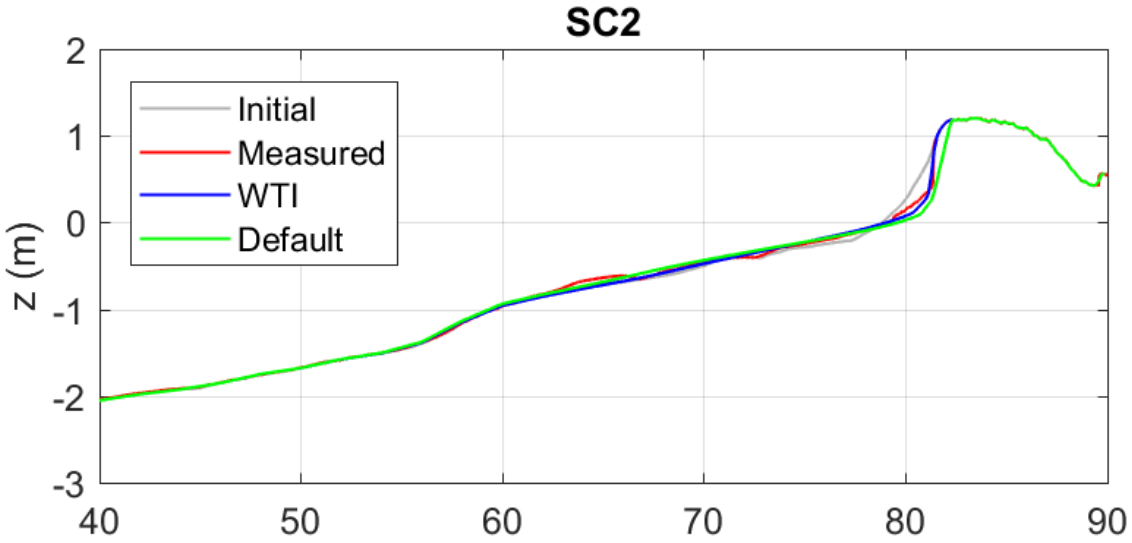


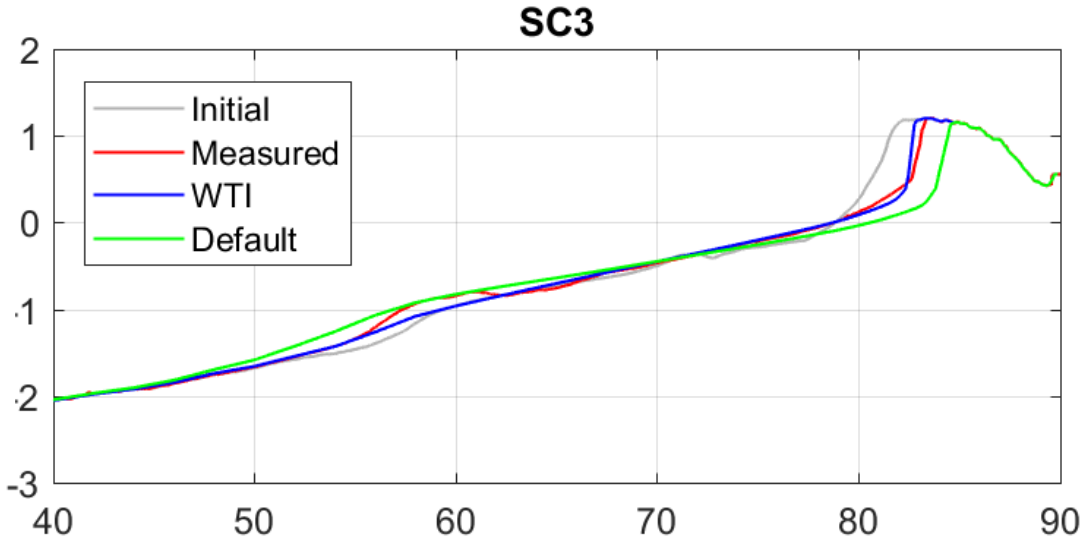
Erosion volume change (-2 m < Z < 0 m)

