EGU General Assembly 2020
Vienna | Austria | 3-8 May 2020

Post-storm recuperation as a stepping-stone towards long-term integrated modelling in steep beaches

Katerina Kombiadou[1,*], Susana Costas[1], Dano Roelvink[2], Robert McCall[3]

[1] Centre for Marine and Environmental Research (CIMA), University of Algarve, Campus de Gambelas, Edf. 7, 8005-139 Faro, Portugal

[2] IHE Delft institute for Water Education, Water Science and Engineering Dept., Westvest 7, 2611AX Delft, the Netherlands

[3] Deltares, Marine and Coastal Systems, Boussinesqweg 1, 2629 HV Delft, the Netherlands

[*] Corresponding author: akompiadou@ualg.pt

ENLACE
Exploring New approaches to simuLAte long-term Coastal Evolution

https://www.cima.ualg.pt/ENLACE/

Introduction – objective

- Integrated modelling approaches for the evolution of the entire dune-beach system have become increasingly sought-after, not only for management purposes, but also to allow better understanding of the feedbacks between processes and scales and a closer approximation of where critical system thresholds may lie.
- The effective reproduction of both destructive and constructive processes over a broad spectrum of temporal scales is crucial to any, such, integrated approach.
- Recent improvements of the XBeach-Duna model regarding approximation of nearshore processes were tested using in-situ data from the Emma storm impacts on a reflective beach (Praia de Faro, in S. Portugal).

Problem setting

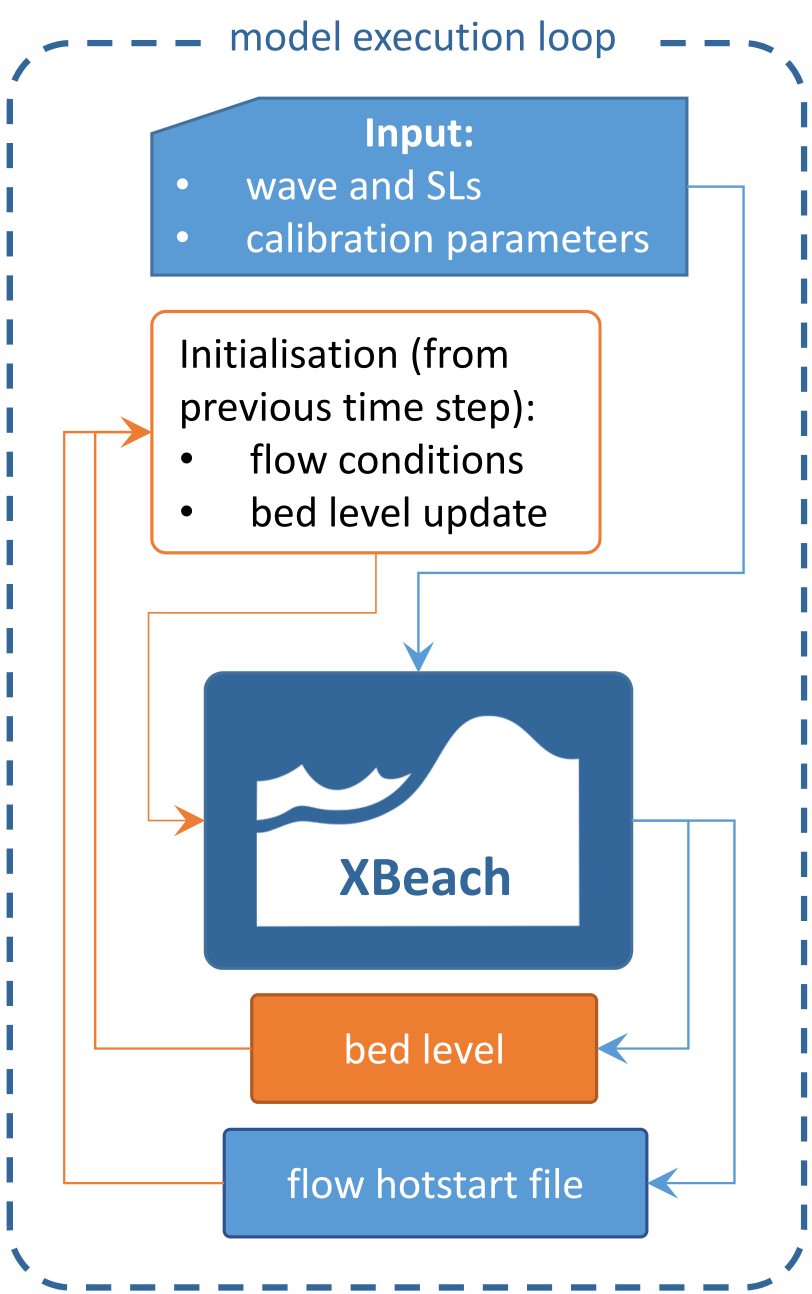
Main question:

Can we reproduce marine recovery of heavily impacted steep beaches in morphodynamic models?

