Enhancing shoreline advance by ploughing the intertidal beach: Physical simulation

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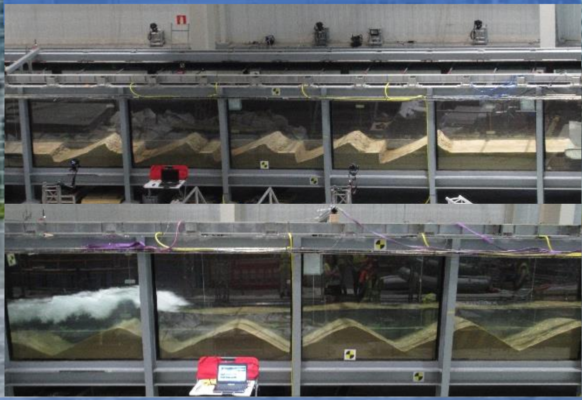
Beach-ART



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- Increasing demand of wide beaches in early spring for tourism.

Wide beach in August

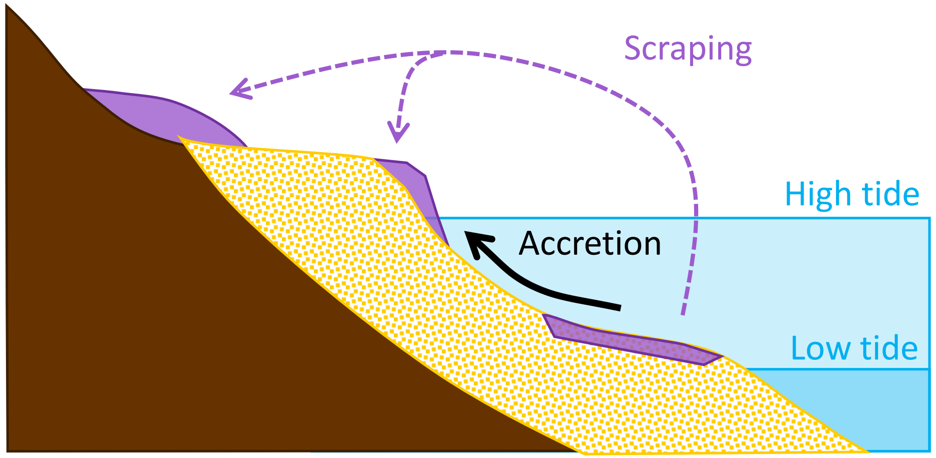
No dry beach in March

- Sand nourishments and scraping campaigns are widespread techniques applied by city councils to get wider beaches in early spring.
- These actions are frequently designed empirically.
- Further studies are needed to develop new methodologies for the design of nature-based beach recovery techniques.

- Beach-ART project analyses beach profile dynamics and assisted recovery techniques with special focus on nature-based solutions to recover beach width after storms.
- The need for a sustainable coastal management produced a rising interest in soft engineering solutions (Hamm et al., 2002):
  - Beach nourishment has been worldwide applied for decades as a fast solution to recover beach width. The potential environmental impacts of this technique and the difficulty to find appropriate sand extraction locations are reducing its applicability.
  - Nature assisted beach enhancement techniques aim to accelerate natural accretion processes reducing the impact of human interventions.
    - Scraping has been used for decades for sand dune nourishment.
    - Ploughing is an innovative technique recently developed.

Hamm, L., Capobianco, M., Dette, H.H., Lechuga, A., Spanhoff, R., Stive, M.J.F., 2002. A summary of European experience with shore nourishment. Coast. Eng. 47, 237–264. https://doi.org/10.1016/S0378-3839(02)00127-8

- Scraping refers to the anthropogenic earth-moving of small volumes of sand from the lower part of the littoral beach system to the upper beach/dune, mimicking the natural beach recovery processes but at a greatly increased rate (Carley et al., 2010).
- This technique has been widely applied since the mid-19th century.



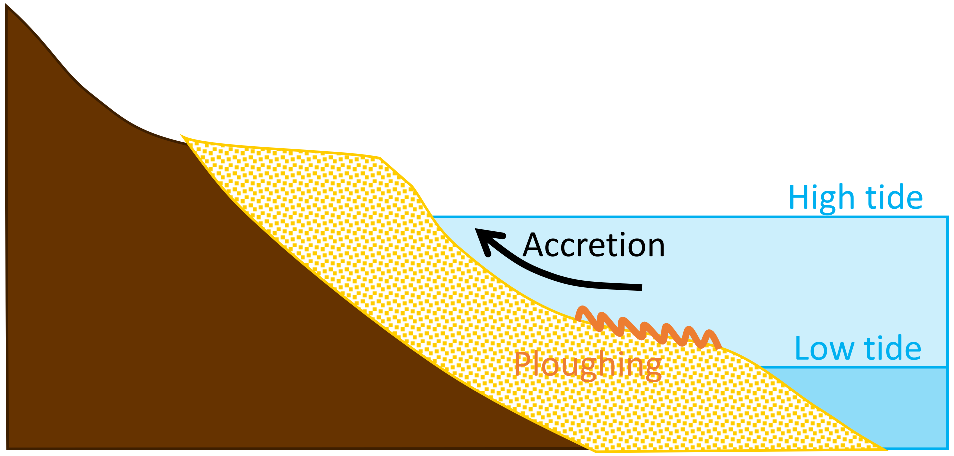
Monge-Ganuzas et al., 2017

Carley et al., 2010

Carley, J.T., Shand, T.D., Coghlan, I.R., Blacka, M.J., Cox, J., Littman, A., Fitzgibbon, B., Mclean, G., Watson, P., 2010. Beach scraping as a coastal management option. 19th NSW Coast. Conf. 1–20.