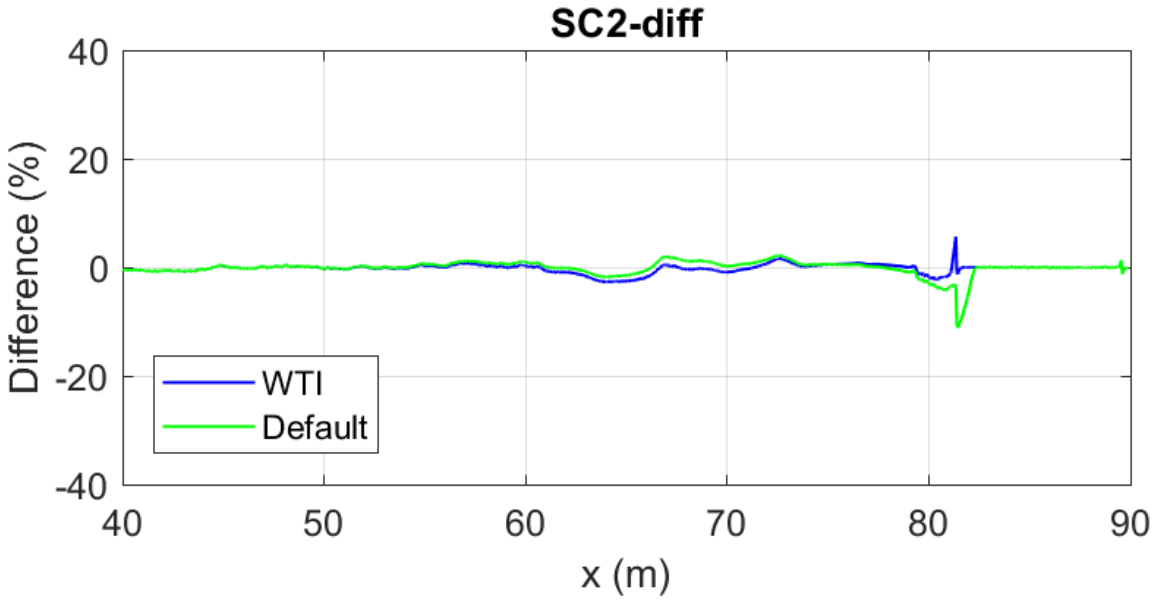


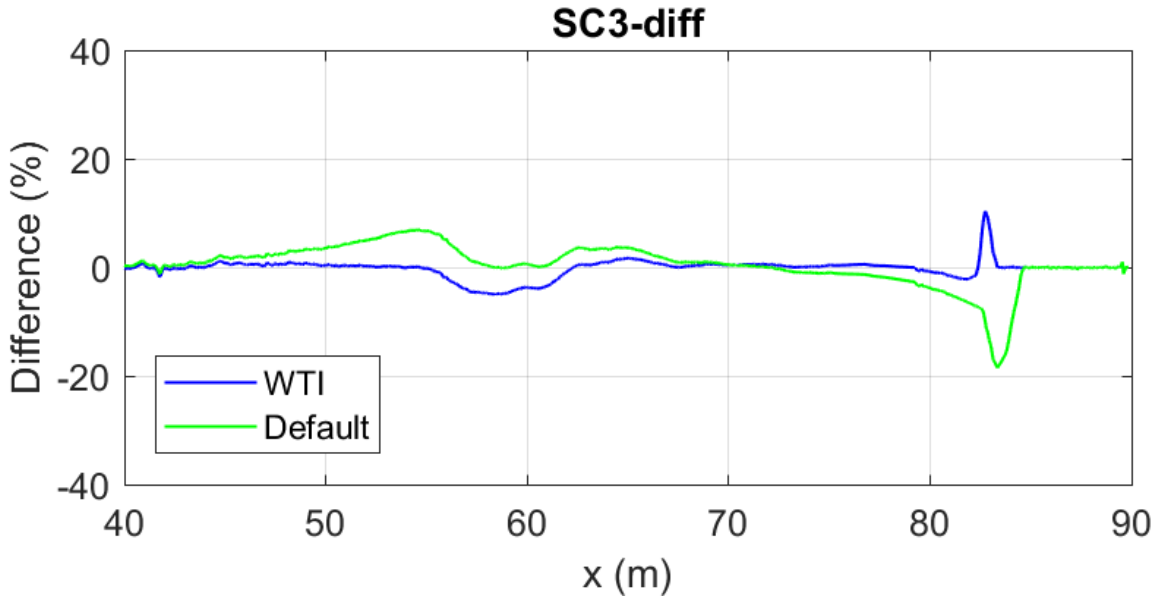
Positive: erosion; negative: accretion