Approach:

Testing Xbeach with erosion and recuperation field data:

- **Morphodynamics:** Xbeach (version 1.23.5526) with hotstart option, run in a loop (see XBeach execution scheme to the left). This allows changing input parameters per run step.
- **Data:** Pre-and post-storm (erosion and recuperation) profiles from a reflective beach in S. Portugal for the Emma storm (28 February – 3 March 2018)



Study site

- The study area is **Praia de Faro** (Faro Beach) in the central part of Ancão Peninsula (W end of the Ria Formosa barrier system in S. Portugal; Figure). The area is characterised by a **steep beachface**, with average slope around 10%, varying from 6% to 15% (Vousdoukas, Almeida, & Ferreira, 2012).

- **Beach storm response and recuperation** has been monitored for the **Emma storm** (28 Feb – 03 Mar 2018), a storm with similar track to some of the most energetic and devastating historical storms in the area that coincided with high spring tides during the storm peak (Ferreira, Plomaritis, & Costas, 2019).

Study site

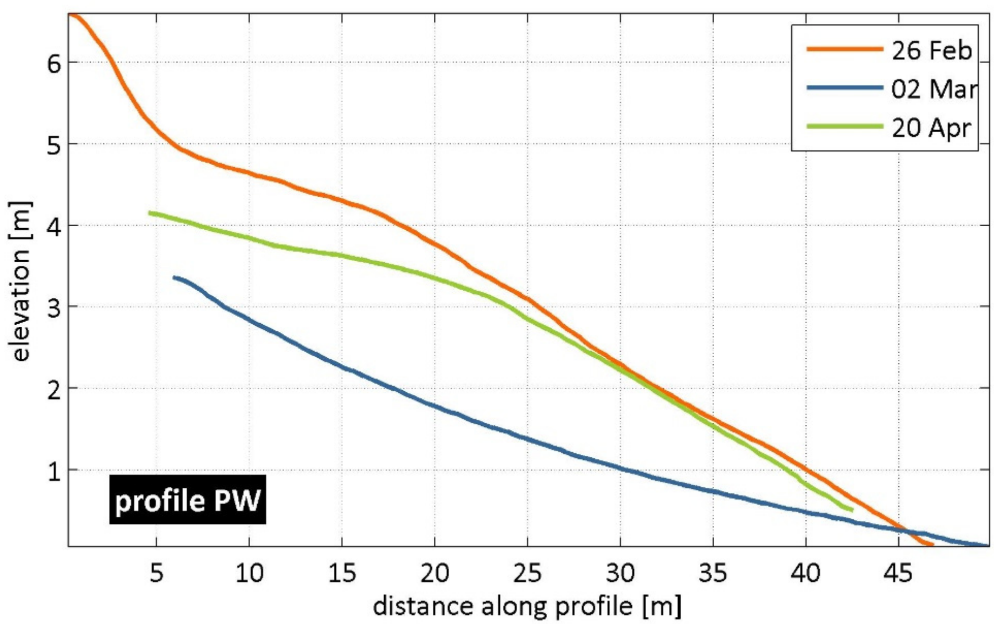
- Two profiles along **Praia de Faro** (PdF, central part of Ancão P.; PW and PE) were measured **before** the storm (26 Feb), **right after the storm peak** (02 Mar) and **50 days later** (20 Apr).