Monge-Ganuzas, M., Gainza, J., Liria, P., Epelde, I., Uriarte, A., Garnier, R., González, M., Nuñez, P., Jaramillo, C., Medina, R., 2017. Morphodynamic evolution of Laida beach (Oka estuary, Urdaibai Biosphere Reserve, southeastern Bay of Biscay) in response to supratidal beach nourishment actions. J. Sea Res. 130, 85–95. https://doi.org/10.1016/j.seares.2017.06.003

- Ploughing is an innovative technique that aims to accelerate natural onshore migration of the intertidal bar by mechanical plough, mobilizing a layer of sand on top of the bar.
- Possible mechanisms are changes of bed roughness and sand decompactation (Gainza et al., 2019).




Laida 2015


Laida 2015

Gainza, J., Garnier, R., Nuñez, P., Jaramillo, C., González, E.M., Medina, R., Liria, P., Epelde, I., Uriarte, A., Monge-Ganuzas, M., 2019. Accelerating Beach Recovery by Plowing the Intertidal Bar: A Field Experiment along the Northern Spanish Coast. J. Coast. Res. 35, 973. https://doi.org/10.2112/jcoastres-d-18-00033.1

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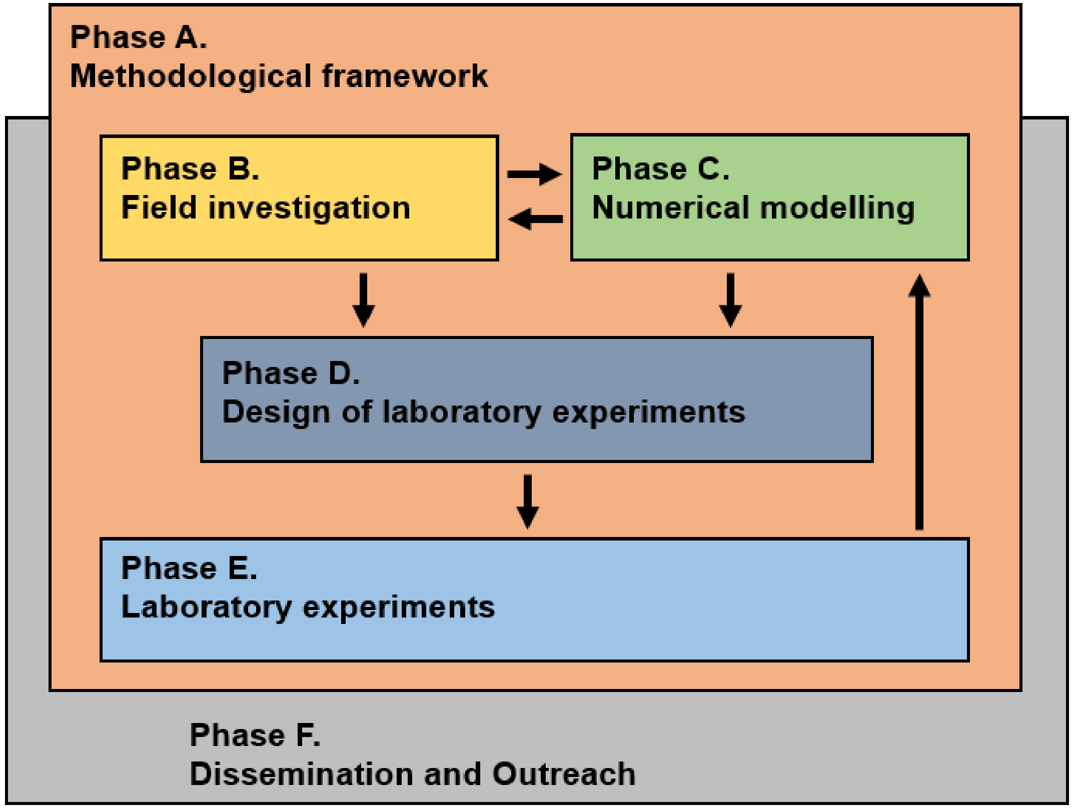
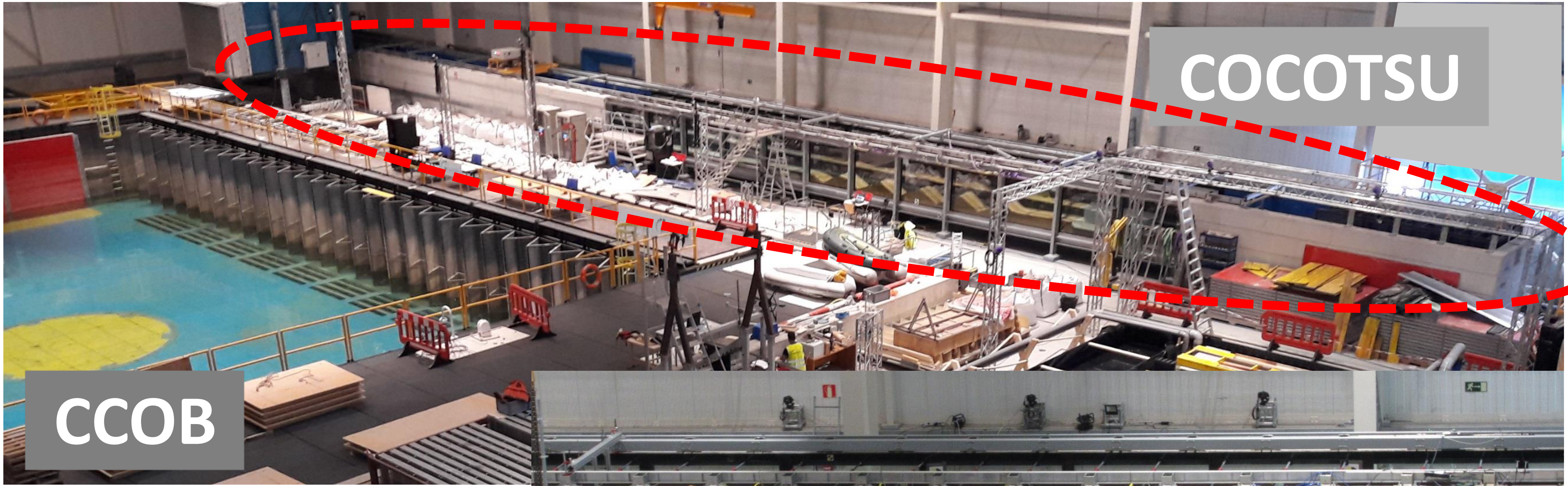
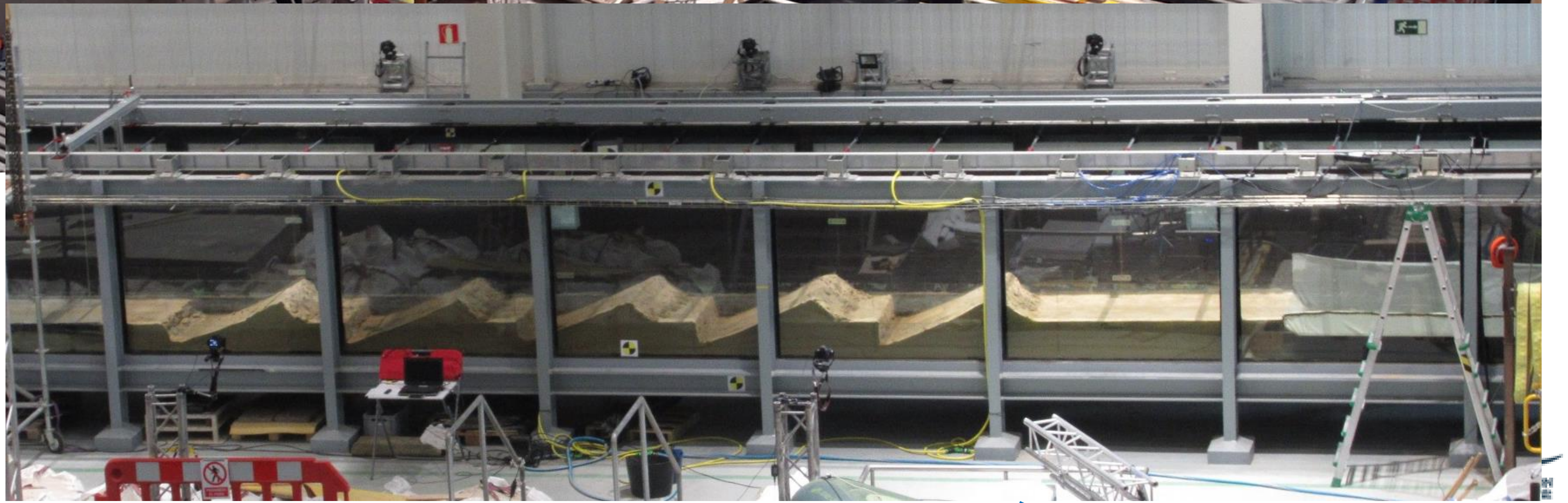
- The aim of the Beach-ART project is to enhance the efficiency and efficacy of beach recovery techniques by proposing a methodology and a set of tools to optimize the design of such techniques.
- The secondary objective is to improve our understanding of beach recovery/erosion and inundation processes in micro, meso and macro-tidal beaches through a combination of:
  - Numerical modeling
  - Field investigation
  - Physical experiments including:
    - Reduced scale simulations of accretion processes and scraping technique
    - Real scale ploughing simulations