Results: model accuracy









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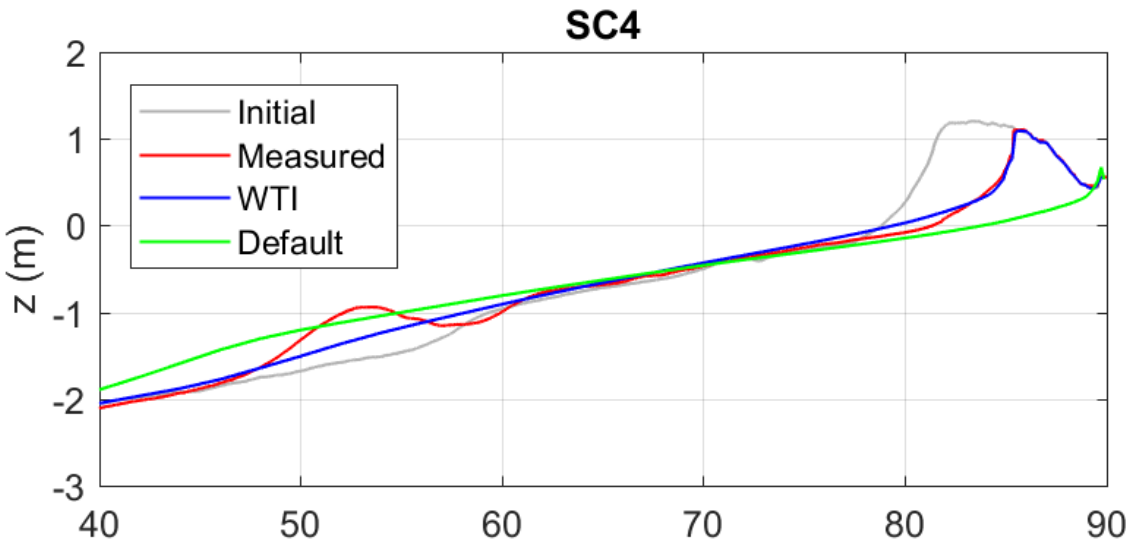