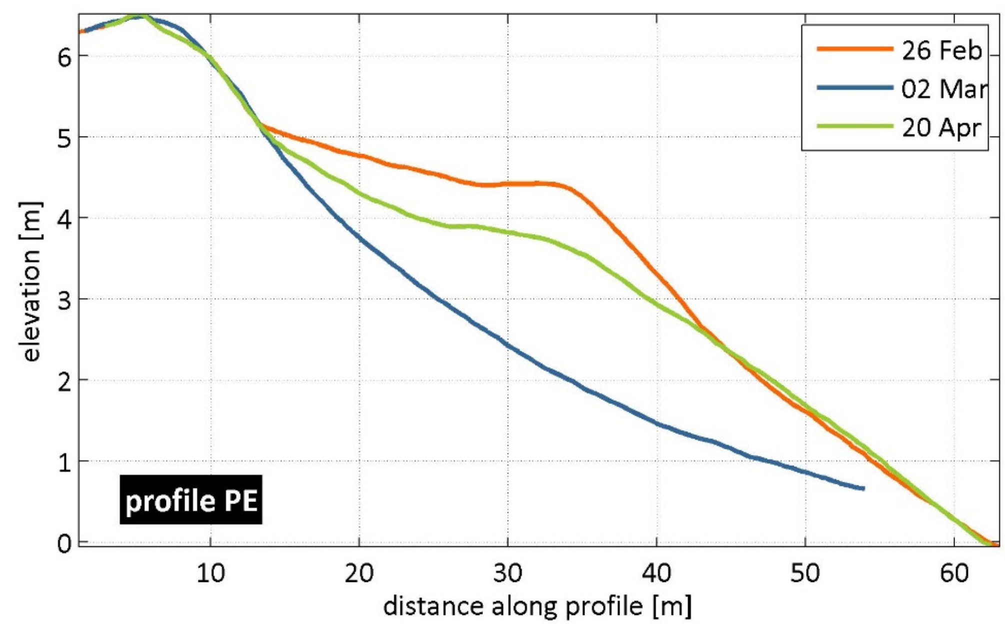

post-storm beach conditions near PW


post-storm beach in the central part of PdF

Field data: morphology

- The profiles show similar patterns of erosion and recuperation, with strong losses during the peak of the storm and almost full recuperation until April 20th (50 days after the storm peak).
- Total volume change values (Table), show very similar erosion over the barrier stretch and slightly lower recovered sand volumes.
- Pre-storm beachface slopes were around 0.14-0.15, post-storm profiles showed intense 'flattening' (slope at 0.05-0.06) and recovered profiles largely regained pre-storm values.





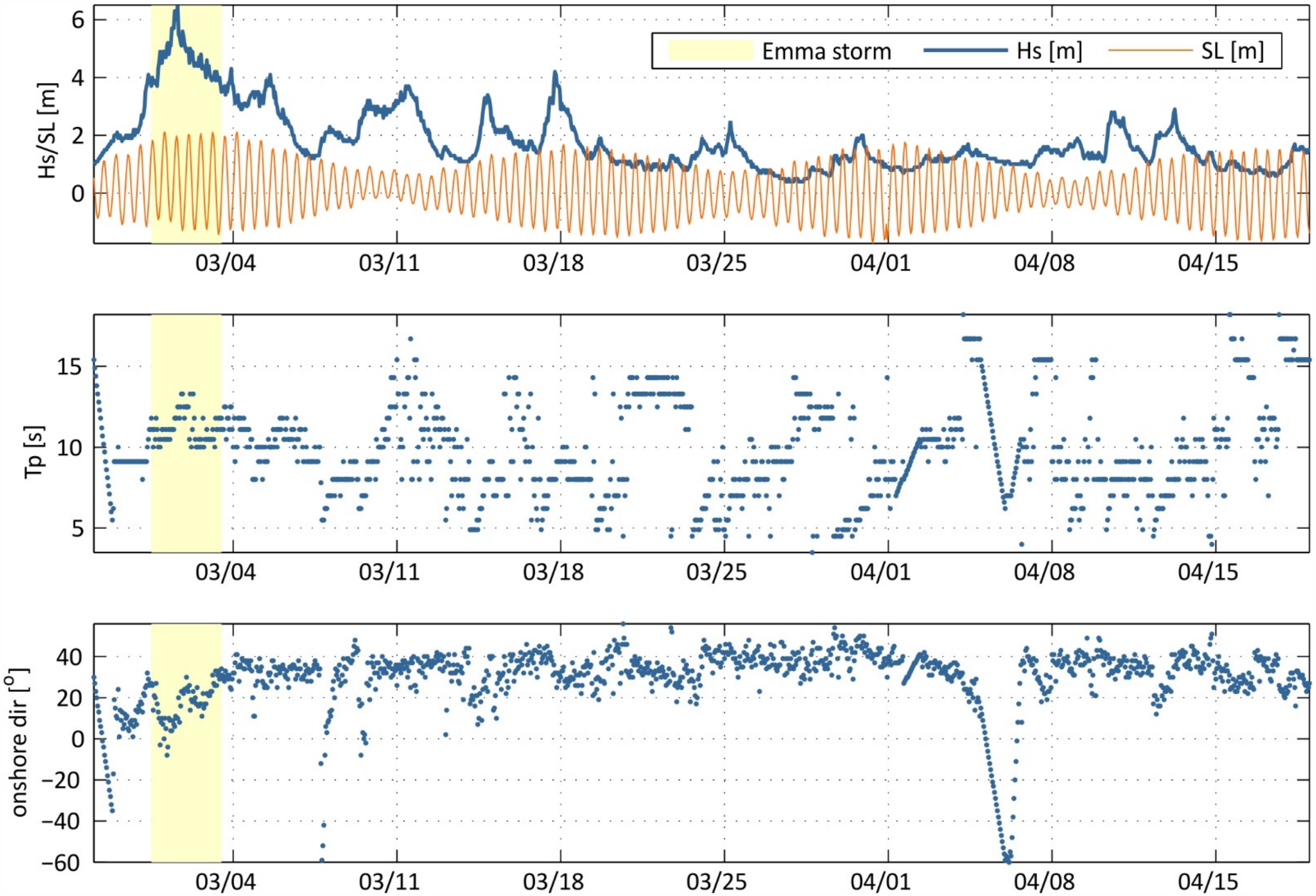
	Total profile change (m^3/m)		Beachface slopes		
Profile	26 Feb to 02 Mar	02 Mar to 20 Apr	26 Feb	02 Mar	20 Apr
PW	-53.07 (-1.46)	+39.80 (+1.10)	0.137	0.056	0.132
PE	-54.63 (-1.35)	+41.22 (+1.02)	0.152	0.064	0.133

Note: values in parentheses refer to m^3/m per m along the profile

Field data: hydrodynamic forcing

Model forcing: 1-hour records of onshore waves and Sea Levels (SLs) for the period 26 Feb – 20 April 2018.