This study is a preliminar analysis of the physical simulations performed

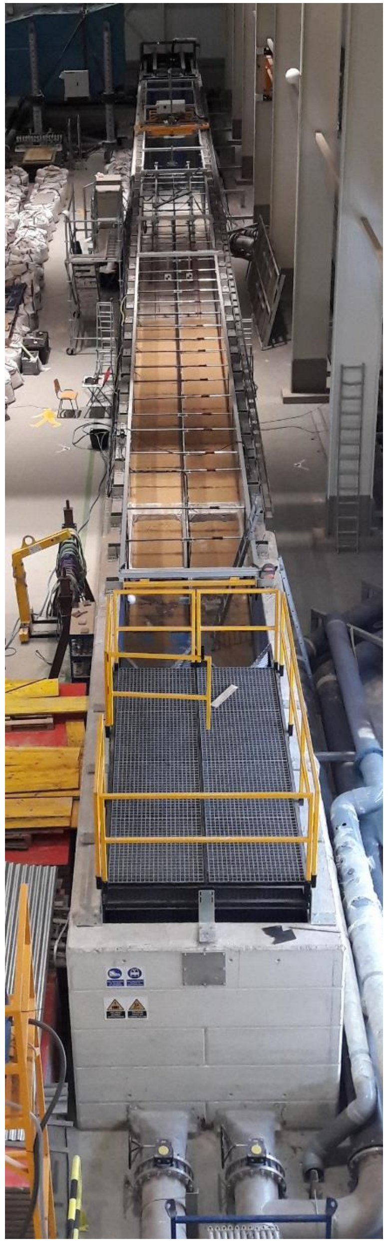


- IHCantabria facilities





- Ploughing physical simulations were performed at COCOTSU flume:
  - 56 m long
  - 2 m wide



Wave maker

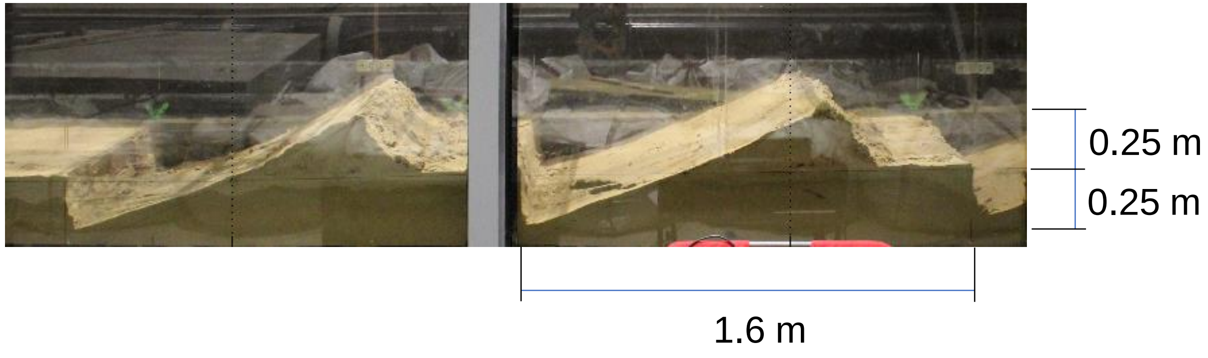
10 m long sandy bottom

Sediment trap boxes

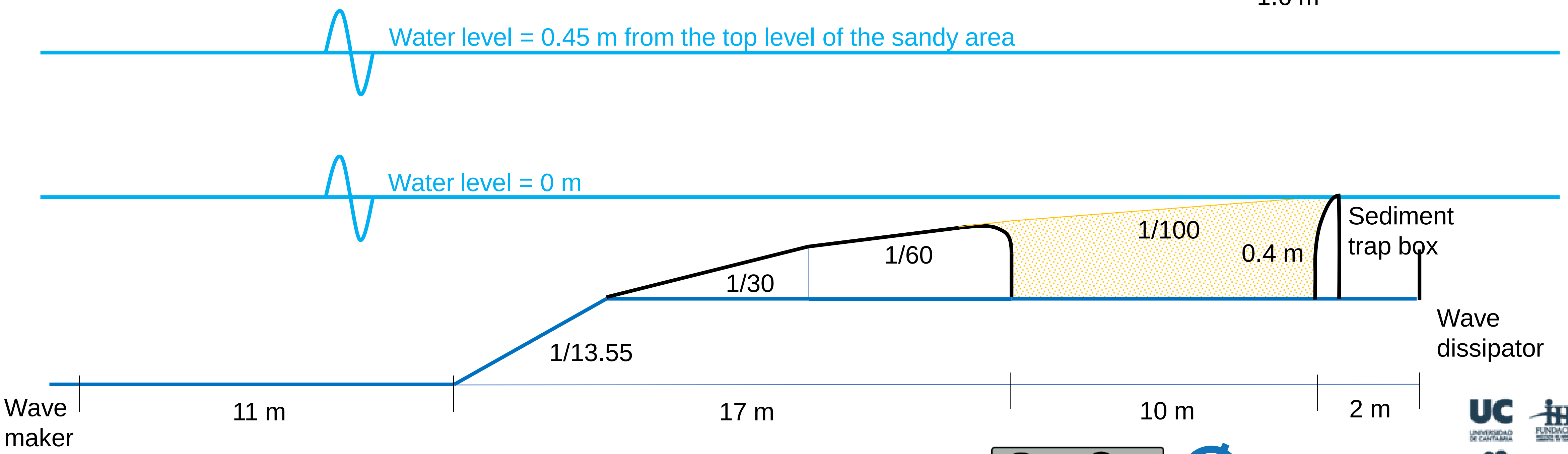
Wave dissipator

- The channel is split longitudinally in two 1 m wide channels.
- Real scale experiment is performed. Each side:
  - Receive the same incident waves, Hs = 0.3 m, Tp = 7 s.
  - Sandy area of 10 m long , 1 m wide, 1/100 slope, D_{50} = 0.318 mm.
  - Landward of the end of the sandy area a sediment trap box captures and weights sand, measuring “accretion”.
  - Several tests were performed with different constant water level, from 0 to 0.45 m above the level of the top of the sand.