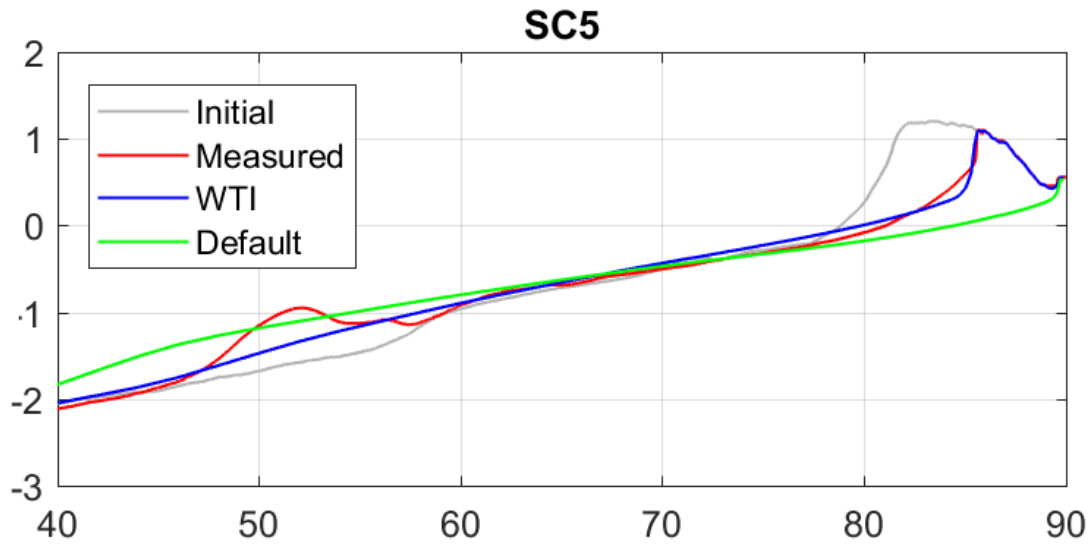

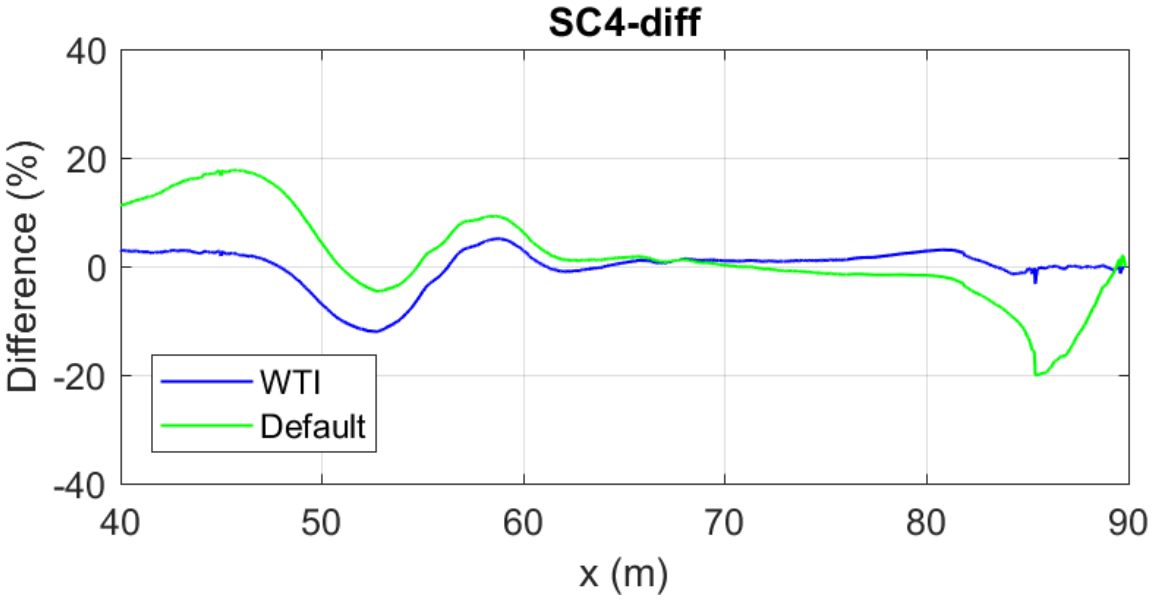

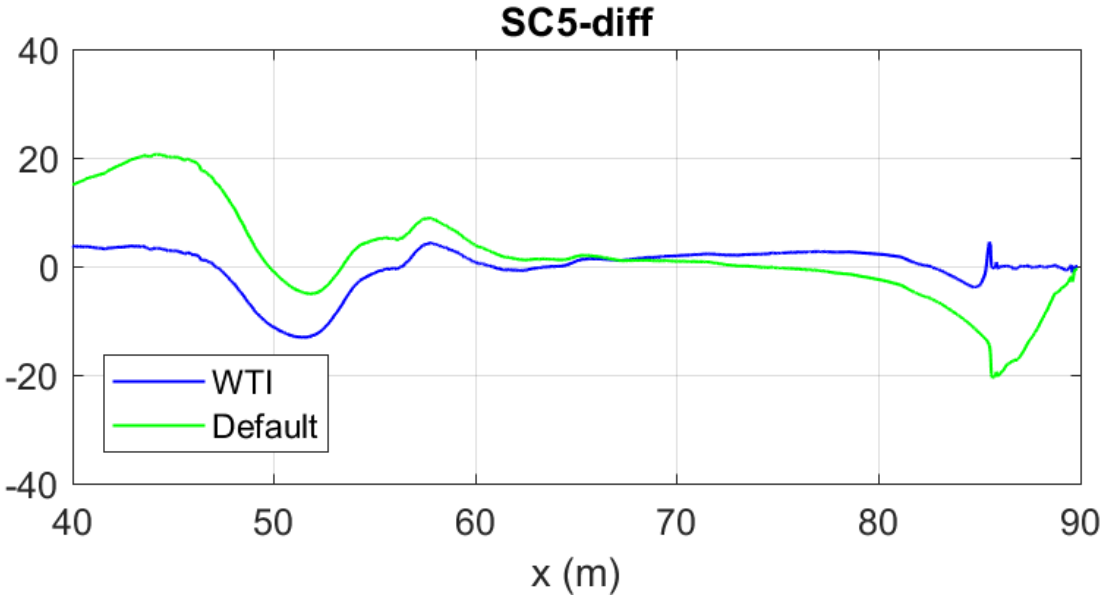

