ICCE 2018
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The State of the Art and Science of Coastal Engineering

Beach Profile Evolution In Front Of Storm Seawalls: A Physical And Numerical Study

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Affiliations:

1) Polytechnic of Bari, 2) University of L'Aquila, 3) University of Calabria, 4) Genth University




PRESENTATION LAYOUT

- INTRODUCTION
- AIMS AND MOTIVATIONS
- PHYSICAL MODEL
- NUMERICAL MODEL
  - PHYSICAL MODEL DESIGN
  - XBEACH VALIDATION
- RESULTS AND DISCUSSION
- CONCLUSIONS AND FUTURE DEVELOPEMENTS

INTRODUCTION

"The HYDRALAB+ project brings together European researchers, industry and stakeholders to improve experimental research, related numeric modelling and field studies aimed at adapting to climate change."

This work is a task inside a wide European Project WALOWA (WAve LOads on Walls) aimed at investigating overtopping wave impacts on a vertical storm wall placed on the top of a dike in mildly sloping shallow foreshore conditions (Streicher et al. 2018). The Project was a cooperation of Ghent University (Belgium), TU Delft (The Netherlands), RWTH Aachen (Germany), University of Bari, University of L'Aquila, University of Calabria, University of Florence (Italy) and Flanders Hydraulics Research (Belgium).

AIMS AND MOTIVATIONS

Besides the study of wave impact forces and pressures on the wall, tests also allow to observe the **morphological evolution of cross-shore beach profile under normally incident, irregular wave attacks, characterized by different wave characteristics** (i.e. height, period and energy).

In particular, **bed scour at the dike toe and its evolution in terms of scour depth, width and distance from the structure toe are investigated as a function of wave height, wave period, wave steepness and flow depth at the toe**.

Moreover, the **numerical study** performed to design the experiments and the preliminary numerical simulations aimed to correctly reproduce the observed evolution are illustrated.

AIMS AND MOTIVATIONS

The aim of this work is to **study** the **evolution of the scour** in front of a **vertical wall dike** using both physical and numerical models.

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The **major part of empirical-based formulas** on scour at coastal structures (pipelines, vertical breakwaters and rubble mound breakwaters with different slopes)

non-breaking regular waves and no-suspension mode of sand transport, i.e. “coarse sand”

AIMS AND MOTIVATIONS

non-breaking regular waves and no-suspension mode of sand transport, i.e. “coarse sand”

These **conditions are very different to the present configuration**

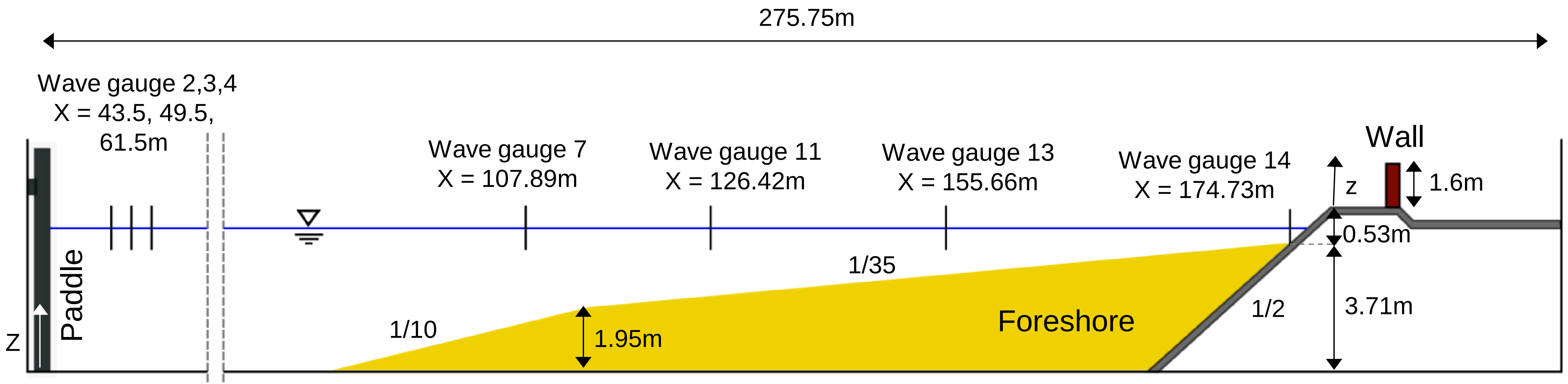
- inclined concrete wall representing the dike
- frequent occurrence of breaking waves
- suspension mode of sediments
- presence of **very shallow and extremely very shallow foreshore**.

AIMS AND MOTIVATIONS

WALOWA tests represent a **relevant novelty in the field of morphodynamic effects near coastal structures for shallow foreshore.**

PHYSICAL MODEL

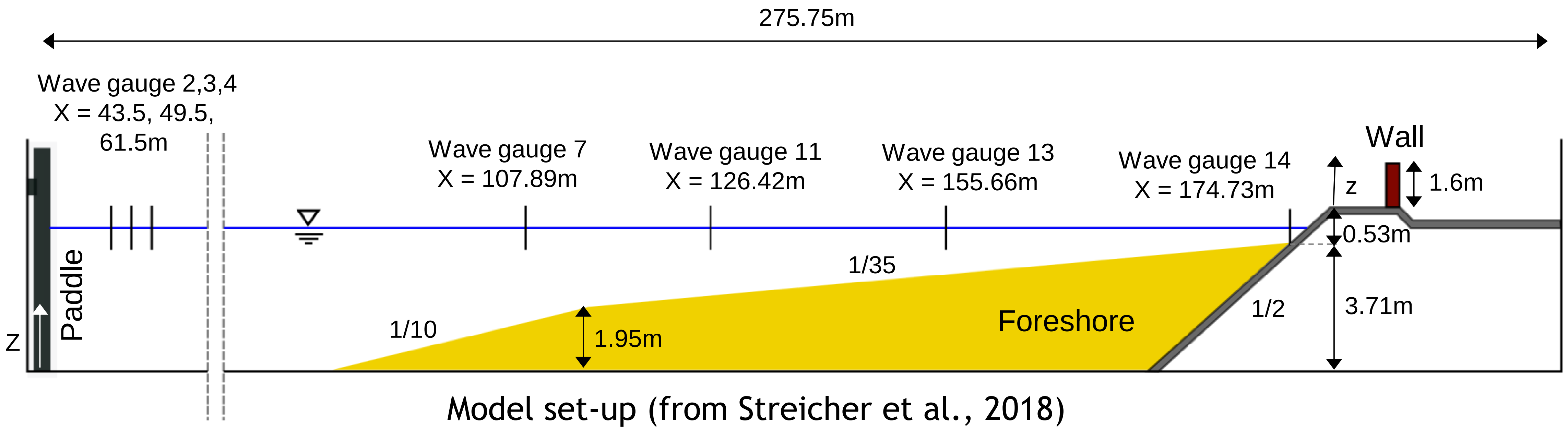
The physical model reproduces the prototype conditions at Froude scale **1:4.3**



Model set-up (from Streicher et al., 2018)

The experimental tests were performed at Delta Flume (Deltares, Delft) in March 2017

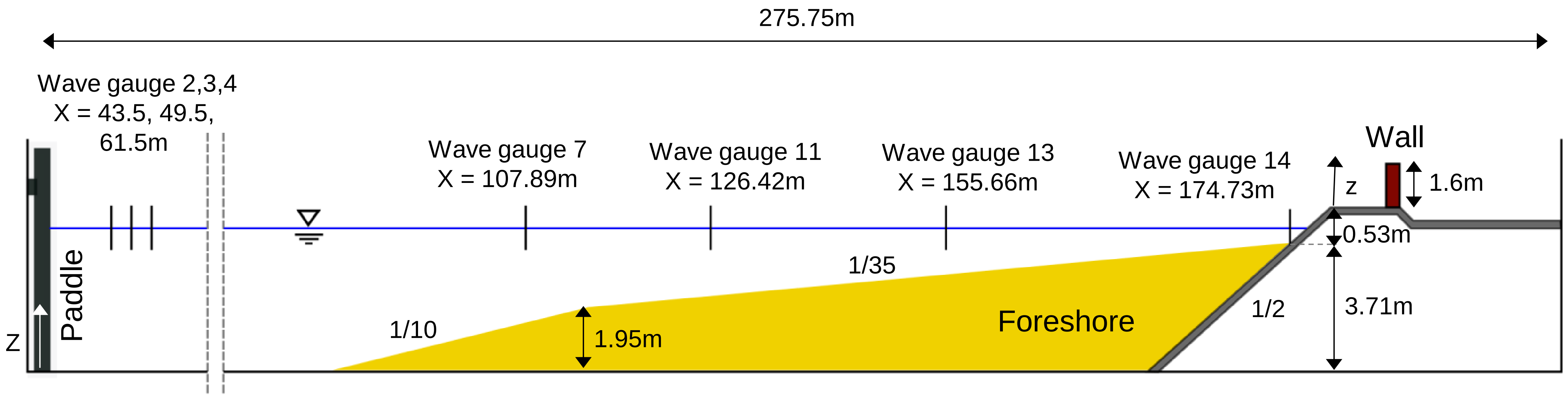
PHYSICAL MODEL



Model set-up (from Streicher et al., 2018)

- Initial sandy foreshore begins about 94 m from the wave paddle with a mean slope of 1/10
- 1/35 sloped foreshore for 61.6 m,
- ½ sloped concrete dike with a promenade about 2 m wide.
- At the end of the promenade a vertical steel wall is realized, 1.6 m high.

PHYSICAL MODEL



Model set-up (from Streicher et al., 2018)

The foreshore is constituted by a **top layer** (≈ 0.4m deep) of a medium sand (according to Wentworth grain size classes) with a **D_{50} equal to 0.32** mm and a **second layer**, below the first one until the flume bottom, made of fine sand with a **D_{50} of 0.23 mm.** The **total foreshore volume** is comprised of **~1000m³** of sand

PHYSICAL MODEL

A series of sea states were reproduced and bottom evolution measured.

Cross-shore beach profiles were measured before and after each test, by means of a mechanical profiler along four cross-shore sections.