- Bottom figure shows setup geometry, a real scale offshore section of an intertidal bar.
- 16 tests were performed for water level of 0, 0.05, 0.1, 0.15, 0.25, 0.35 and 0.45 m.
- One side of the channel is manually ploughed emulating a real plough made by a tractor.
- Five ridges and furrows were dig, with wave-length of 1.6 m and amplitude of 0.25 m.

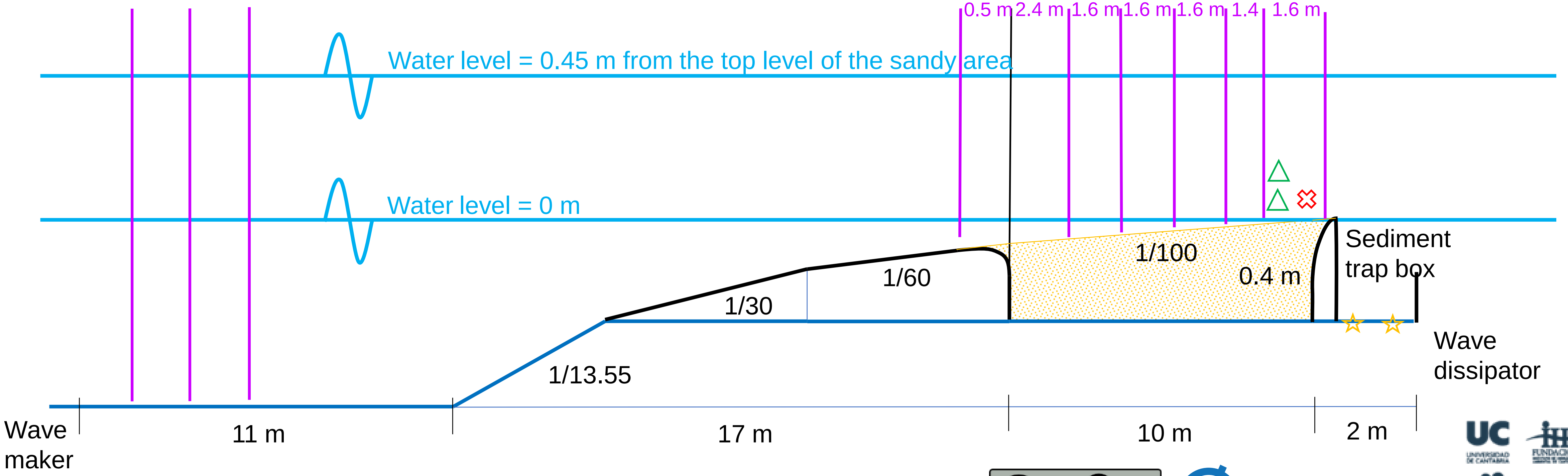


COCOTSU sketch



- Hydrodynamics and morphodynamics were measured continuously during each test of 1 h of waves.
  - ○ 16 resistive wave gauges measure water level
  - △ 4 ADV measure current velocities next to the top of the sandy area (2 each side)
  - ☆ 8 load cells continuously weight total sediment load trapped in the boxes (4 at each side)
  - 2 OBS measure suspended load at each side next to the top of the sandy area (1 each side)
  - 5 video camera record bottom evolution and wave propagation through the windows at each side of the channel
  - 1 laser scanner accurately measures initial and final 3D geometry of the sandy bottom

COCOTSU sketch



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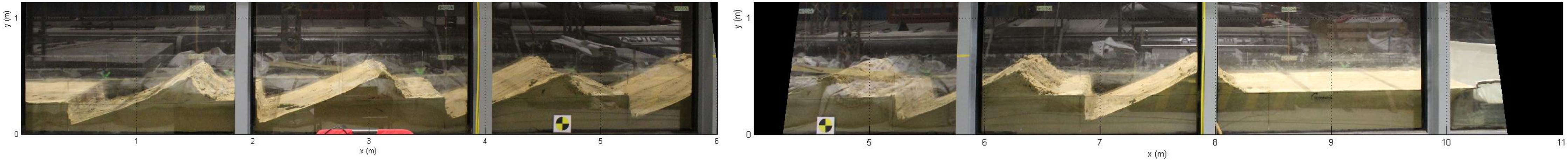
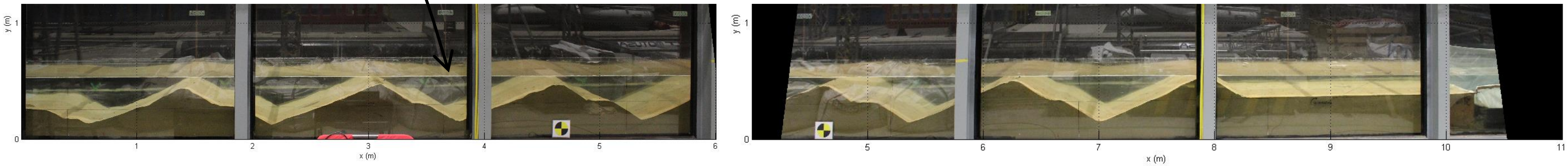
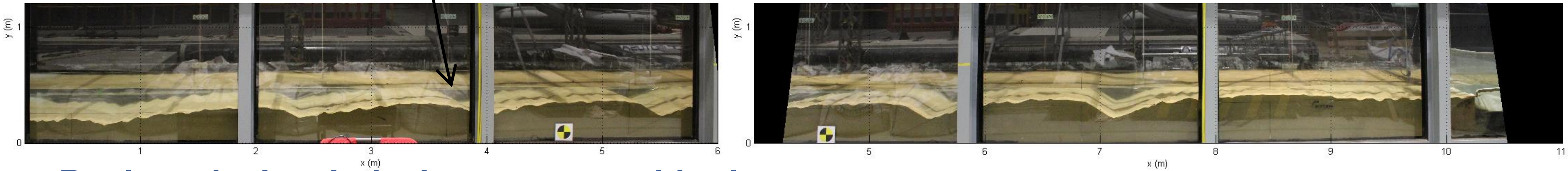
- Initial shape of sand with channel empty of water mimics mechanical plough.



