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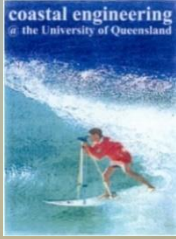

Physical modelling of the response of non-nourished and nourished beach profiles to storm surge or sea level rise

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Outline

- Background
- Previous work in the field
- Experimental setup
- Results and implications
- Conclusions and further work

Beach nourishment – widely used shore protection method

Figure 6. View of the beach nourishment project within the Town of Duck, looking north - Pre-Construction (left), Post-Construction (right).

- Beach nourishment is a key strategy used to mitigate against the effects beach erosion under storm surge or sea level rise (*SLR*).

Beach nourishment – concept and practice is effective

- Adding sediment to an equilibrium profile should result in a horizontal (seaward) shift of the equilibrium profile to accommodate the added sediment (Dean, 2002).

- "Beach nourishment is a win-win adaptation strategy because it holds sea level rise at bay and then more than pays for itself through increased tax revenues generated by beach users" (Jim Houston).

https://www.fsbpa.com/14AnnualConfPresentations/HoustonFSBPA.pdf

Beach nourishment – placement location

- Most effective placement location subject to debate
- Subject to cost, equipment, volume etc.
- What about with sea level rise?

Beach nourishment – buffer against sea level rise

- Comparisons of different strategies are very difficult under field conditions
- Timescale of laboratory experiments versus sea level rise timescale is an issue -
- - But previous experiments are lacking
- Compare to recent experiments with no nourishment (Atkinson et al., 2018) investigating Bruun rule and variants (Rosati et al., 2013; Dean and Houston, 2016) plus Profile Translation Model (PTM)

Laboratory experiments - methodology

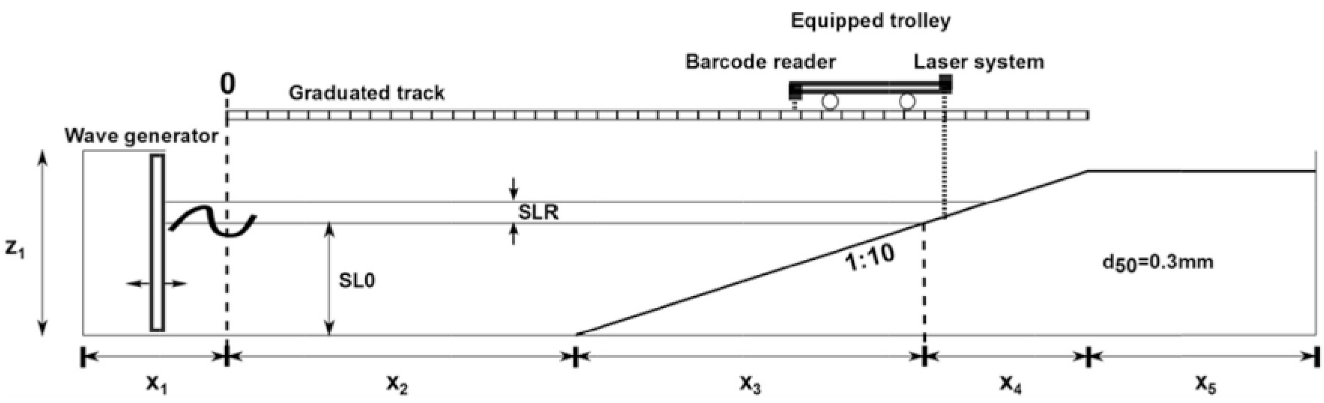
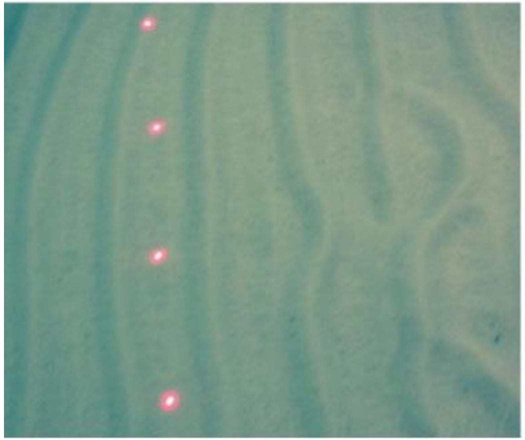