After each test, the foreshore **was not restored** to its initial configuration

The weel has a Diameter equal to 0.10m

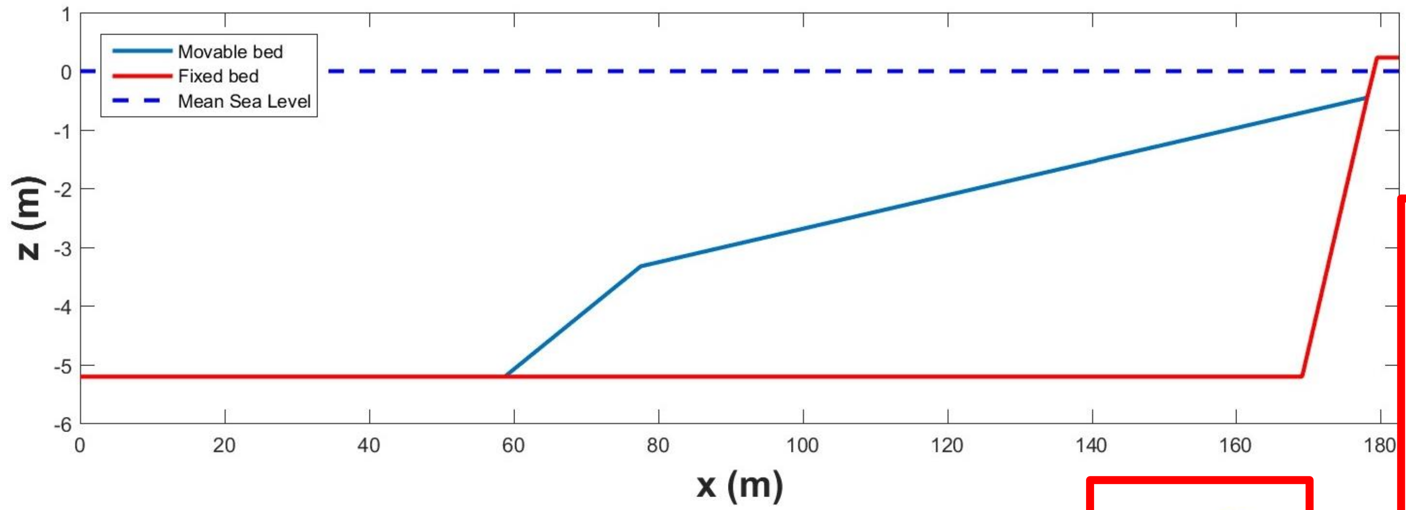
PHYSICAL MODEL DESIGN

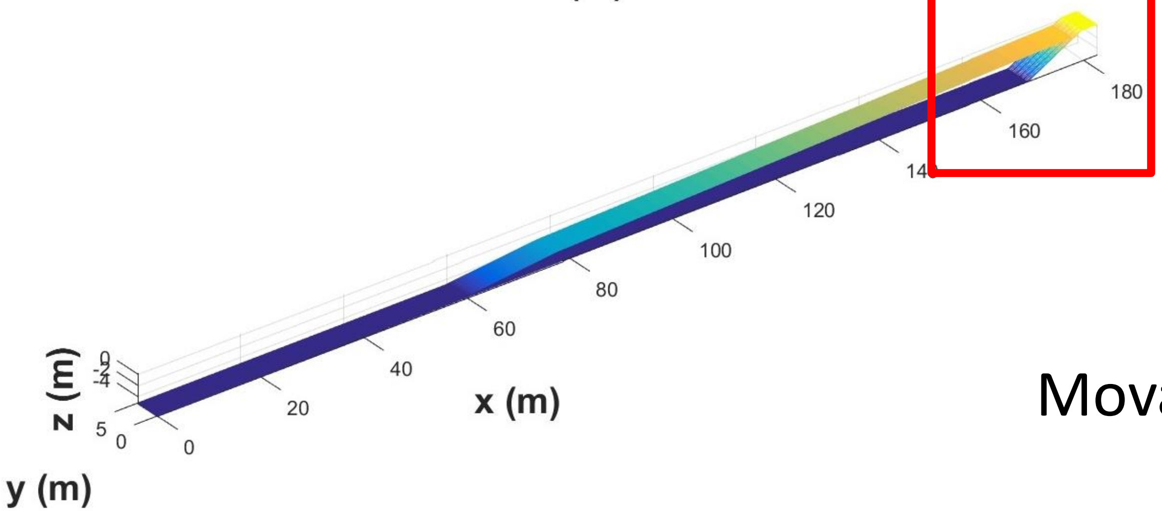
In order to design the experiment, i.e. estimate the expected amount and location of erosion/accretion **a series of preliminary numerical XBeach simulations was performed** in order to gain insight about the evolution of the foreshore.

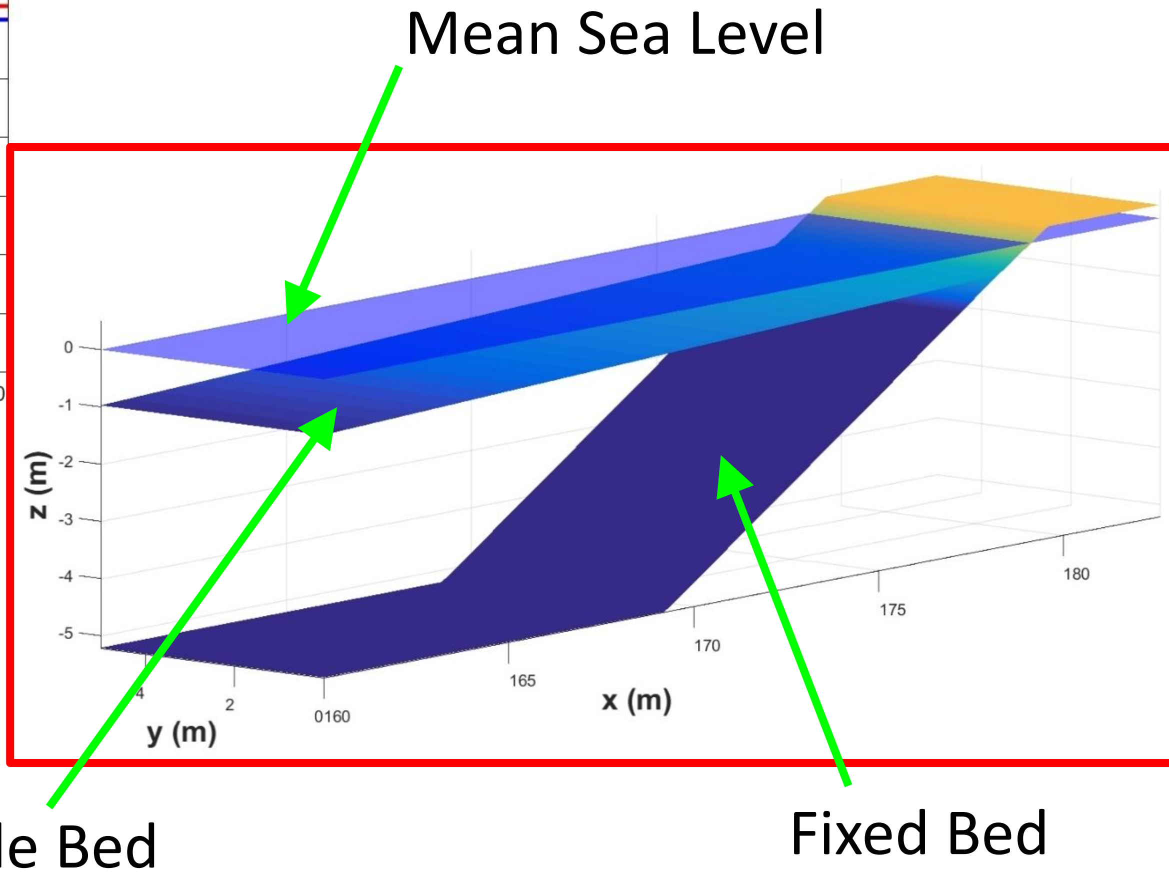
It as to be stressed that these numerical simulations are preliminary as the results (at this step) are not validated against observations.

The validation of the numerical model has been done at the end of the tests and will be presented in next slides.

PHYSICAL MODEL DESIGN: COMPUTATIONAL DOMAIN







PHYSICAL MODEL DESIGN

A preliminary sensitivity analysis was performed by varying incident waves type (regular and wave groups) and boundary conditions (back and front).

All simulations were performed in 2D.

The final bottom configurations have been compared and used to evaluate the expected amount and location of erosion/accretion

PHYSICAL MODEL DESIGN

- Both **stationary wave boundary conditions (STAT)** and wave groups based on **Jonswap spectra (VAR)** have been simulated
- **Adsorbing (ADS2d) and wall boundary conditions** were imposed at the offshore and inshore boundaries respectively
- The duration of each simulation was selected to be equal to the experimental one.

PHYSICAL MODEL DESIGN: TESTS PROGRAM

Simulation		$H_{s\text{-paddle}}$ (m)	T_p (s)	h_{paddle} (m)	Exp. Duration (min)	Sea State	Sim. Duration (min)	B.C. (front and back)
MB_1	_STAT_ADS	1.21	6.61	5.21	110	Stationary	110	Absorbing (2D)
	_STAT_WALL							wall
	_VAR_ADS					Jons. (Wave Groups)	125 (110+15)	Absorbing (2D)
MB_2	_STAT_ADS	1.45	7.24	5.31	121	Stationary	121	Absorbing (2D)
	_STAT_WALL							wall
	_VAR_ADS					Jons. (Wave Groups)	136 (121+15)	Absorbing (2D)
MB_3	_STAT_ADS	1.21	6.61	5.21	331	Stationary	331	Absorbing (2D)
	_STAT_WALL							wall
	_VAR_ADS					Jons. (Wave Groups)	346 (331+15)	Absorbing (2D)