Wave timeseries (Hs, Tp, Dir) were collected from the Faro buoy (located offshore C. St. Maria, at a depth of 93 m). Sea Levels refer to surge levels (storm surge model of Puertos de Estado) and astronomical tides for Faro.



Calibration parameters

After extensive numerical rests, the selected XBeach calibration parameters include:

- **bermslope:** coefficient set to 10 times the usual bed slope term and leads to a strong local onshore transport when the actual slope is less than the 'bermslope' (Roelvink & Costas, 2019). Range of values tested: 0.0-0.28. Calibrated range: 0.13-0.25, varying inversely with $(Ho \cdot Lo)^{1/2}$
- **facua**: Calibration factor time averaged flows due to wave skewness and asymmetry. Range of values tested: 0.15-0.5. Calibrated range: 0.28-0.45, varying inversely with $(Ho \cdot Lo)^{1/2}$
- **delta:** fraction of the wave height, added to water depth to adjust maximum wave height in wave breaking formulations. Range of values tested: 0.0-0.8. Calibrated range: 0.1-0.6 for low and high beachface slope, respectively.

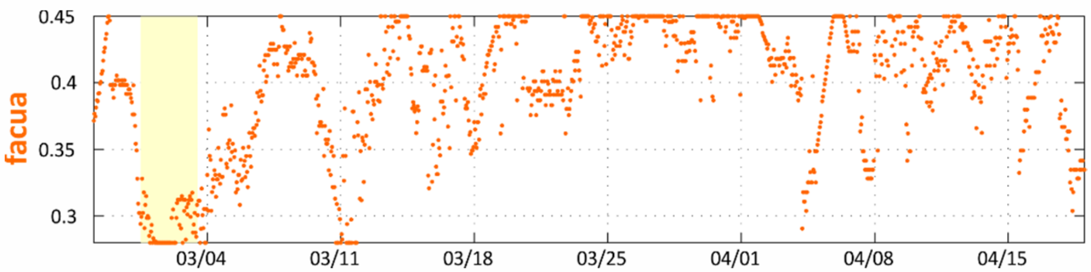
Hydrodynamics were simulated resolving both short and wave variations on the wave group scale (surfbeat mode), while considered wave breaking was modelled using the time-varying dissipation rate model of Roelvink (1993). Morphodynamic acceleration factor (morfac; Roelvink, 2006) of 5 was used in the simulations.