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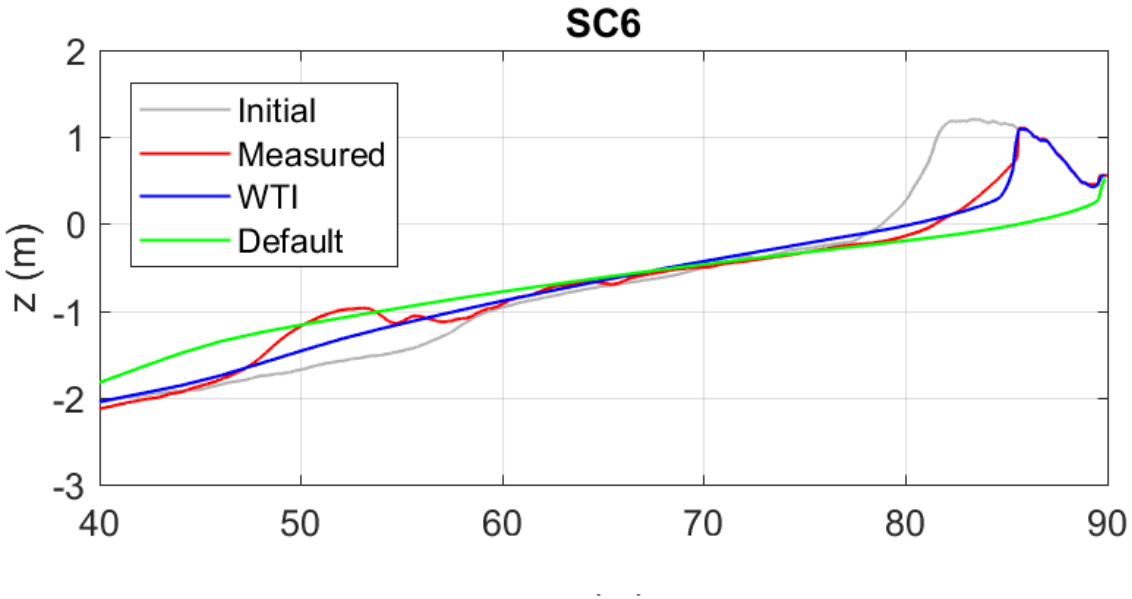