- Water at test level before the wave simulation. Bedforms are inundated.



- Water at test level after 1 hour of wave simulation.
- Ridges and furrows reduced its height and migrated landward.



- Bed evolution is being extracted by image processing.

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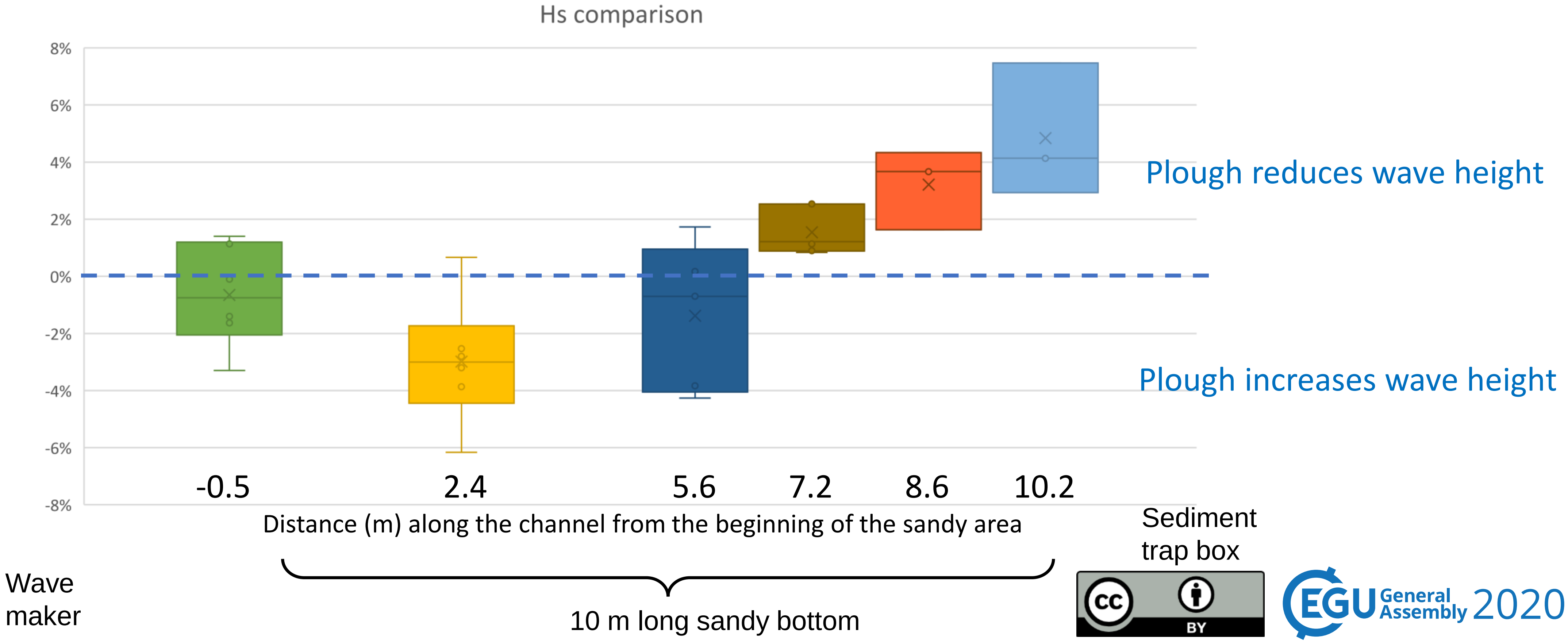
• Wave dissipation is bigger for ploughing.

- Significant wave height was measured by resistive wave gauges at 12 points over the sandy area (6 points each side)
- The difference of wave height between both sides was computed and made adimensional dividing by the generated Hs = 0.3 m.
- Results for each test with different water levels are grouped statistically in the next figure.
- Wave height is consistently reduced by ploughing (1 to 7%) at the final 3 m of sandy area.
- Wave height reaching the sandy area of each side (see -0.5m point) differs less than 2%.