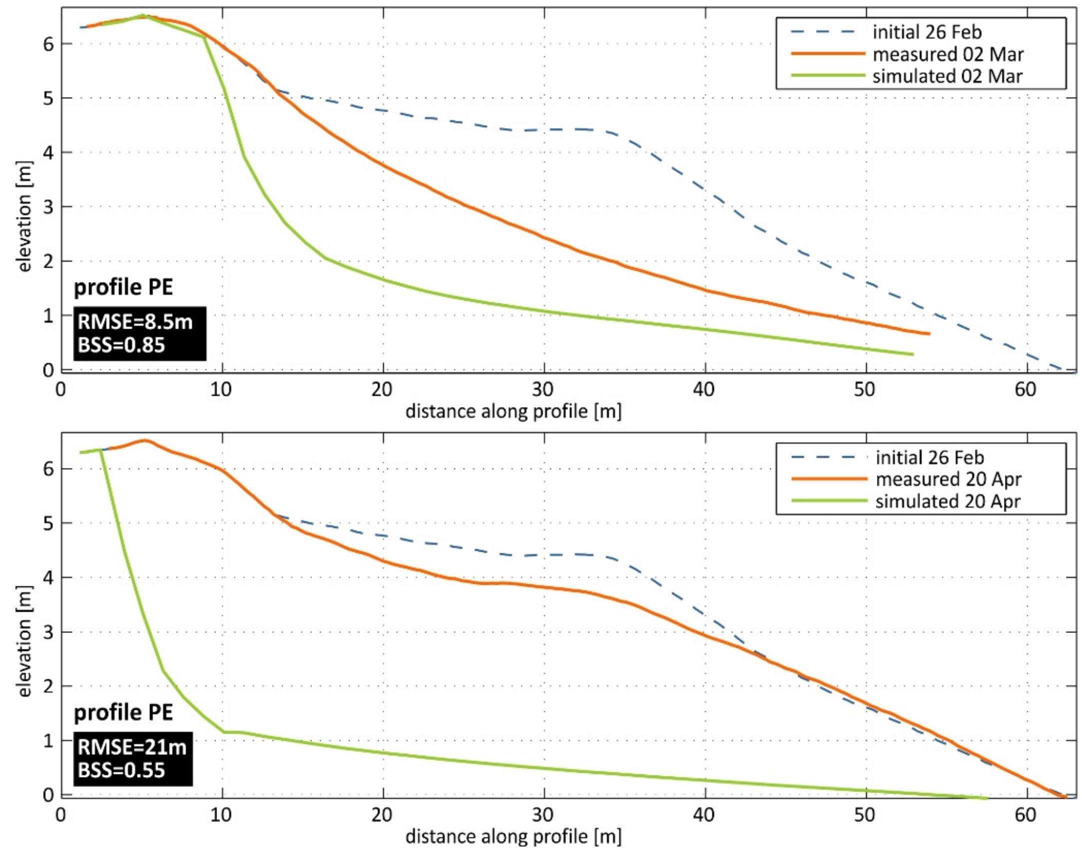
Results

Tests considering only **facua** (figure for PE) show that the model:

(a) greatly overestimates erosion, with excessive steepening of the eroded profile (26 Feb – 02 Mar), and

(b) continues to erode after the end of Emma with no ability to reproduce recovery (02 Mar – 20 Apr).



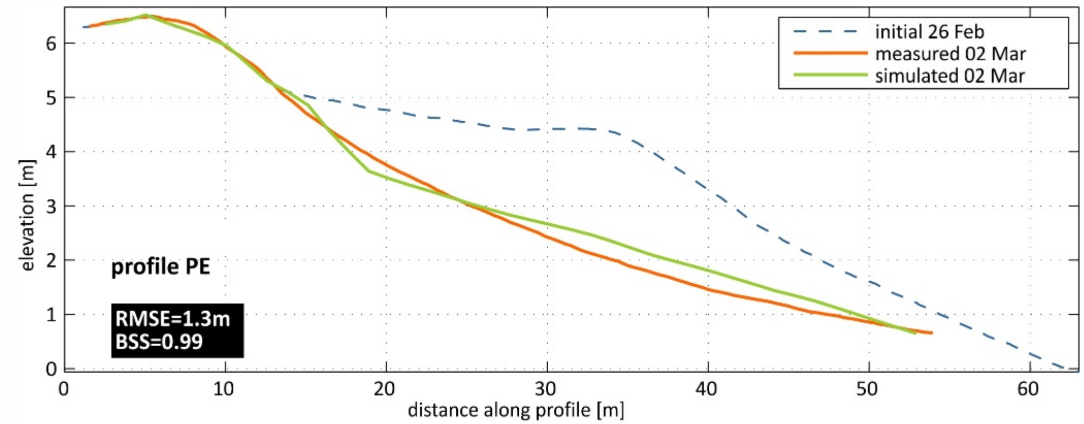


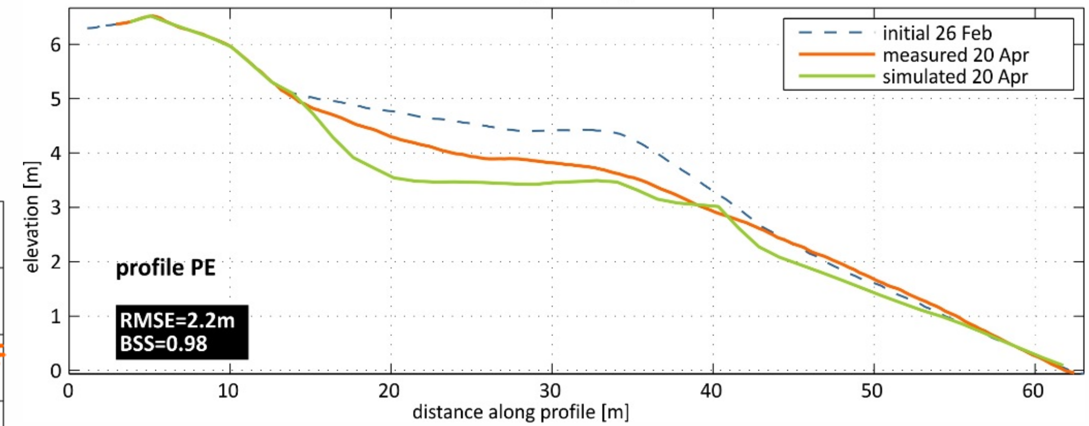
$$\text{facua} = 0.53 - 0.0085 \cdot \sqrt{H_o \cdot L_o}, \qquad [0.28, 0.45\,]$$