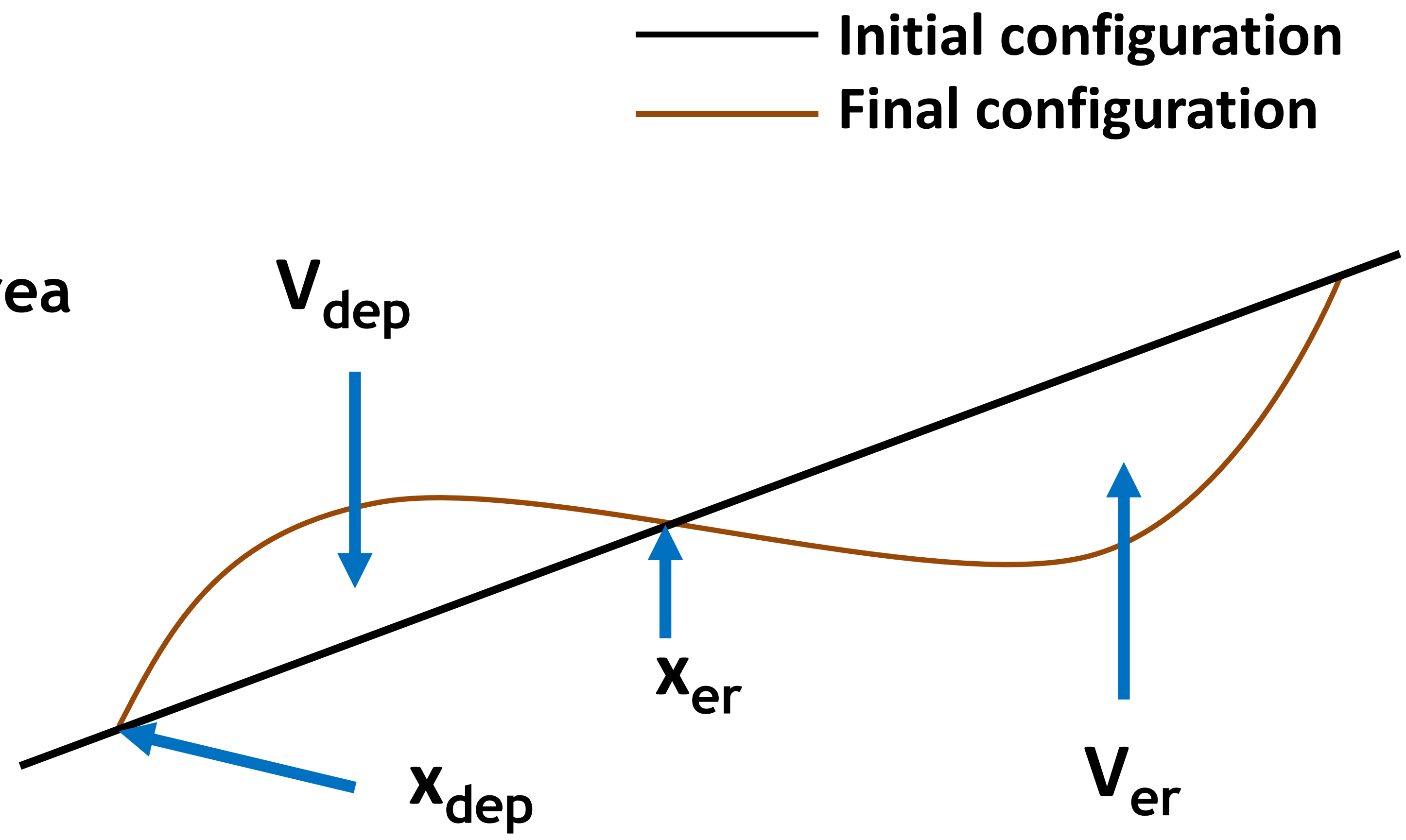
RESULTS AND DISCUSSION

V_{dep} = Deposition Volume

x_{dep} = End of the deposition area

x_{er} = End of the erosion area

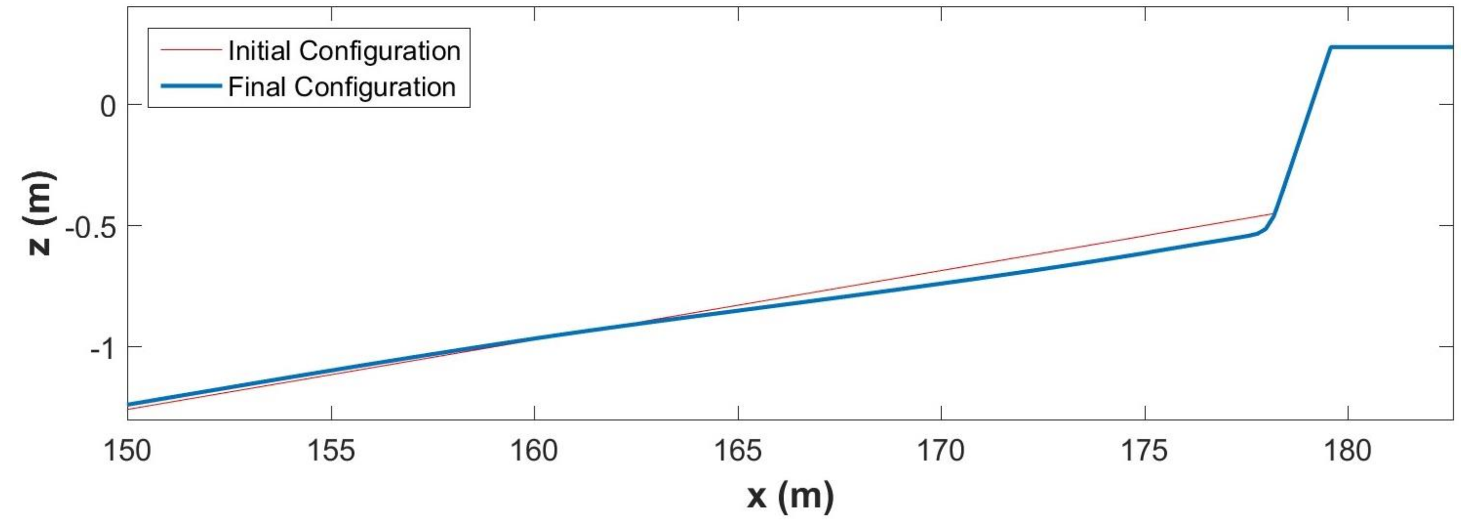
V_{er} = Eroded Volume

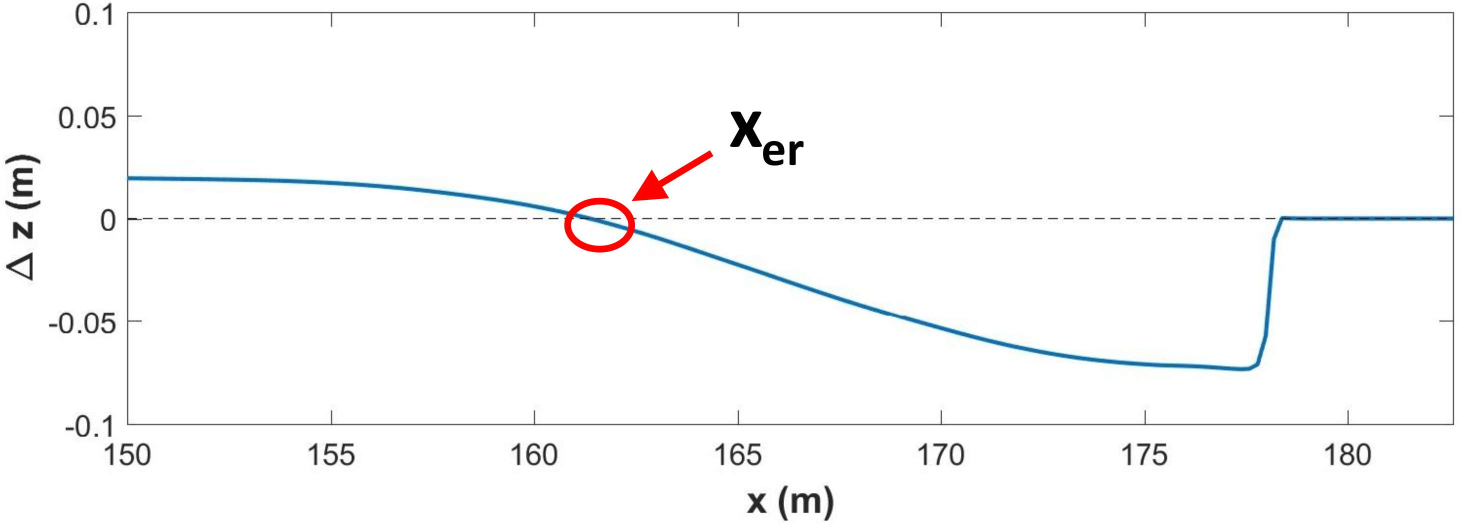


RESULTS AND DISCUSSION

SIMULATION MB-1-VAR-ADS (Stationary WB conditions)

Hs = 1.21 m
Tp = 6.61 s





PHYSICAL MODEL DESIGN

RESULTS AND DISCUSSION

SIMULATION MB-1-STAT-ADS (Wave groups)

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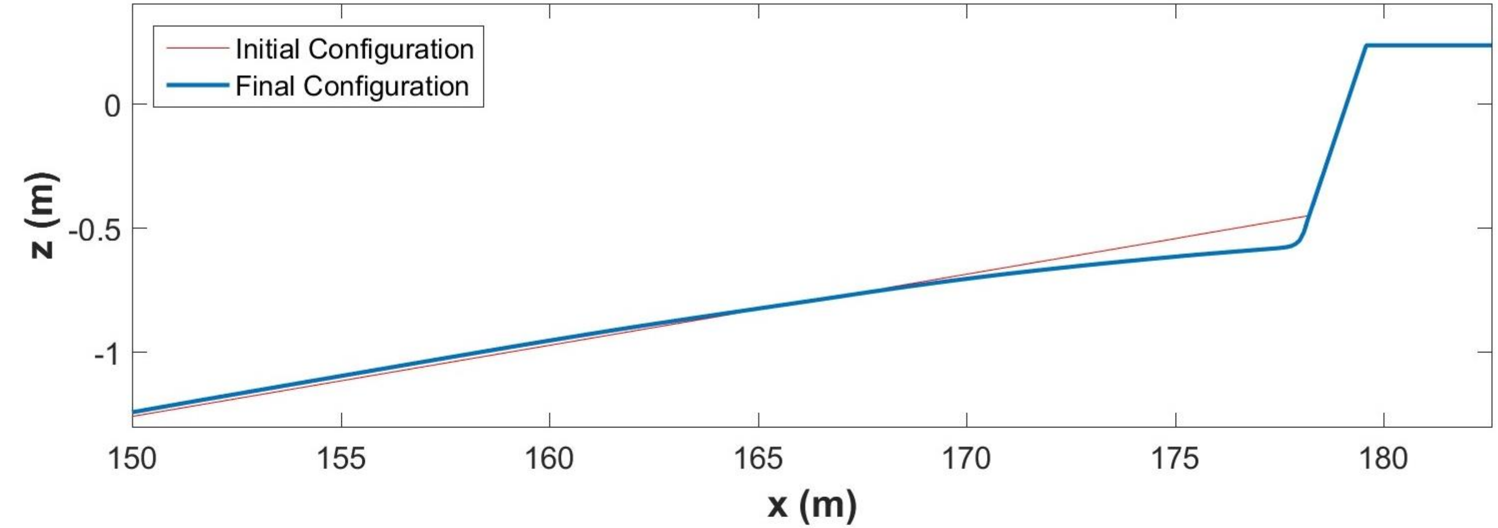

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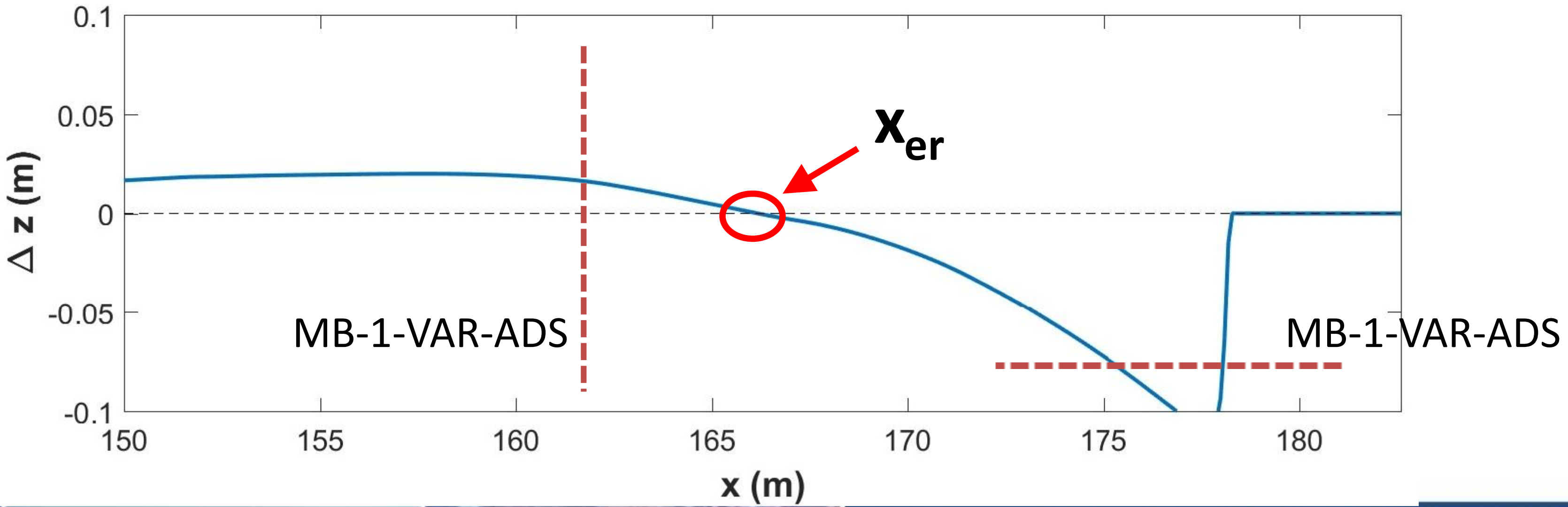
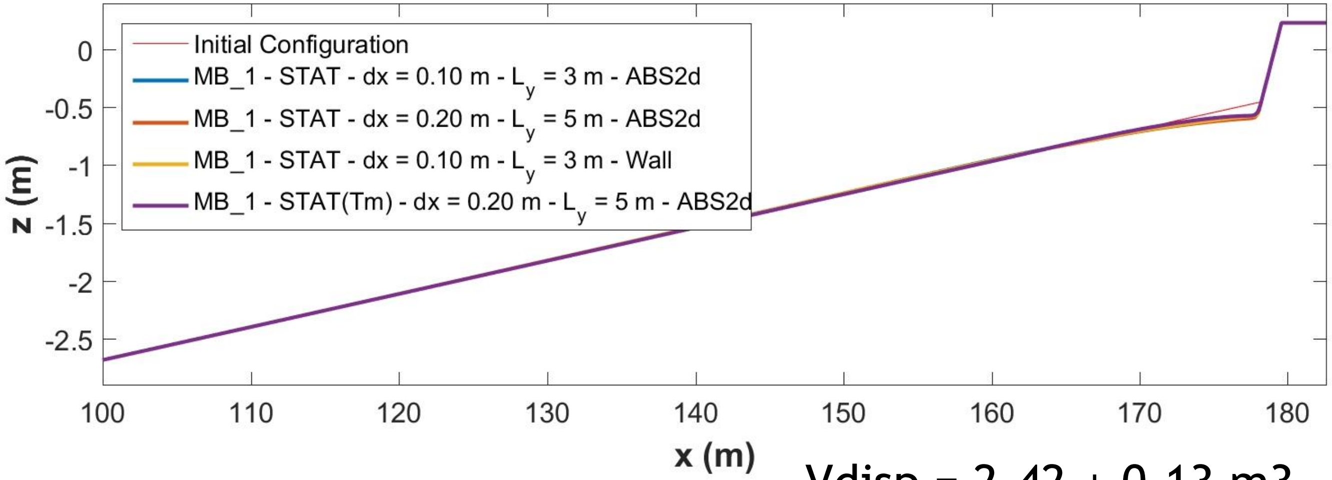
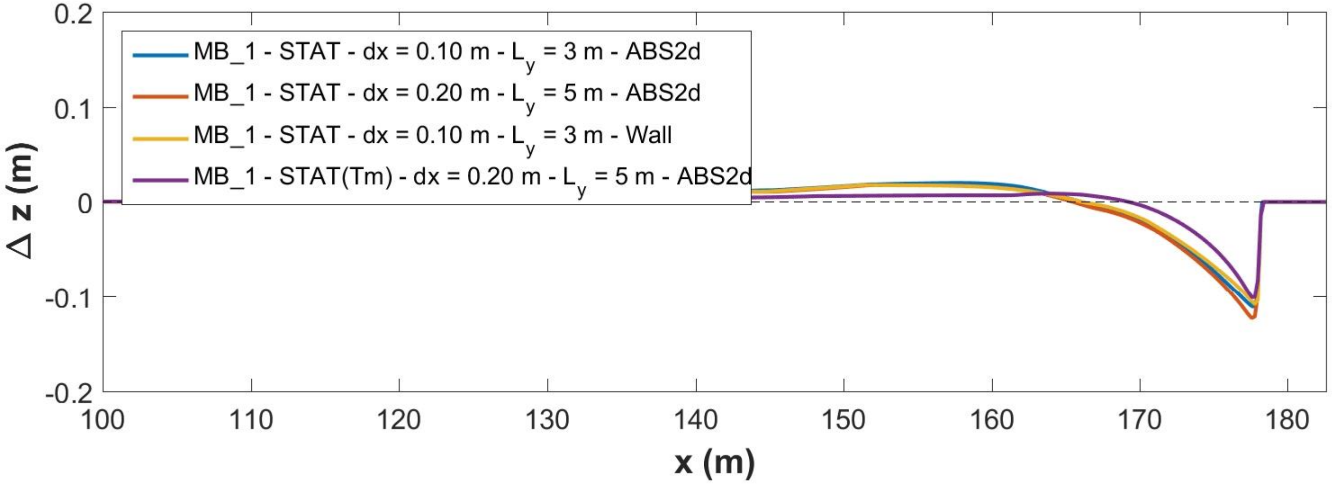