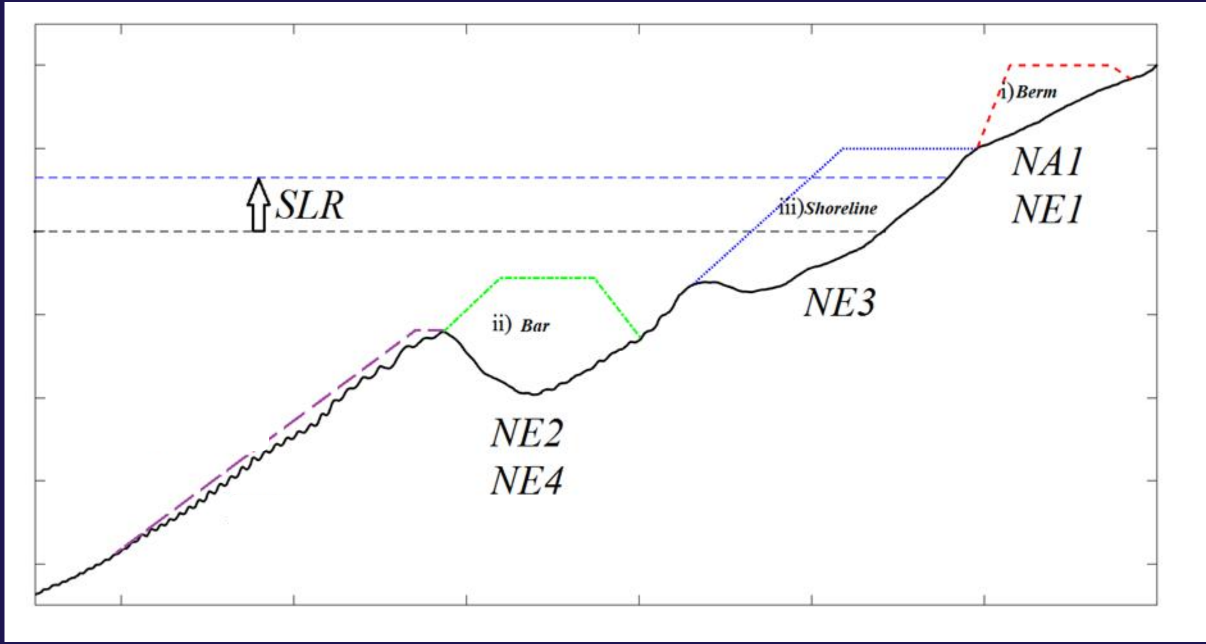
Fig. 2. Wave flume and instrumentation schematic ($x_1 \approx 3$ m; $x_2 \approx 7$ m; $x_3 \approx 6$ m; $x_4 \approx 2$ m; $x_5 \approx 2$ m; $z_1 = 1$ m).



- Wave flume, random waves, active wave absorption,
- 8-line laser profiler measures from above the water surface
- High resolution and high frequency sampling of morphology