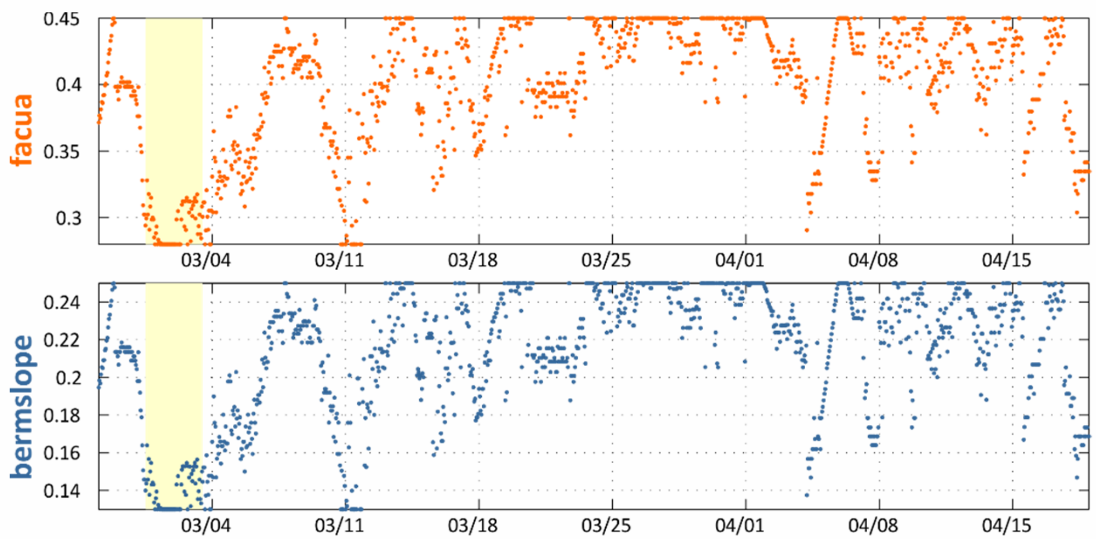
Results

Adding the **bermslope** factor allows significant improvement, especially for the erosion phase (26 Feb – 02 Mar), stabilising the simulated slope.

Under recovery (02 Mar – 20 Apr), **bermslope** allows for berm formation (otherwise impossible to reproduce) and fairly accurate reproduction of the lower part of the profile (under ~3m). Still, recovery of the upper part of the profile is underestimated, with sand not reaching elevations over 3.5m.





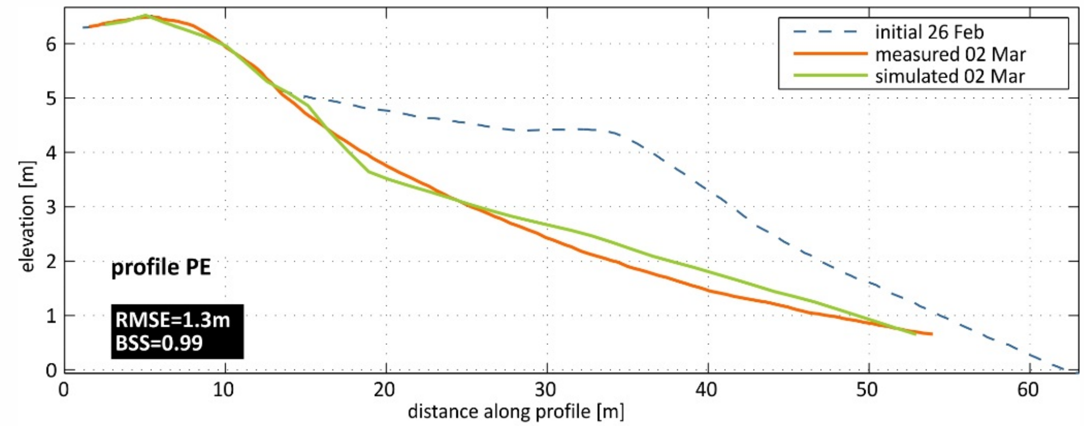


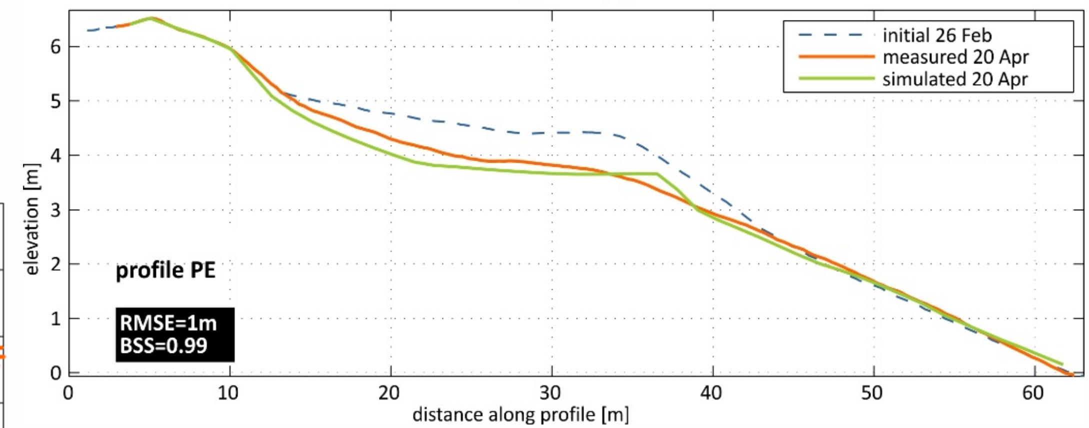
$$\text{facua} = 0.53 - 0.0085 \cdot \sqrt{H_o \cdot L_o}, \qquad [0.28, 0.45\,]$$