RESULTS AND DISCUSSION



Vdisp = 2.42 ± 0.13 m3

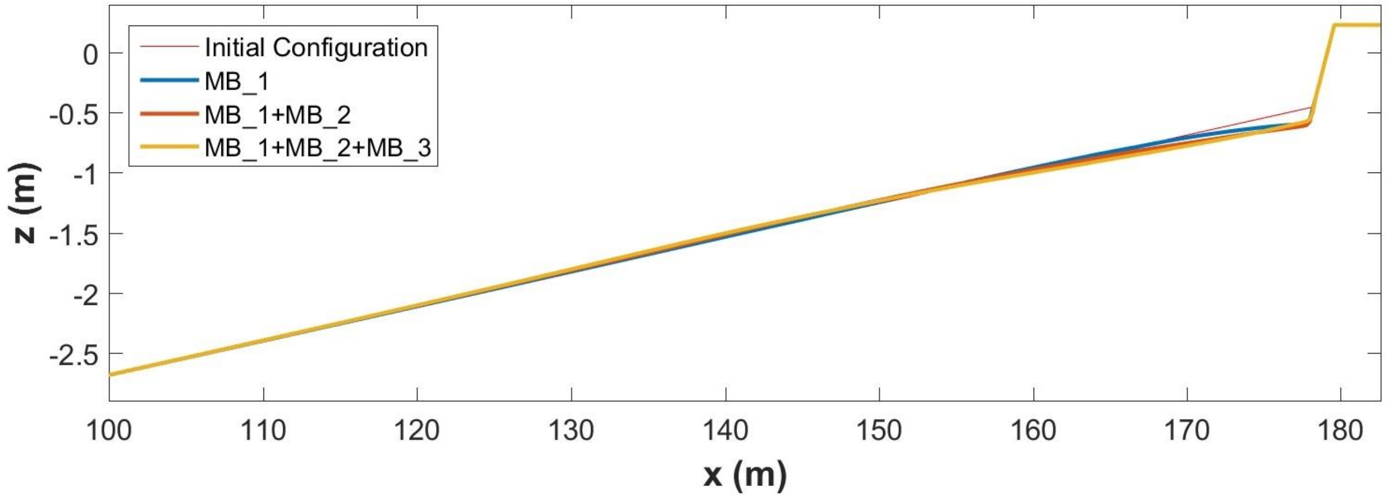


- Boundary conditions do not influence significantly the results
- Ly (transversal dimension) slight influences the results

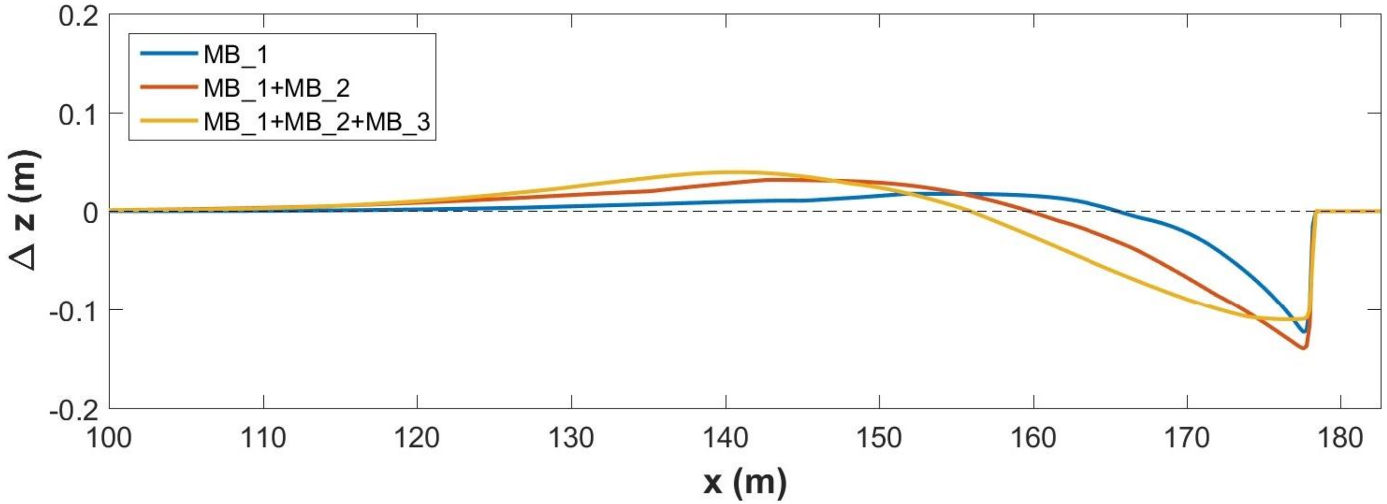
BC	L_y (m)	dx (m)	x_{dep} (m)	x_{er} (m)	V_{dep} (m^3)
ABS_2D	3	0.10	140.4	166.2	2.53
	5	0.20	141.4	165.6	2.30
WALL	3	0.10	140.6	166.2	2.43

RESULTS AND DISCUSSION

A further series of was performed to estimate the erosion/accretion pattern at the end of MB tests (without reprofiling at the end of each test).



STATIONARY CONDITIONS



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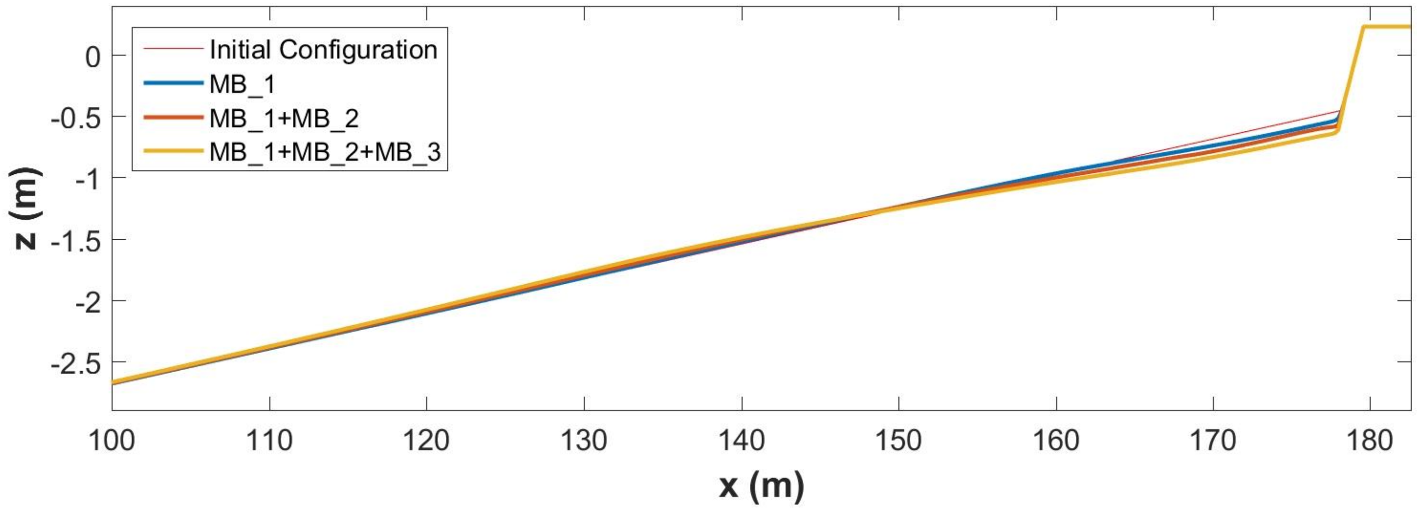

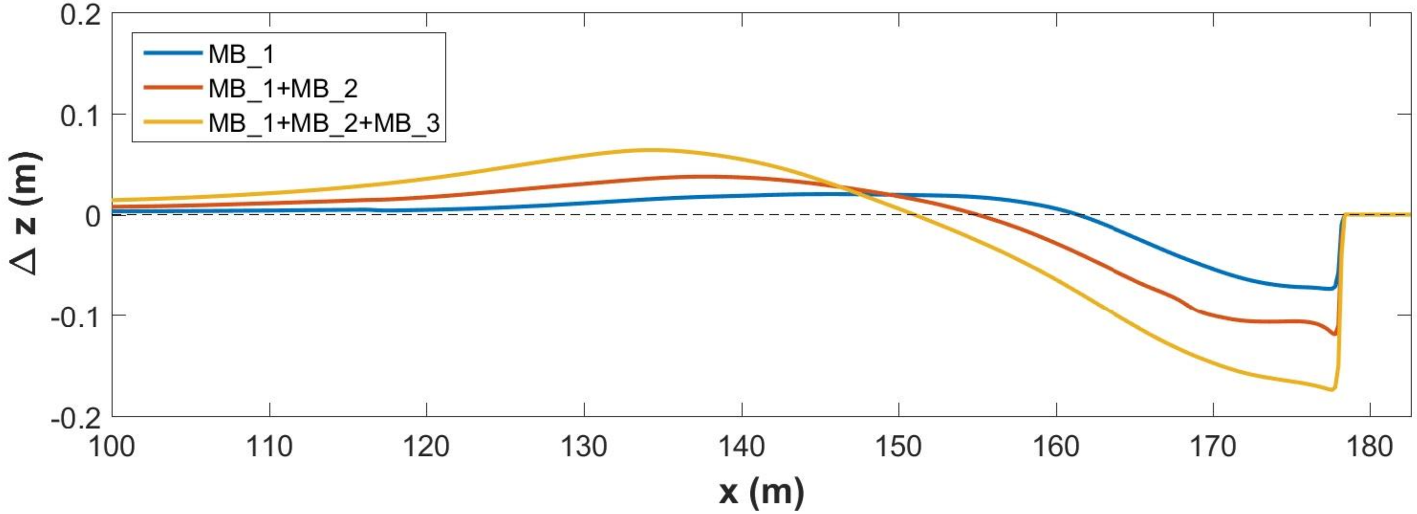

WAVE GROUPS

RESULTS AND DISCUSSION

The total displaced volume is **13÷23 m^3** (depending on wave groupiness) with erosion expected within about 30 m offshore the seawall (x≈177 m) and accretion within further 40 m (accretion greater than 2 cm)

Considering these results was possible to accept the possibility to do not reprofile at the end of each test because of the small morphodynamic changes.