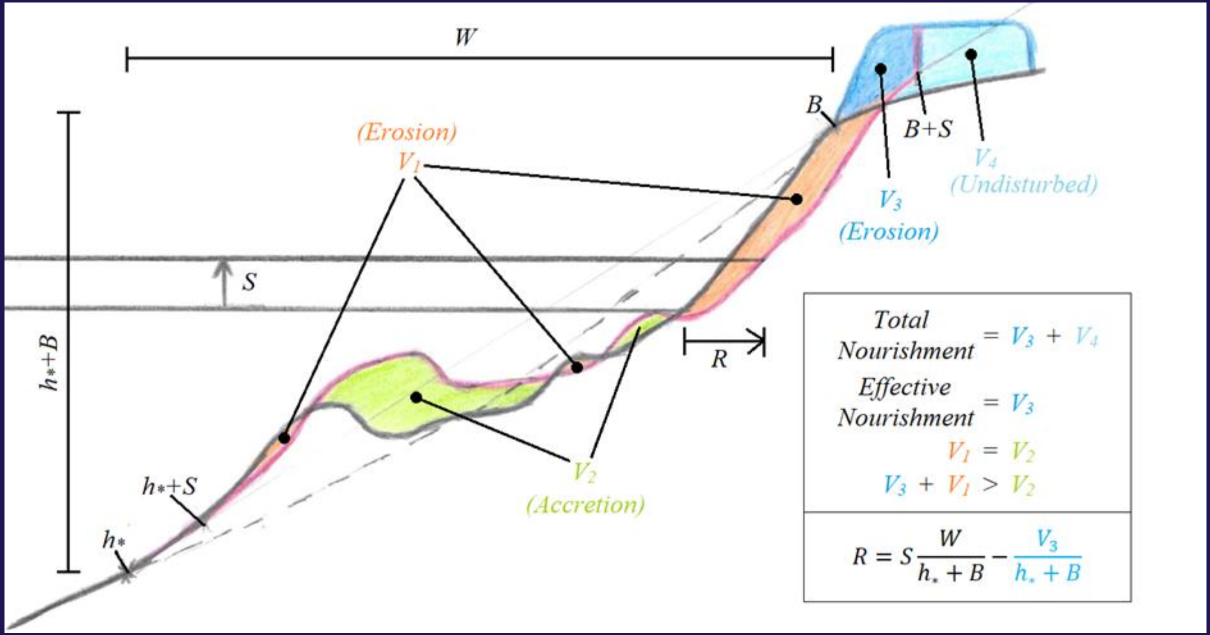
Atkinson and Baldock, *C.Eng.*, 2016; Atkinson et al., *C. Eng.*, 2017

Laboratory experiments – nourishment placement



- Conceptual sketch of different nourishment placements on a profile at equilibrium (solid black line) formed at the initial water level (horizontal black-dash line). "*SLR*" is water level rise.

Laboratory experiments – effective nourishment volume



$$R = SLR\frac{W + \frac{[V_D - V_N]}{SLR}}{B + h_*}$$

Nourishment vol. V_N

Deposition vol. V_D

- Comparison with Dean and Houston (2016) or Rosati et al. (2013) requires assessment of effective nourishment volume, not just nourishment volume.

Laboratory experiments – dealing with profile change

- Profile shape is not maintained perfectly so R_{shore} is not a reliable estimator

- Mean profile recession calculated by averaging the recession of all contours (exact if volume is conserved (no measurement errors)).

$$R_m = \overline{R(z)} = \frac{1}{z_B - z_{h*}} \int_{-\infty}^{\infty} \left\{ \overline{x_{t1}(z + SLR)} - \overline{x_{t0}(z)} \right\} \mathrm{d}z$$

- Useful in the field ?

Laboratory experiments – wave conditions, run time

- Waves

- Monochromatic, [H, T, Ω]=[0.07m, 2s, 0.9], Accretion

- Jonswap, [H_{sig}, T_p, Ω]=[0.125m, 1.2s, 2.8], Erosion

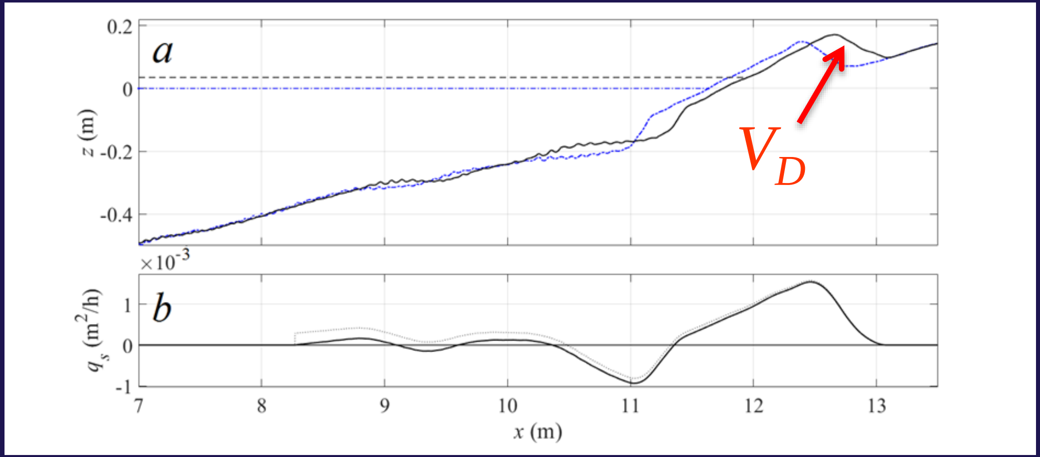
- Water level change

- 0.03-0.065m, 50% of wave height

- Duration

- 50-200 hours at each water level, run to "equilibrium"