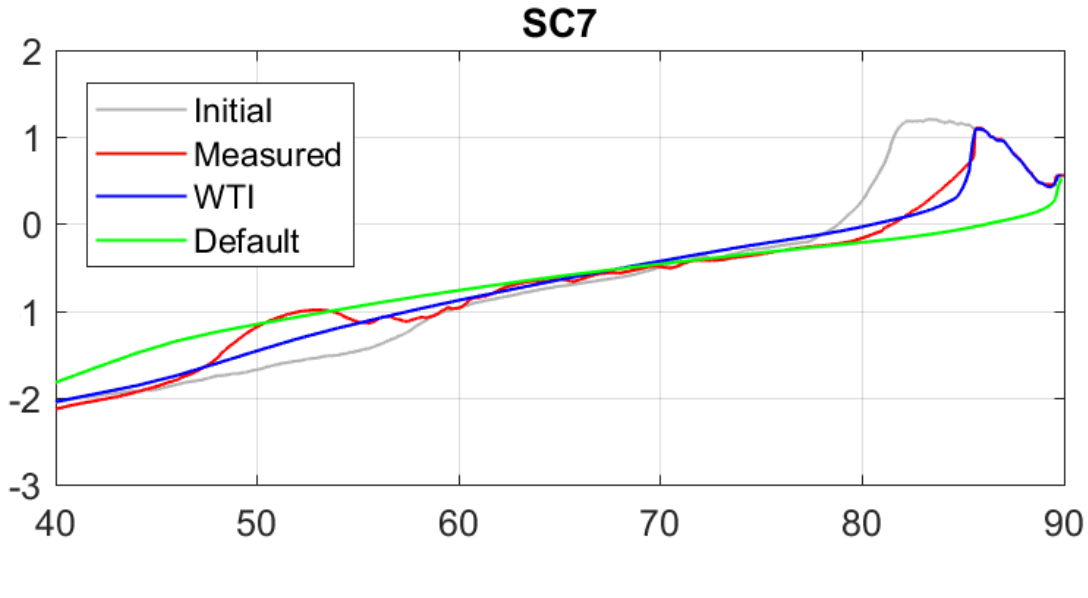

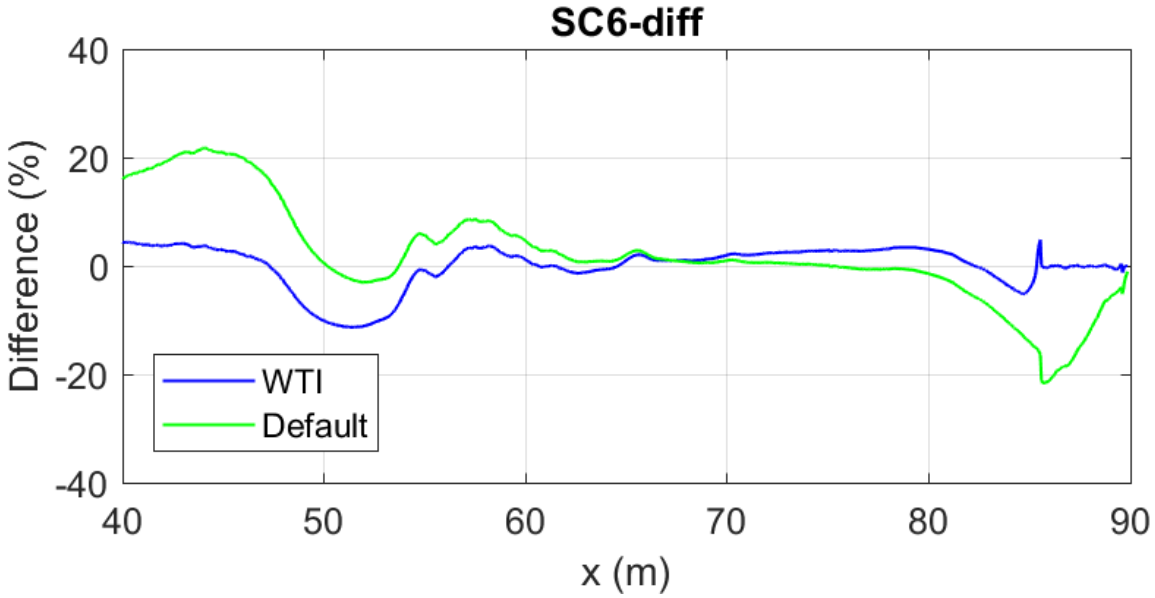

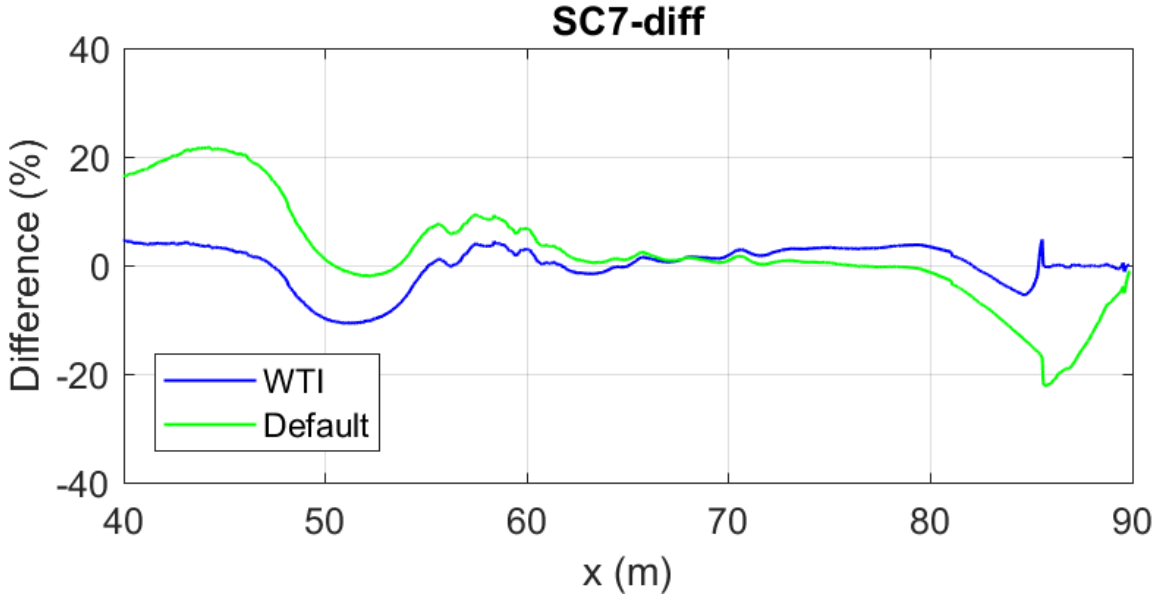

Conclusion

- Experimental results:
  - Major dune erosion occurred in SC3 and SC4, higher erosion rate in the beginning of SC4.
  - Dune erosion in this experiment was mainly affected by both wave condition and surge level.
- XBeach modeling with WTI parameters accurately predicted (compared with default setting):
  - Dune face retreat location
  - Total erosion volume change above and under the mean surface level
- XBeach modeling with WTI parameters still need to be improved:
  - Swash zone beach slope
  - Underwater sand bar formation and migration

XBeach developer's comments

- Keynote speech in International Coastal Symposium 2018
- Estimated equilibrium slope of swash zone from observations: typically steeper for coarser grain size than XBeach prediction
- Trying to improve sand bar formation and movement by implementing the vertical profile of horizontal wave velocity

Possible solutions

- Detailed, intra-wave approach
  - Resolve complex swash processes
  - Many processes uncertain and computation very time-consuming
  - Still with many coefficients