PHYSICAL MODEL: TESTS PROGRAM

testID	Waves	h_{paddle}	h_{toe}	A_c	$H_{m0,off}$	$H_{m0,toe}$	$T_{m-1,0,off}$	$T_{m-1,0,toe}$	$h_{toe}/H_{m0,off}$
-	-	m	m	m	m	m	s	s	-
Bi_1_4	~18	3.99	0.28	0.25	1.11	0.36	6.76	19.89	0.25
Bi_1_5	~18	4.00	0.29	0.24	1.29	0.42	6.99	21.55	0.22
Bi_1_6	~18	4.01	0.30	0.23	1.23	0.40	7.40	21.44	0.24
Bi_2_4	~18	4.13	0.42	0.11	1.17	0.44	6.10	19.36	0.36
Irr_1_F	~1000	3.99	0.28	0.25	1.05	0.30	5.80	12.30	0.27
Irr_2_F	~3000	4.00	0.29	0.24	0.92	0.29	5.36	10.39	0.32
Irr_2_S	~3000	3.99	0.28	0.25	0.92	0.29	5.38	9.35	0.30
Irr_3_F	~3000	4.12	0.41	0.12	0.92	0.36	5.36	7.98	0.45
Bi_2_5	~18	4.14	0.43	0.10	1.27	0.49	6.16	17.31	0.34
Bi_2_6	~18	4.14	0.43	0.10	1.30	0.51	6.24	17.14	0.33
Bi_2_6_R	~18	4.14	0.43	0.10	1.31	0.50	6.19	17.26	0.33
Irr_8_F	~1000	4.13	0.42	0.11	0.49	0.35	3.83	4.85	0.86
Irr_4_F	~1000	3.79	0.08	0.45	0.87	0.22	5.41	12.05	0.09
Irr_5_F	~1000	3.78	0.07	0.46	1.05	0.26	5.82	13.55	0.07
Irr_1_F_R	~1000	4.01	0.30	0.23	1.06	0.35	5.80	10.43	0.28
Irr_7_F	~1000	4.00	0.29	0.24	0.65	0.29	4.65	7.00	0.45
Irr_2_F_R	~3000	4.01	0.30	0.23	0.92	0.32	5.36	8.55	0.33
Bi_1_6_R	~18	4.01	0.30	0.23	1.34	0.48	6.07	17.50	0.22
Bi_3_6	~18	3.77	0.06	0.47	1.05	0.31	6.52	22.79	0.05
Bi_3_6_1	~18	3.77	0.06	0.47	1.16	0.34	6.64	21.71	0.05
Bi_3_6_2	~18	3.76	0.05	0.48	1.28	0.35	6.36	19.59	0.04
Irr_6_F	~1000	3.77	0.06	0.47	0.65	0.19	4.68	10.05	0.09

RESULTS AND DISCUSSION

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Irr_1_F	~1000	3.99	0.28
Irr_2_F	~3000	4.00	0.29
Irr_2_S	~3000	3.99	0.28
Irr_3_F	~3000	4.12	0.41
Bi_2_5	~18	4.14	0.43
Bi_2_6	~18	4.14	0.43
Bi_2_6_R	~18	4.14	0.43
Irr_8_F	~1000	4.13	0.42
Irr_4_F	~1000	3.79	0.08
Irr_5_F	~1000	3.78	0.07
Irr_1_F_R	~1000	4.01	0.30
Irr_7_F	~1000	4.00	0.29
Irr_2_F_R	~3000	4.01	0.30
Bi_1_6_R	~18	4.01	0.30
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Bi_3_6_1	~18	3.77	0.06
Bi_3_6_2	~18	3.76	0.05
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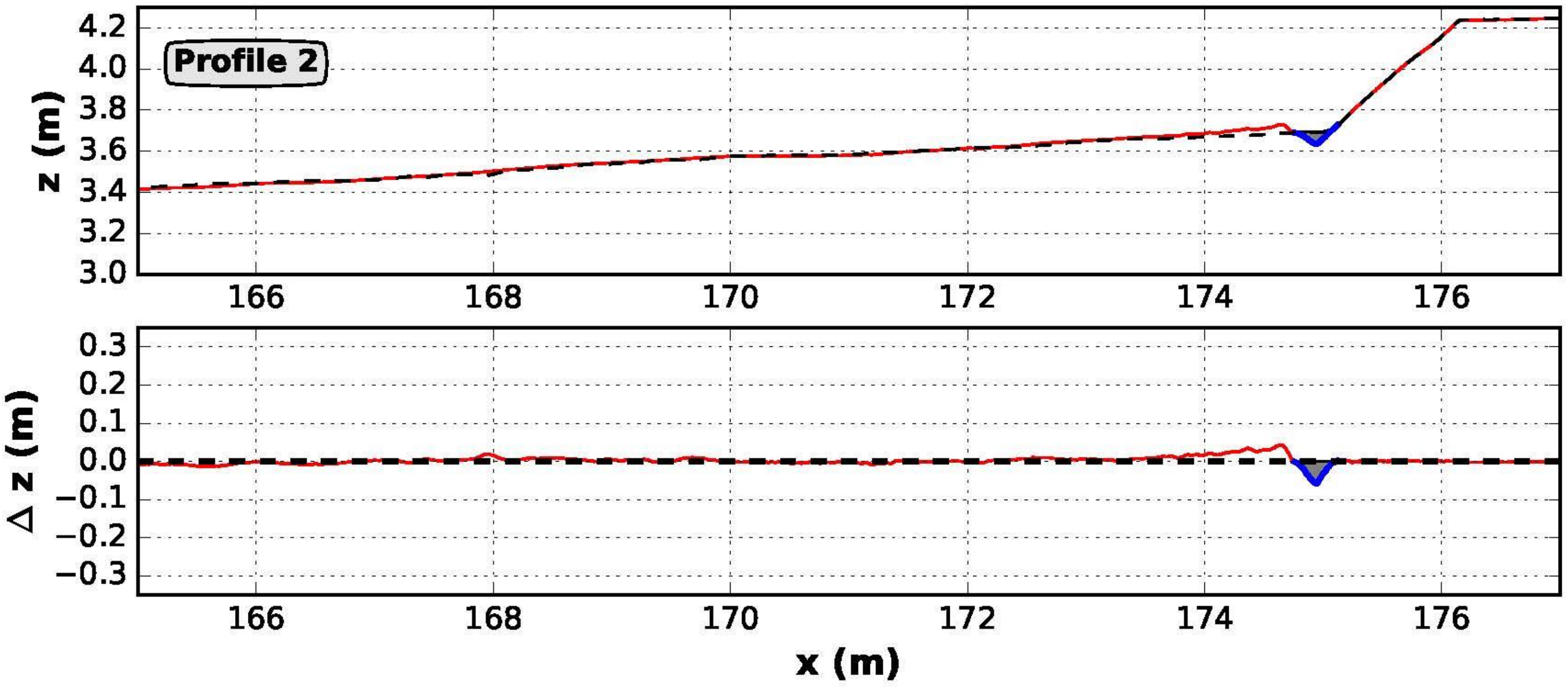
The displayed profile was measured at the center line in the Delta Flume



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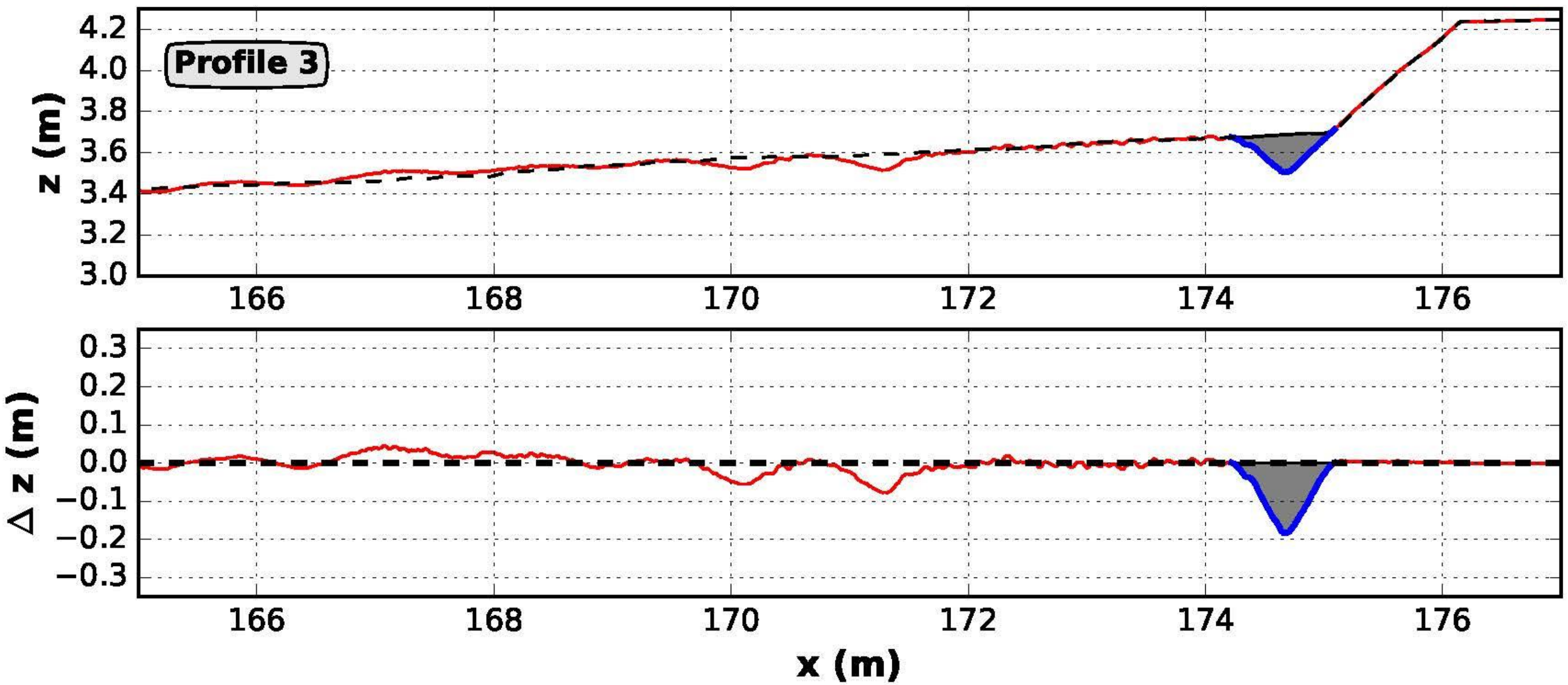