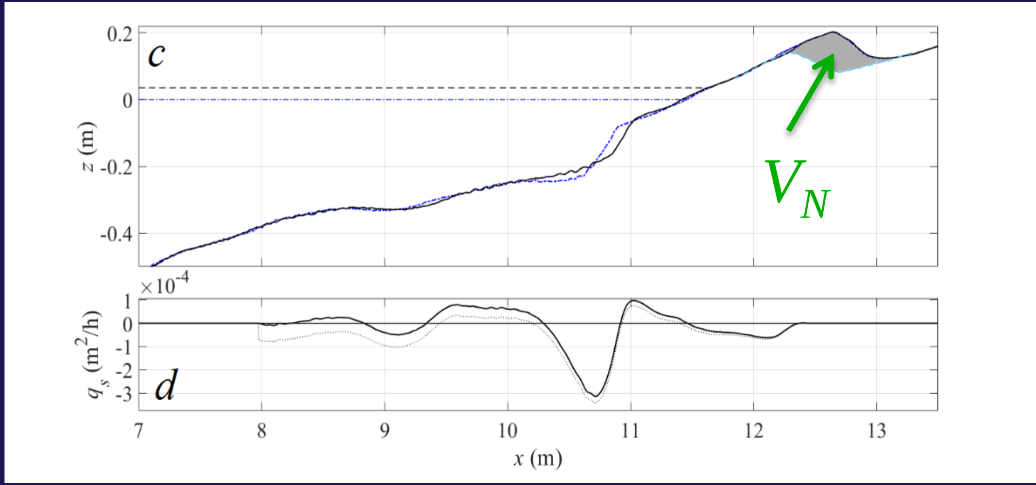
Results – infilling behind berm, accretionary waves