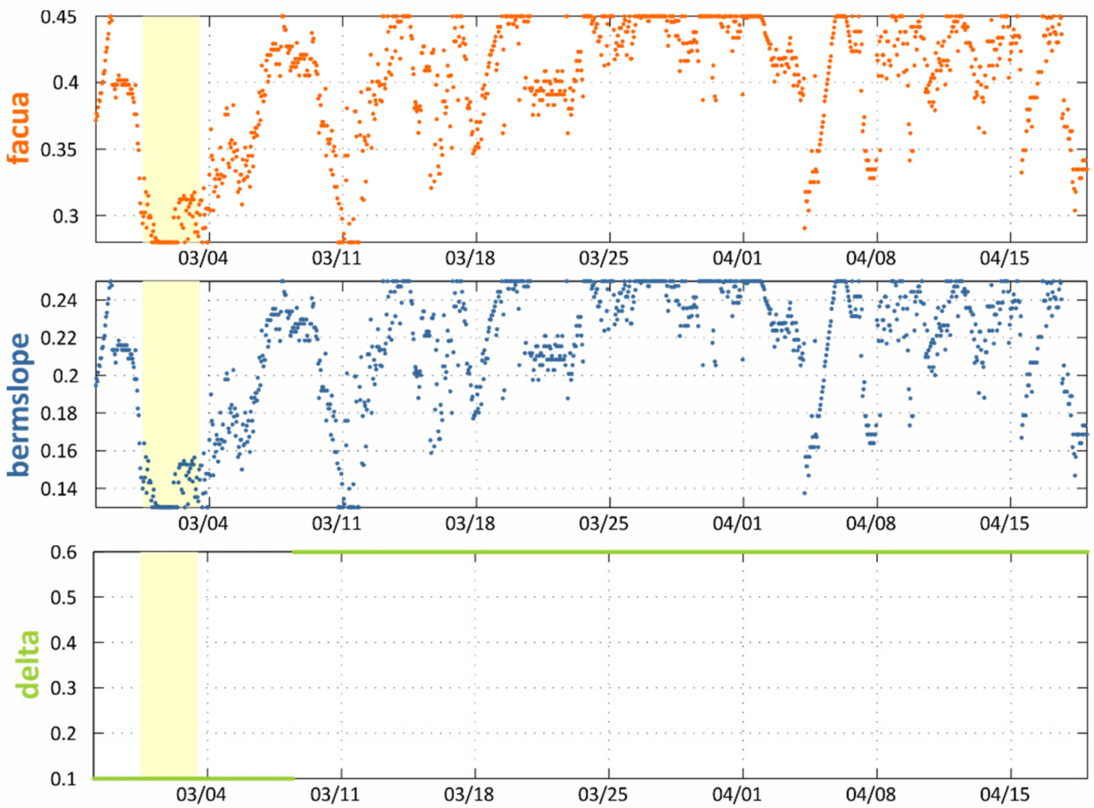
$$\text{bermslope} = 0.31 - 0.006 \cdot \sqrt{H_o \cdot L_o}\,, \qquad [0.13, 0.25]$$

Results

Increasing the **delta** parameter for low profile slopes (recovery conditions) strongly improved simulated recovery (02 Mar – 20 Apr), allowing to drive sand volumes higher into the profile (up to 4.5m).