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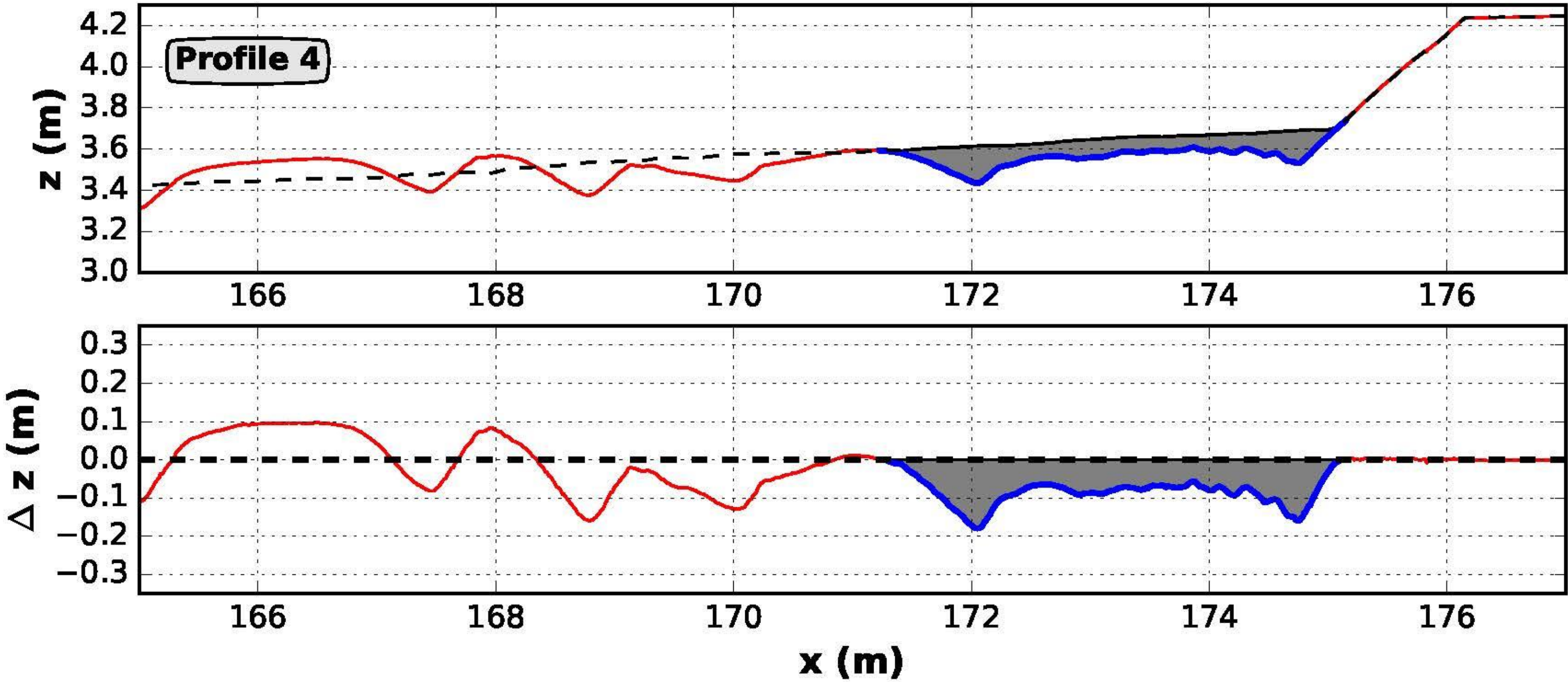

RESULTS AND DISCUSSION

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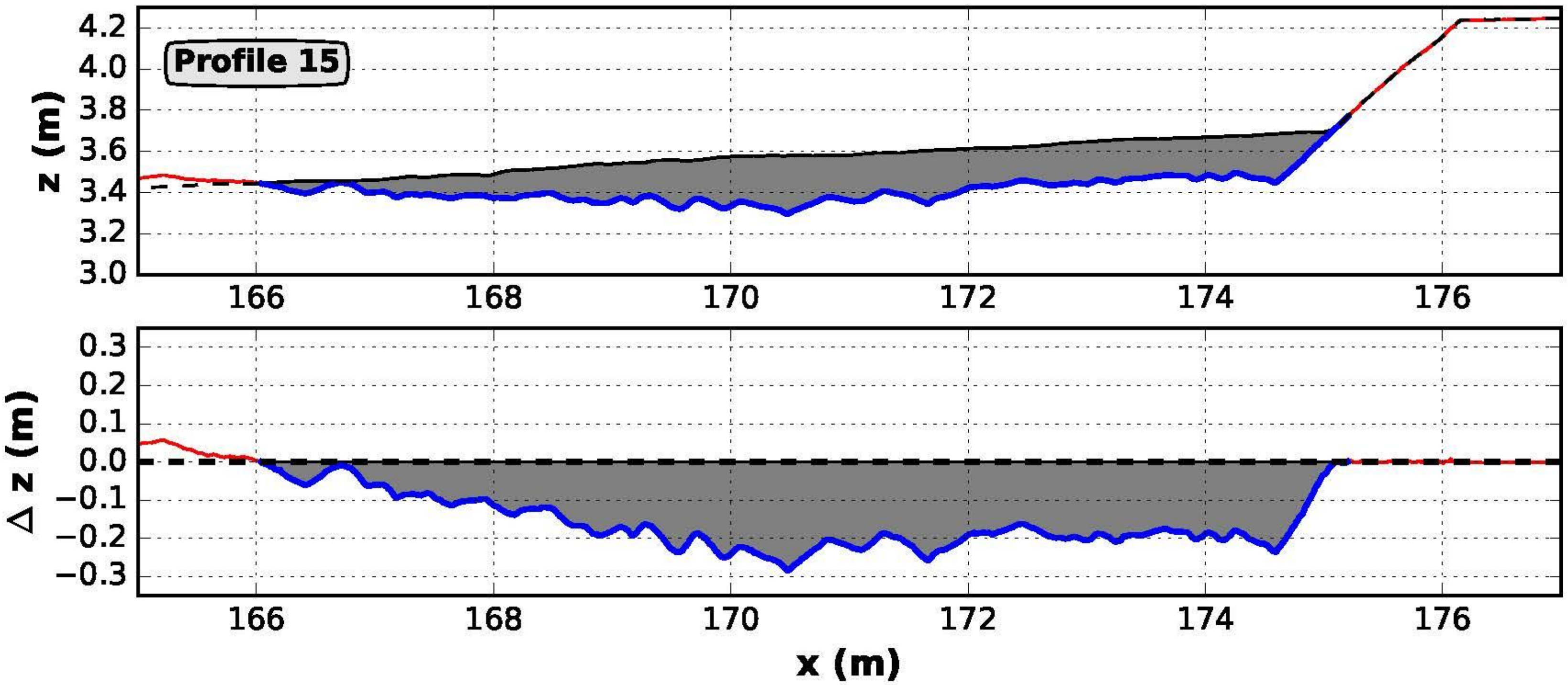

RESULTS AND DISCUSSION

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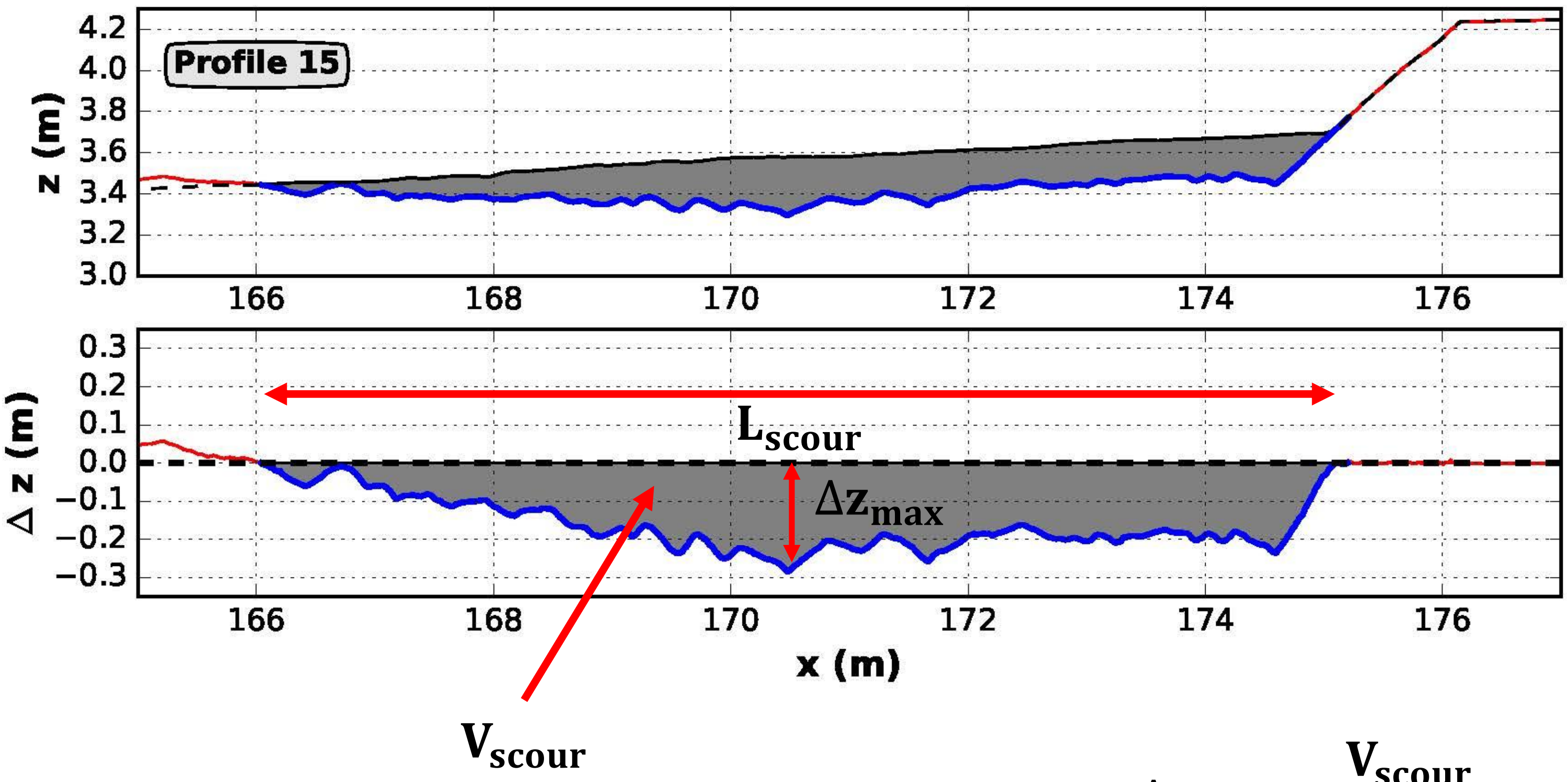
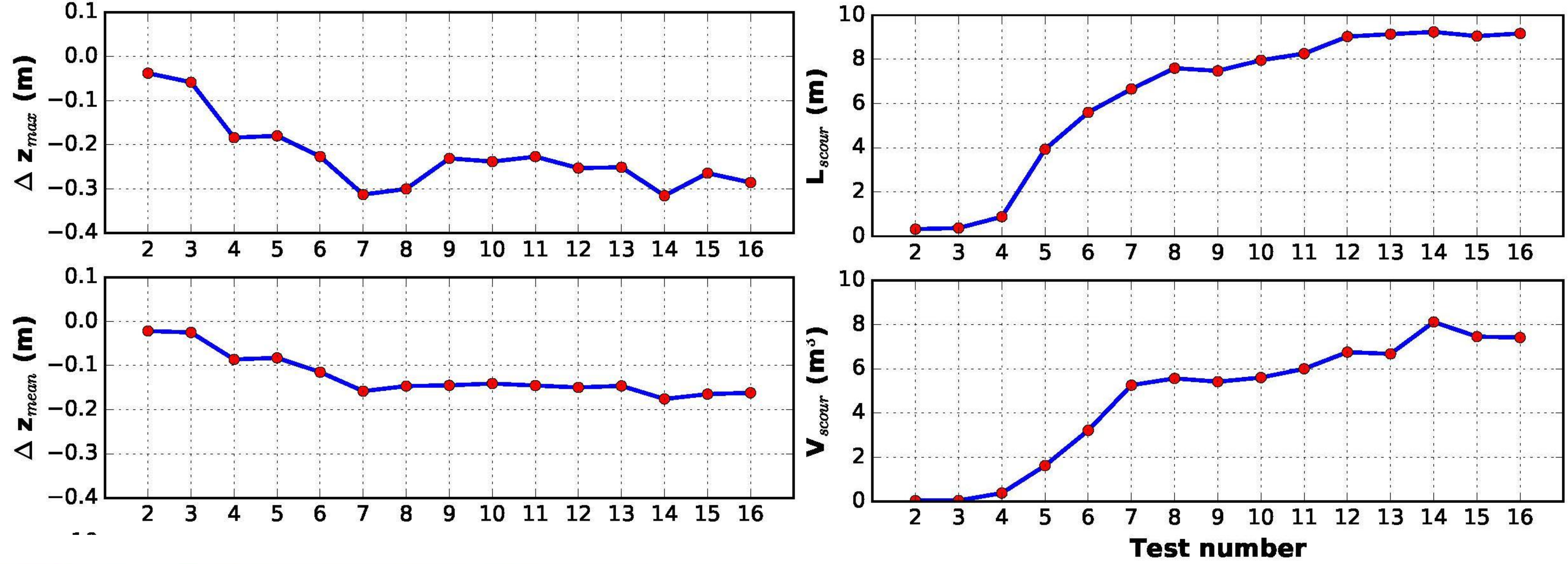