- Heuristic approach
  - Estimate equilibrium slope of swash zone from observations: typically steeper for coarser grain size
  - Introduce an up-slope term in the swash zone that nudges the profile toward the desired *bermslope*

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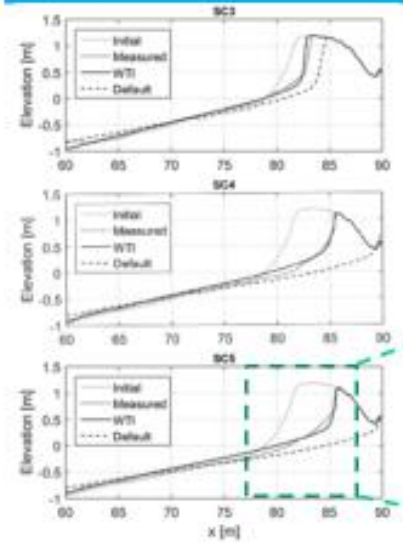
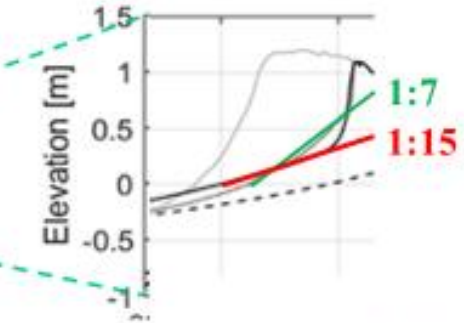
New validation against large-scale data Oregon Large Wave Tank



- Excellent agreement using new 'WTI' settings
- But: slope of swash zone much steeper in reality



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Numerical Simulation and Large-Scale Physical Modelling of Coastal Sand Dune Erosion

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Movable bed experiments at Chonnam National Univ.

- Large-scale dune erosion experiments at Chonnam National University from mid-December, 2018
- Flume dimension: 100m(L) x 2m(W) x 3m(H), Hmax=1.3m
- Simplified dune profile + storm & normal wave conditions <- determined by Xbeach modeling
- Measurements: profile, vertical profile of wave velocity, sediment concentration, ground water level measurements
- Any comment and suggestion are welcome!