No nourishment

- Overtopping, deposition, recession,

R_{shore} = 0.31 m

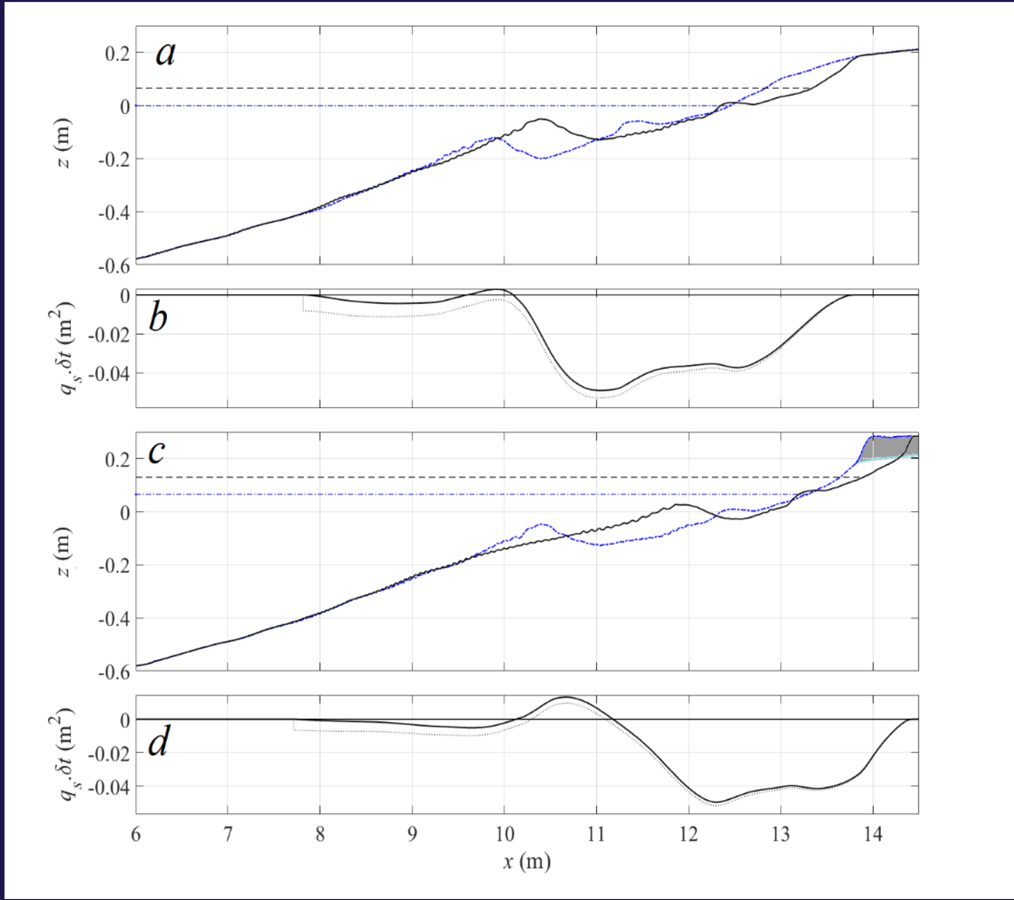


Nourishment

- No overtopping, deposition prevented,

R_{shore} =0.18m

Results – berm placement, erosive waves



No nourishment

- Erosion, profile translation

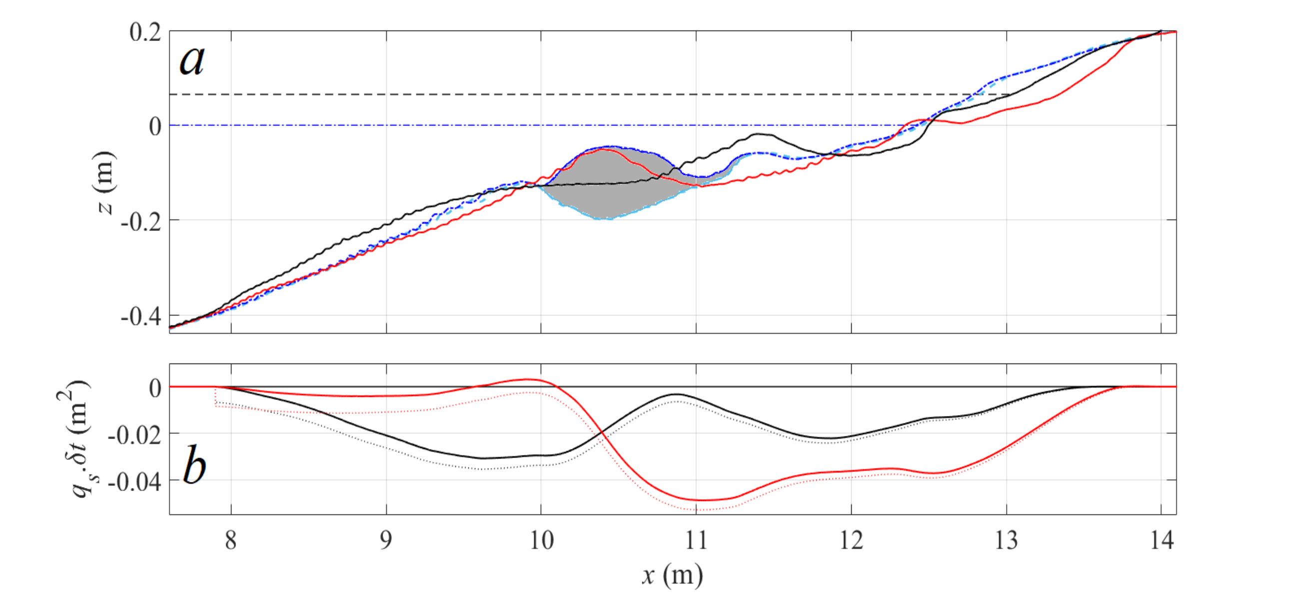
R_{shore} = 0.89 m

Nourishment

- Erosion, bar degeneration

R_{shore} = 0.61 m