$$\Delta z_{mean} = \frac{V_{scour}}{L_{scour}}$$

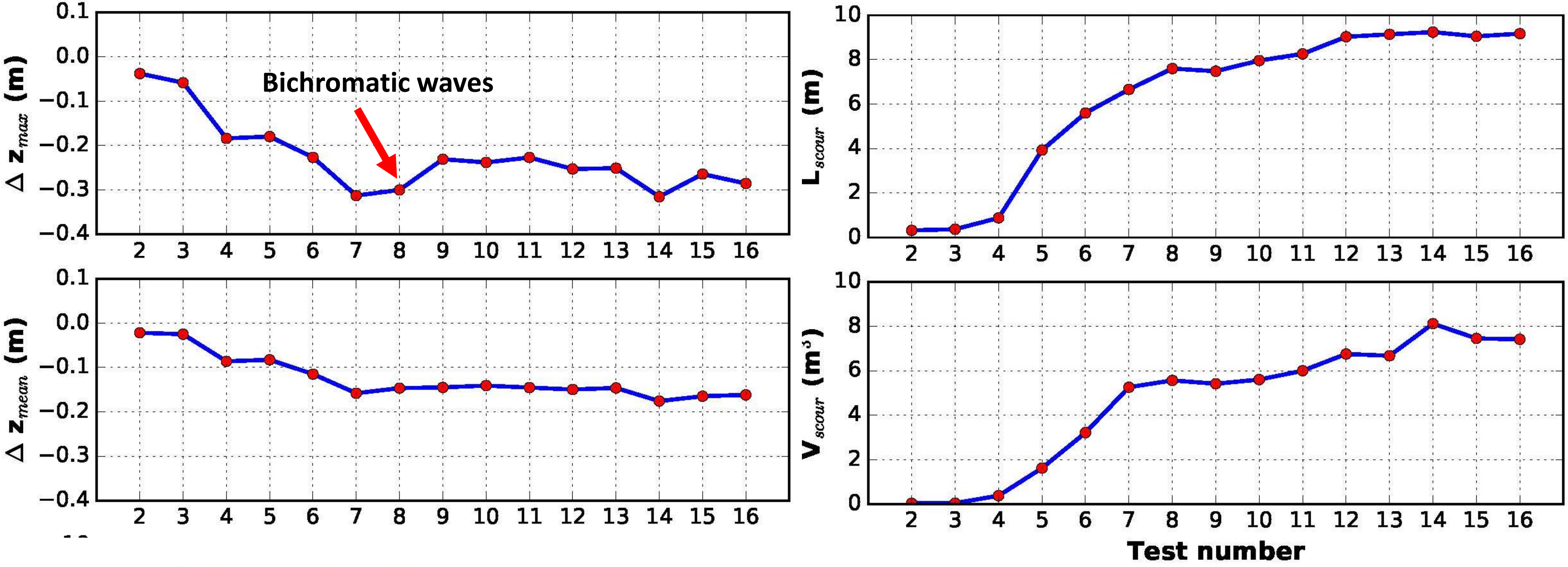
RESULTS AND DISCUSSION

Scour evolutions related to test number



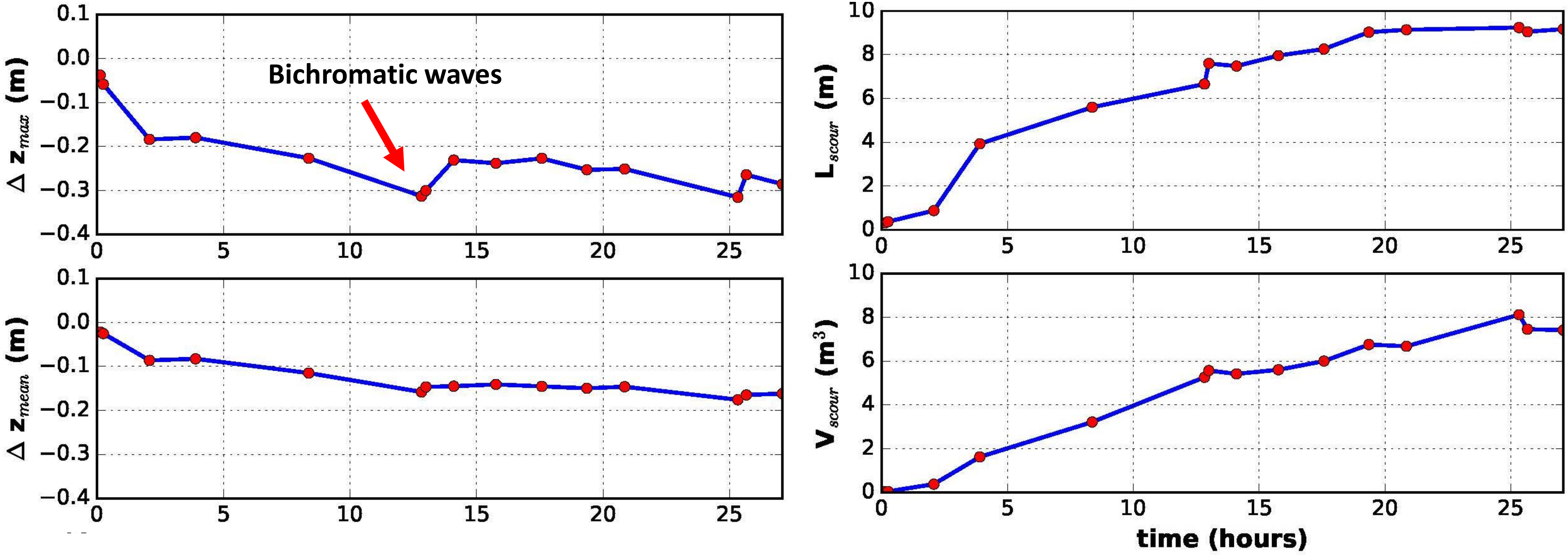
RESULTS AND DISCUSSION

Scour evolutions related to test number



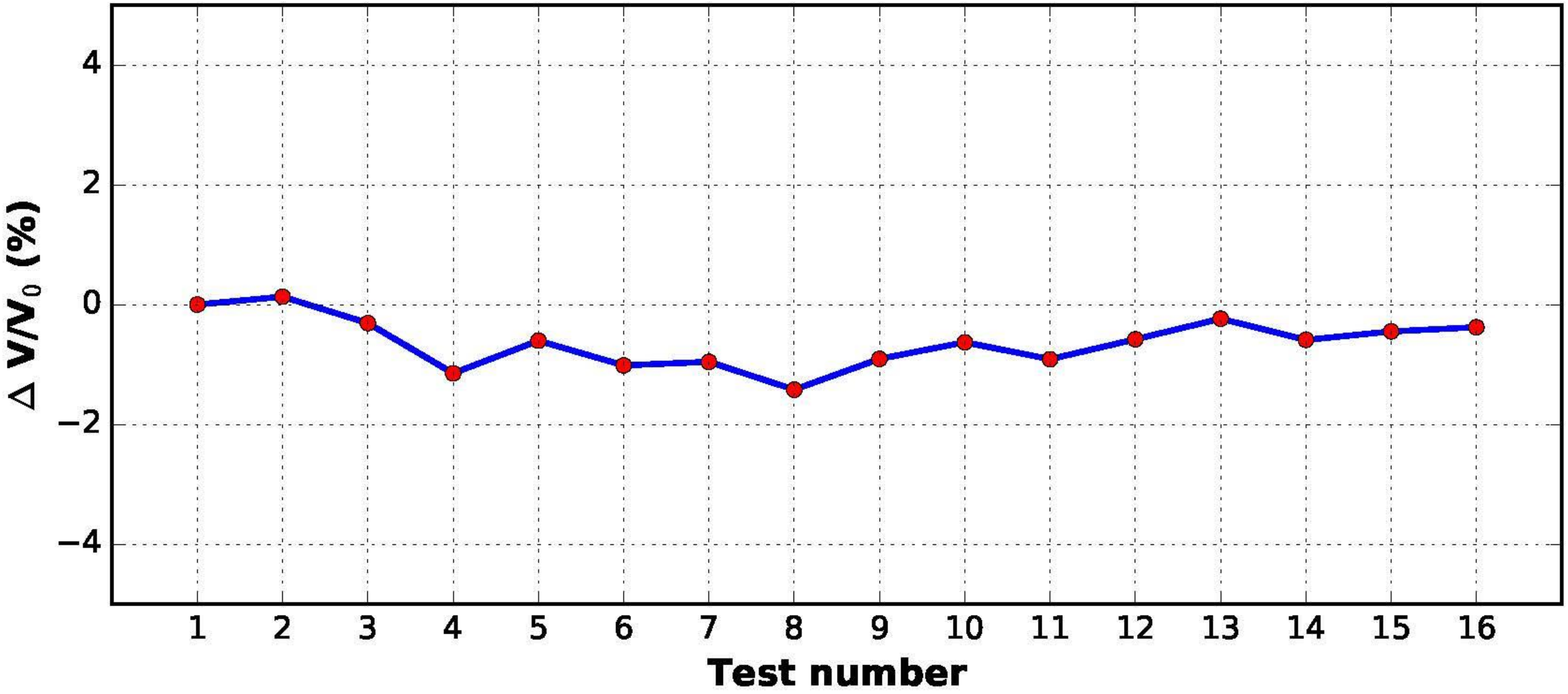
RESULTS AND DISCUSSION

Scour time evolution



RESULTS AND DISCUSSIONS

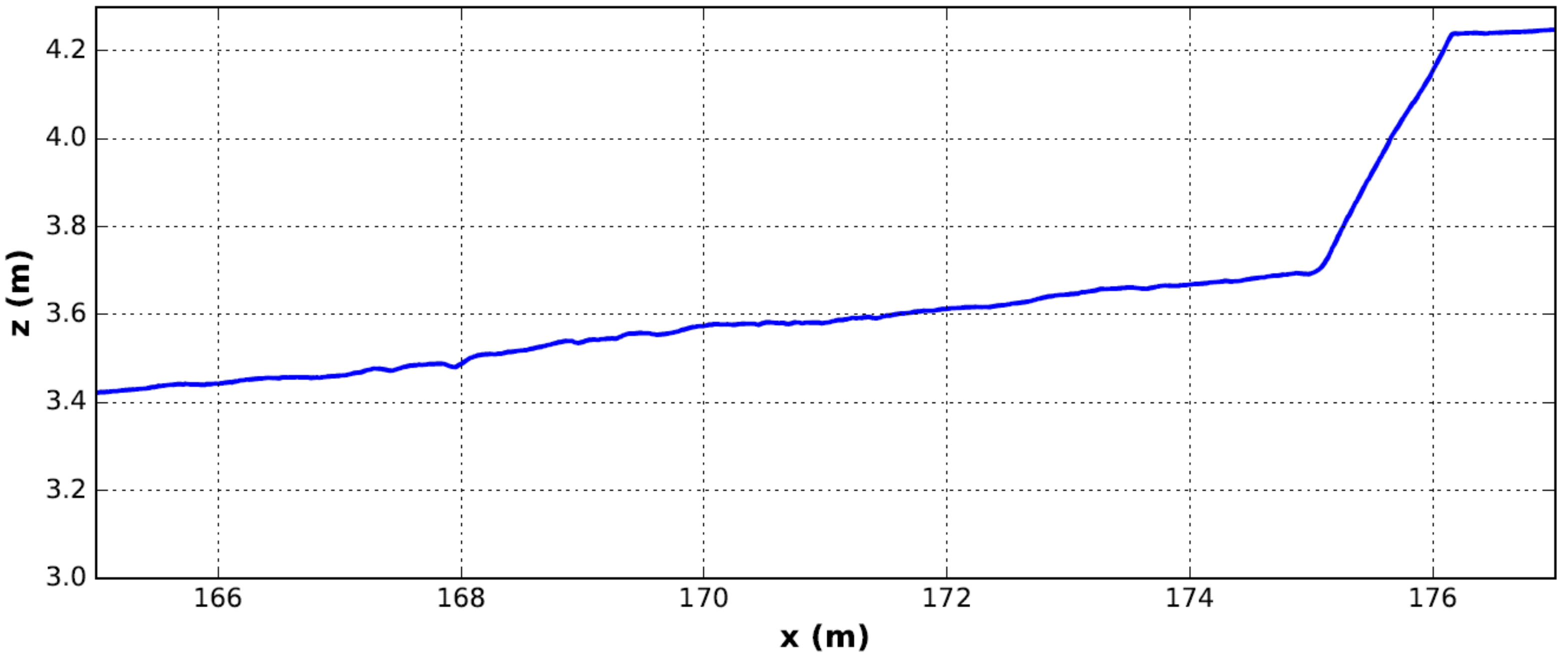
Variations percentage



Numerical Simulations – Preliminary results

A series of XBeach numerical simulations was performed to reproduce the observed evolution.