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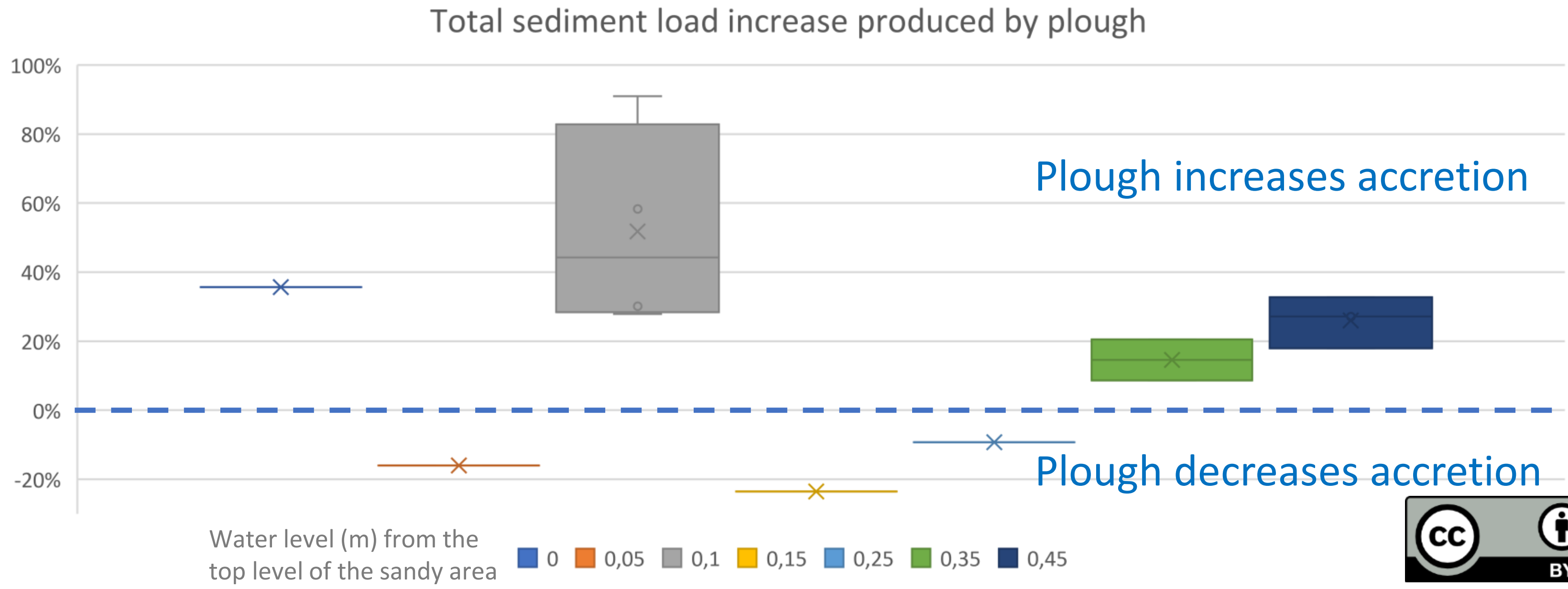
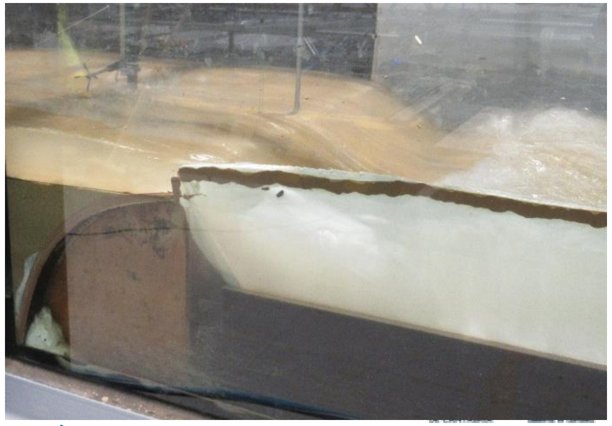
- Weight of sand trapped in the boxes of natural and ploughed sides is compared.
- During the experiments, an issue related to pressure cells weighting the sediment was detected. The issue was fixed and consequently:
  - Results for water level 0.1 m, 0.35 m and 0.45 m are reliable and obtained statistically from results of 2 to 4 tests with the same water level. The sediment of these tests was extracted manually and weighted externally to check accuracy.
  - It took 30 mins to waves of test with water level of 0 m to pass the ridges but then bottom load was the biggest registered during the experiments.
  - Results for levels 0.05 m, 0.15 m and 0.25 m are being checked with laser scanner data.