Results – surf zone nourishment, erosive waves



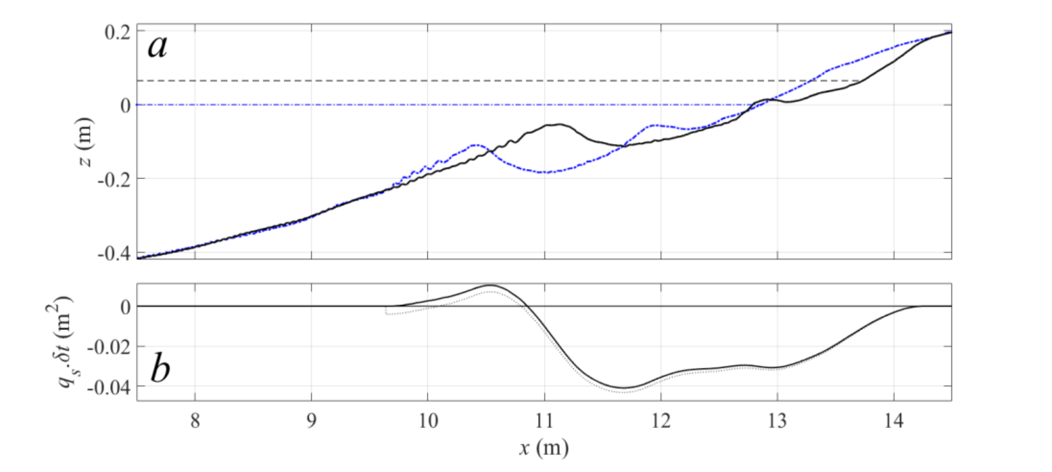
No nourishment

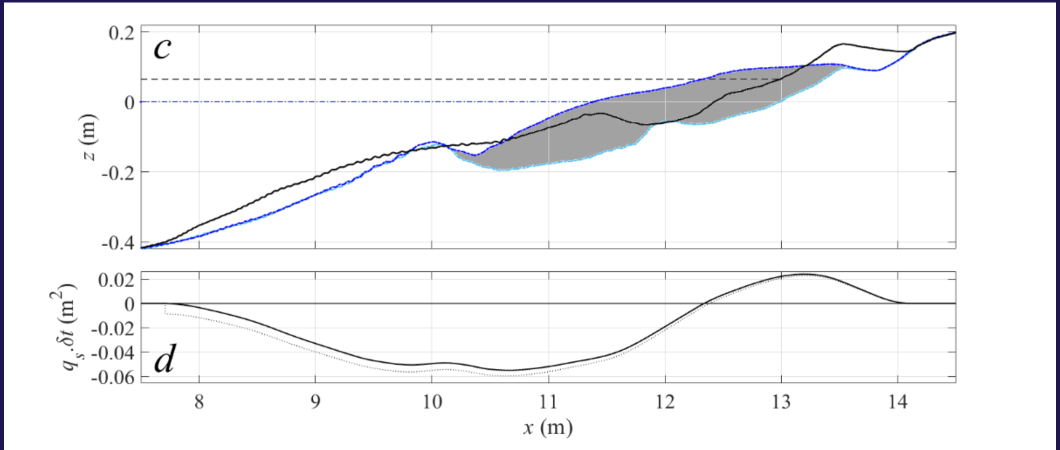
- Erosion, R_{shore}=0.69 m

Nourishment

Reduced erosion, nourishment moves offshore, R_{shore}=0.49 m

Results – shoreline placement, erosive waves





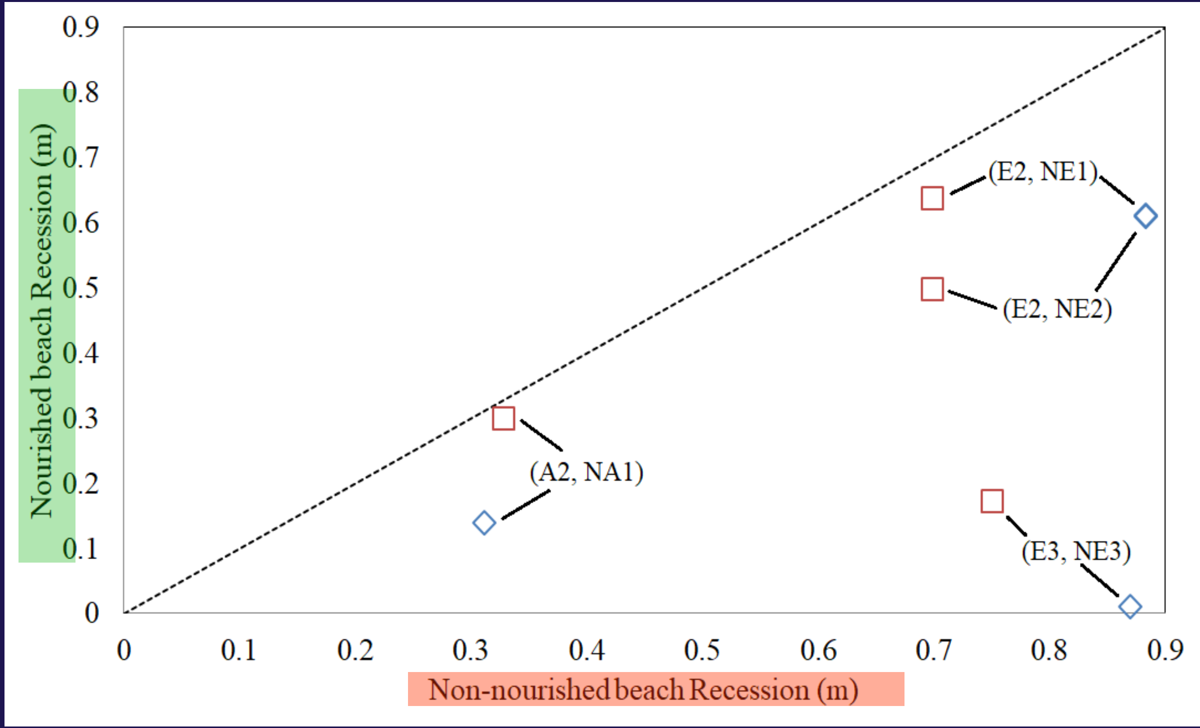
No nourishment

- Erosion, profile translation,
- R_{shore}=0.87m

Nourishment