The initial configuration of the first simulation was set equal to the observed one.



Numerical Simulations – Preliminary results

Scour evolutions related to test number

A series of XBeach numerical simulations was performed to reproduce the observed evolution.

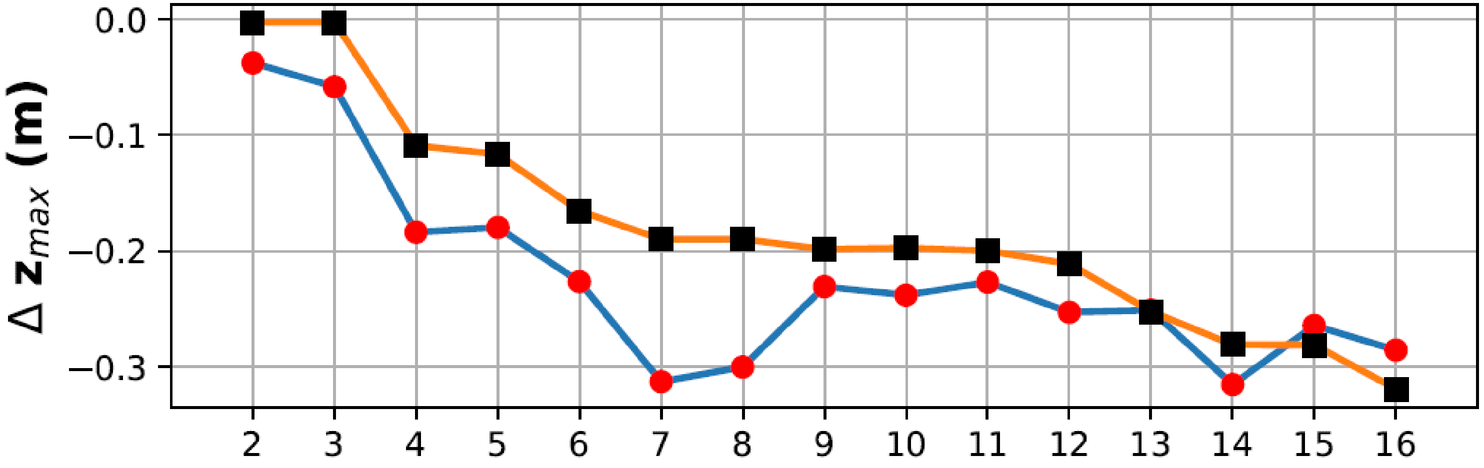
The initial configuration of the first simulation was set equal to the observed one.

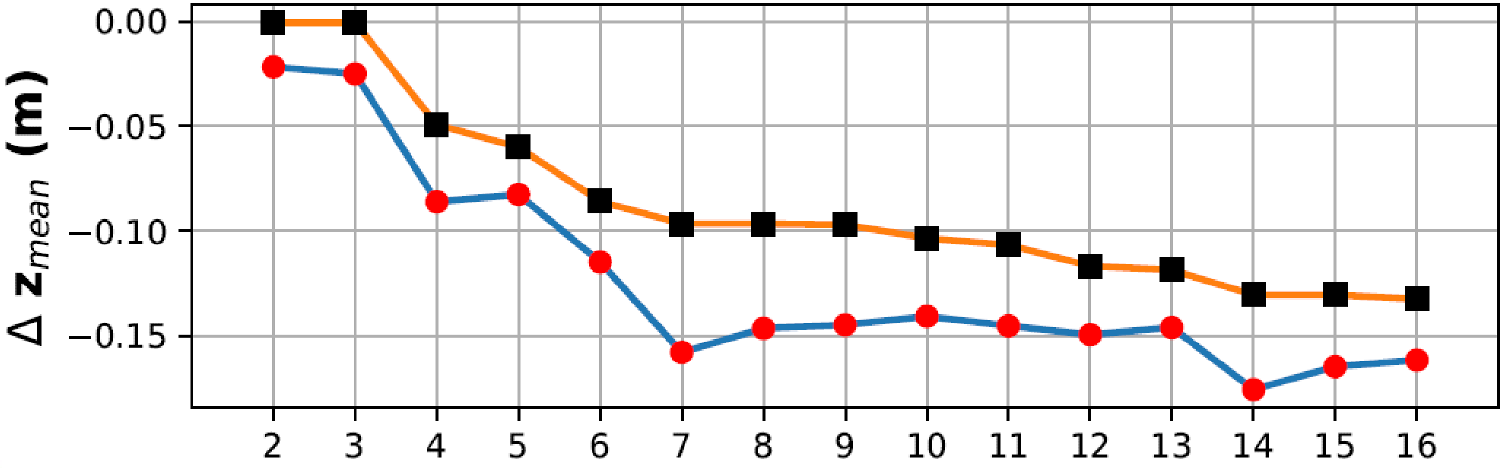
The initial configuration of the succeeding simulations was set equal to the final configuration (computed) of the preceding simulations.

The computed cross shore profiles were then analyzed and compared to the observed ones.

Numerical Simulations - Preliminary results

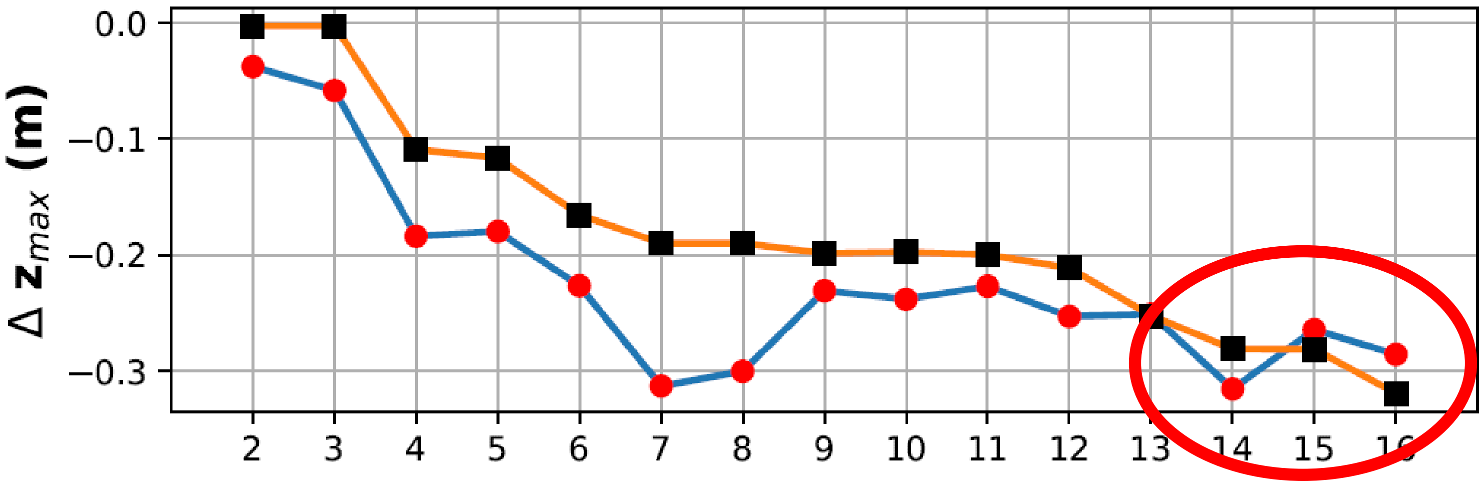
Scour evolutions related to test number

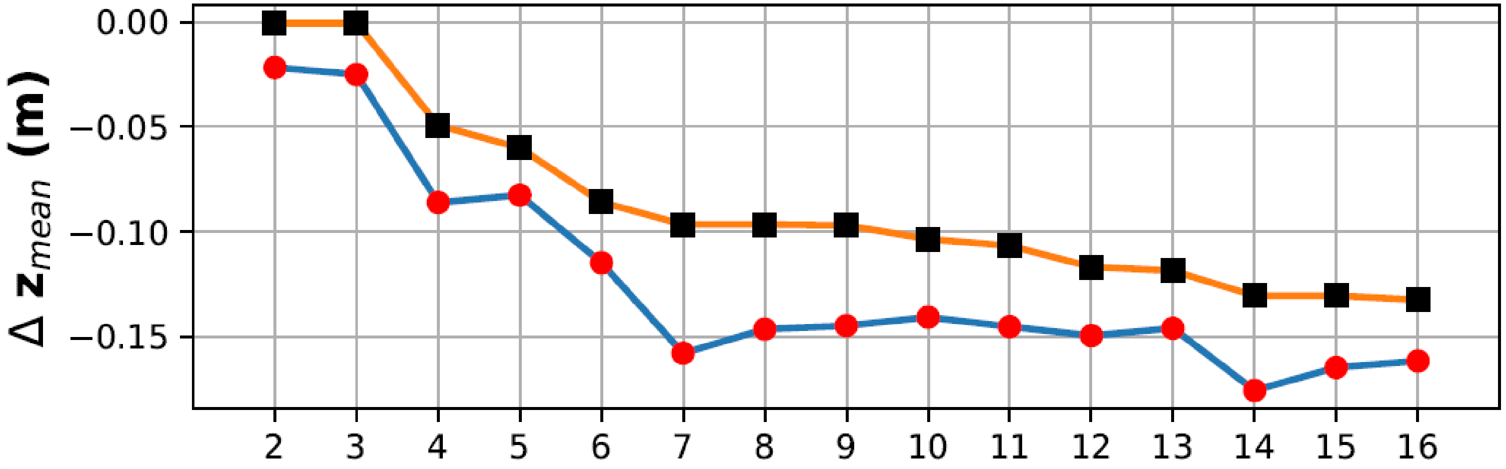




Numerical Simulations - Preliminary results

Scour evolutions related to test number





CONCLUSIONS

In the paper, foreshore morphological evolution based on a physical model and numerical simulations is reported and discussed.

Bed scour at the dike toe and its evolution in terms of scour depth, width and distance from the structure toe are investigated.

The numerical study was performed to design the experiments and to reproduce the observed evolution

The importance of the numerical simulations for physical model design is underlined.

The work is still in progress with the aim to provide insight (and design criteria) about morphodynamic evolution in front of sea walls with shallow foreshore.

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Thank you for your attention

any questions/comments?

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Marine Sediments: Processes, Transport and Environmental Aspects

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Message from the Guest Editors

In recent years, increasing attention has been paid to water quality and environmental aspects related to sediment transport driven by both ambient forcing and human activities. Indeed, estuarine, coastal, and harbor areas often undergo operations to nourish beaches, to maintain navigation channels, to remove contaminated sediment, and so forth. Hence, much research is needed related to the sediment processes, transport, and related environmental aspects of marine sediments. The aim of this Special Issue is to collect novel research results in this field.

Authors are invited to submit papers dealing with topics including but not limited to the following:

- marine sediment processes, transport, and environmental aspects related to dredging operations
- coastal sediments transport
- harbor siltation
- sustainable costal defence systems
- contaminated sediment management

Research based on field observation, numerical and experimental modelling, and theoretical models is expected to be part of the Special Issue. Also, methodological approaches, comprehensive reviews, and best practices on national and international scales are welcome.

Special Issue