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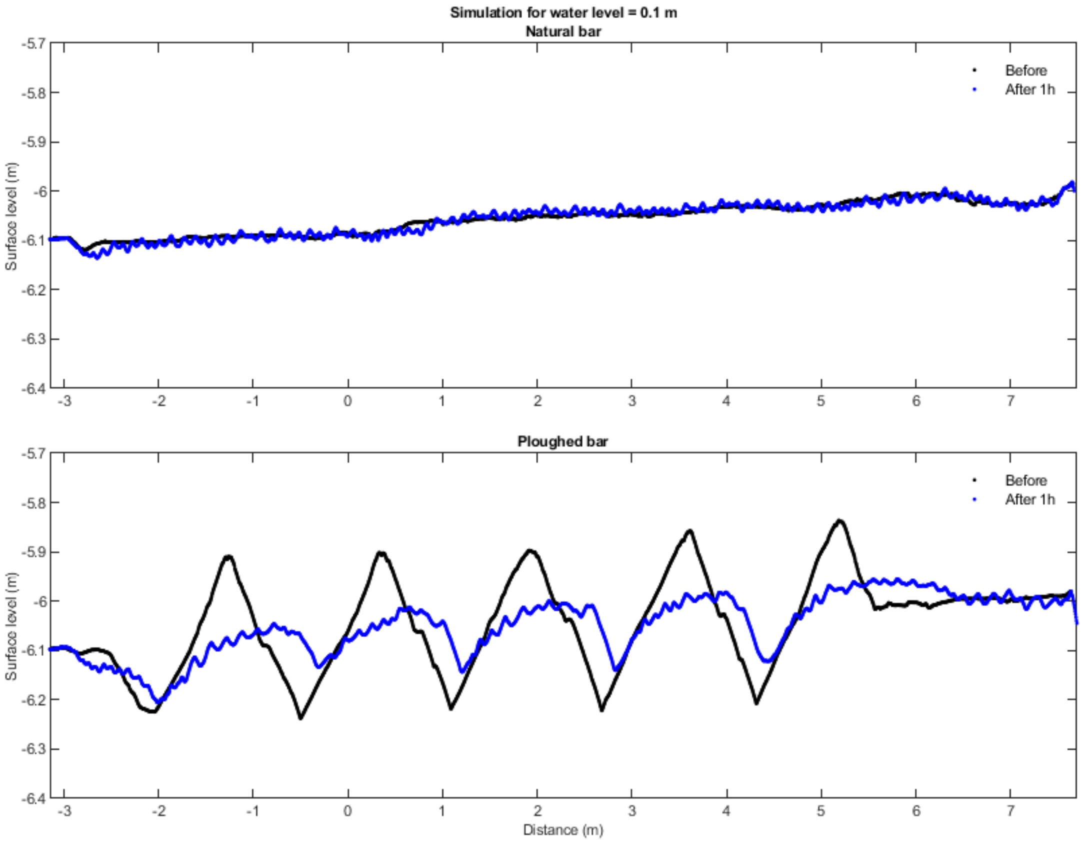
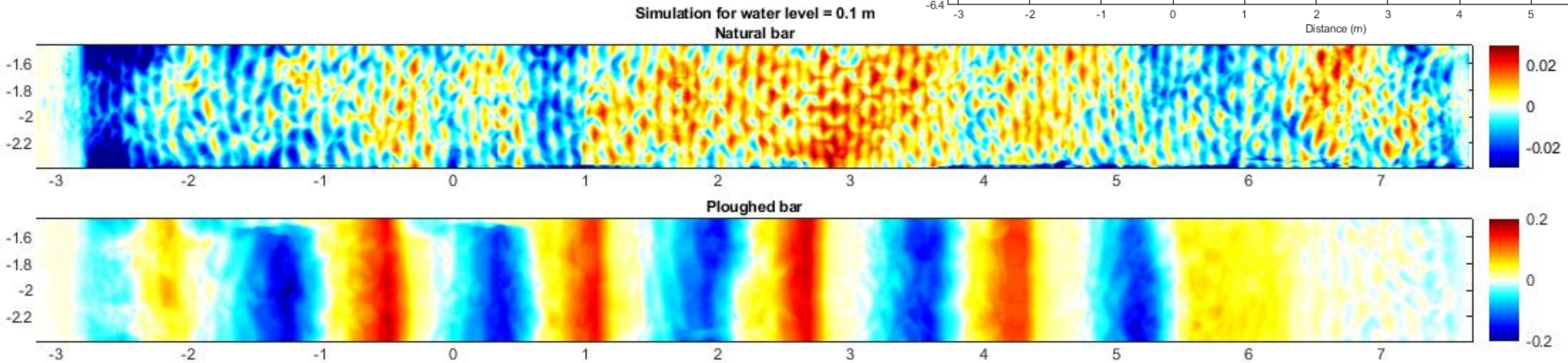
- 3D geometry of the sandy area was obtained before and after wave simulation by means of laser scanner.
  - Figure on the right shows profile evolution of the central section of each sandy area.
  - Figure on the bottom shows bathymetric differences. Note that color scale is different for each panel.
- Differences of bathymetries for both sides will allow a secondary calculation of the total sediment volume mobilized.





Conclusions

- Ploughing is an innovative nature assisted beach enhancement technique that aims to help beach recovery during calm weather periods, minimizing the impacts on the environment.
- Performed physical simulations at real scale allow the comparison of hydro and morphodynamics of an intertidal bar in its natural state and ploughed.
- The preliminary data analysis performed shows that:
  - Wave dissipation is bigger for ploughed side.
  - Total sediment load of ploughed side is consistently bigger for most water levels.
  - Results indicate that ploughing the intertidal bar is a promising technique to accelerate accretion processes that occur in nature.
- Further analysis of the physical simulation data and collection of new field and experimental data are required to determine its profitability to be widely applied.
- If ploughing is worth it, numerical simulations will help the design of detailed procedures for its application to real sites.

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