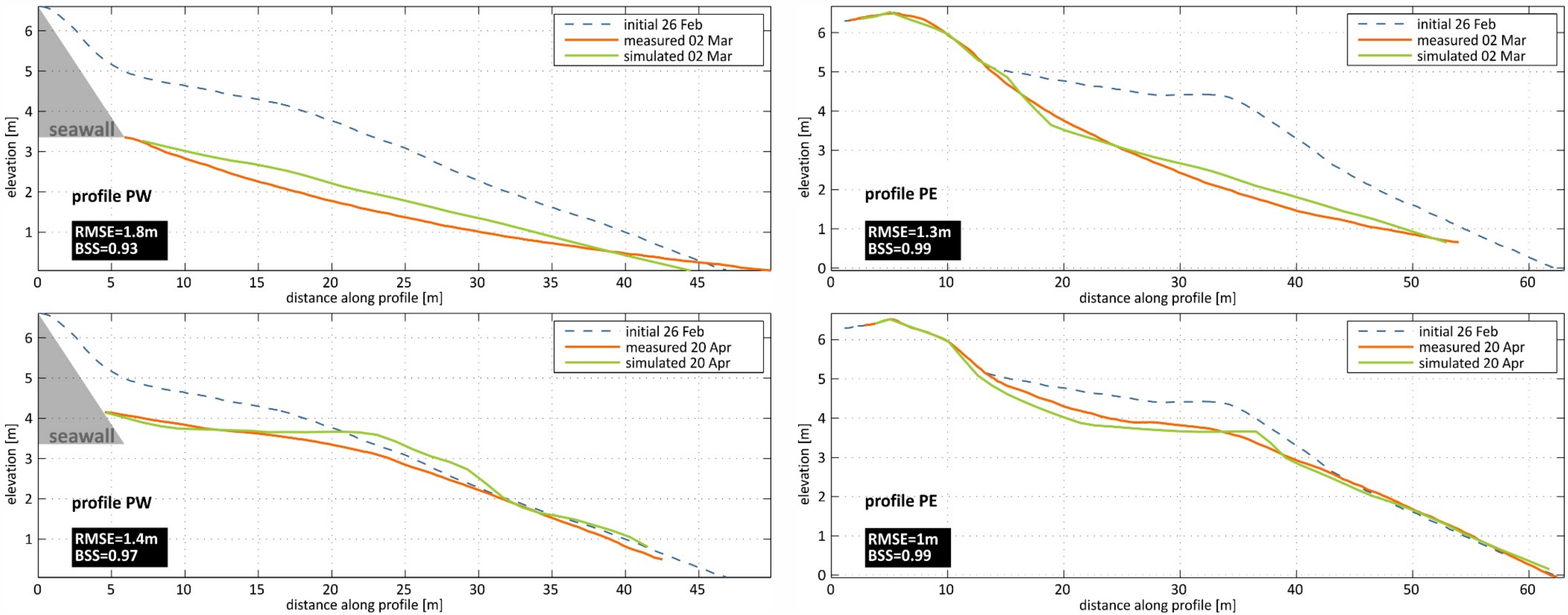
$$\text{facua} = 0.53 - 0.0085 \cdot \sqrt{H_o \cdot L_o}, \qquad [0.28, 0.45\,]$$

$$\text{bermslope} = 0.31 - 0.006 \cdot \sqrt{H_o \cdot L_o}\,, \qquad [0.13, 0.25]$$

$$\text{delta} = \begin{cases} 0.1 \text{ for } \beta < 0.7 \\ 0.6 \text{ for } \beta \geq 0.7 \end{cases} \qquad (\beta\text{: beachface slope})$$

Results

- Similar model performance is obtained for the PW profile (assuming the same calibration parameters), with low (Root Mean Square Error) RMSEs and high (Brier Skill Score) BSS values.
- Fine tuning of profile PW can further increase model performance.
- The solution presented regarding the temporal variability of calibration parameters is non-singular. It is expected that equally good model peformance can be obtained from different combinations.



Concluding remarks

- Preliminary model results, considering bermslope, facua and delta as calibration parameters, compare well with measured post-storm and recovered profiles, showing high model skill under both erosive and constructive regimes.
- Bermslope allowed for the formation of berms and the stabilisation of the nearshore profile, especially important in the case of reflective beaches, like Praia de Faro. Without it, the model was unable to stabilise the beachface slope of the eroded profile and continued to erode throughout the simulation.
- High facua values were necessary to account for onshore sediment transport and recovery of eroded volumes (of the order of 75-78% in the analysed timeframe).
- The inclusion of delta was necessary to drive sediment higher intro the profile, as the recovering profile gradually steepened, allowing to sand to reach elevations within 3.5 to 4.5m.
- Building from this event-scale analysis, a gradual increase of temporal windows in simulated forcing conditions through wave schematisation is planned, aiming to optimise between gains in simulation time and losses in geomorphic change information. This step will allow passing on to dependable long-term simulations of the beach-dune system evolution.

EGU General Assembly 2020
Vienna | Austria | 3-8 May 2020

References

Ferreira, Ó., Plomaritis, T. A., & Costas, S. (2019). Effectiveness assessment of risk reduction measures at coastal areas using a decision support system: Findings from Emma storm. *Science of the Total Environment*, 657, 124–135. https://doi.org/10.1016/j.scitotenv.2018.11.478

Roelvink, D. (1993). Dissipation in random wave groups incident on a beach. *Coastal Engineering*, 19(1–2), 127–150. https://doi.org/10.1016/0378-3839(93)90021-Y

Roelvink, D. (2006). Coastal morphodynamic evolution techniques. *Coastal Engineering*, 53(2–3), 277–287. https://doi.org/10.1016/J.COASTALENG.2005.10.015

Roelvink, D., & Costas, S. (2019). Coupling nearshore and aeolian processes: XBeach and Duna process-based models. Environmental Modelling & Software, 115, 98–112. https://doi.org/10.1016/J.ENVSOFT.2019.02.010

Vousdoukas, M. I., Almeida, L. P. M., & Ferreira, Ó. (2012). Beach erosion and recovery during consecutive storms at a steep-sloping, meso-tidal beach. *Earth Surface Processes and Landforms*, 37(6), 583–593. https://doi.org/10.1002/esp.2264

ENLACE

UAlg CIMA TUDelft Deltares Enabling Delta Life

Acknowledgments
The work was implemented in the framework of the ENLACE project (ref. 28949 FEDER), funded by FCT (Fundação para a Ciência e a Tecnologia, Portugal.