- Berm built,
- R_{shore}=-0.1m, and still zero after 100 hours

Results – Nourished versus non-nourished recession

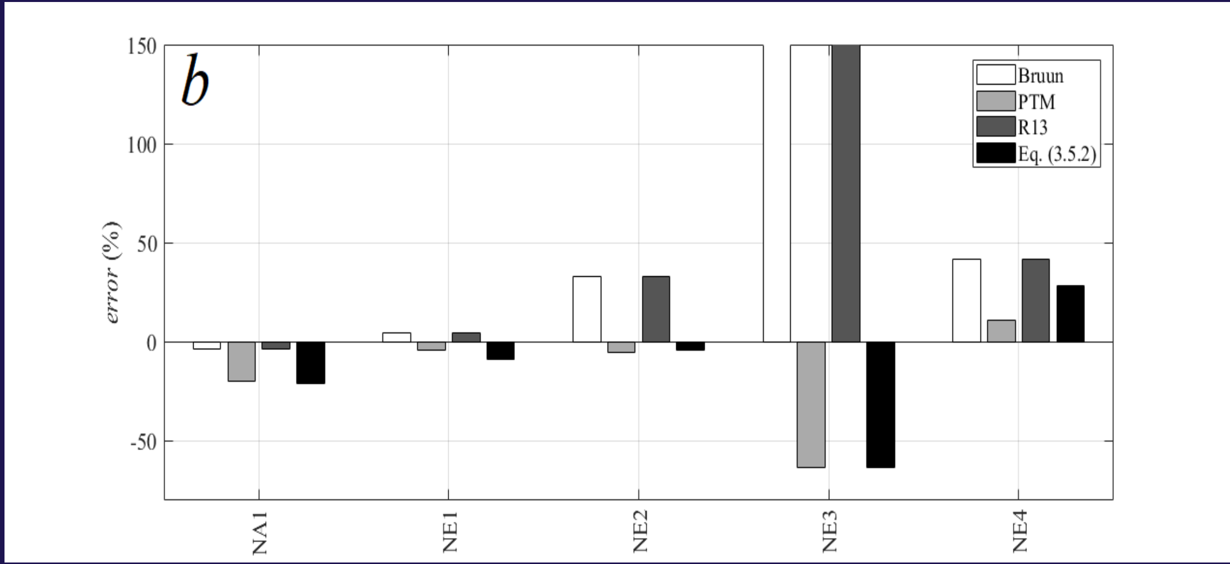


R_{shore} – blue diamonds;

R_m – red squares;

- Shoreline recession is reduced to a greater extent than the mean recession of the profile

Results – measured versus predicted recession



$$R = SLR\,\frac{W + \dfrac{[V_D - V_N]}{SLR}}{B + h_*}$$

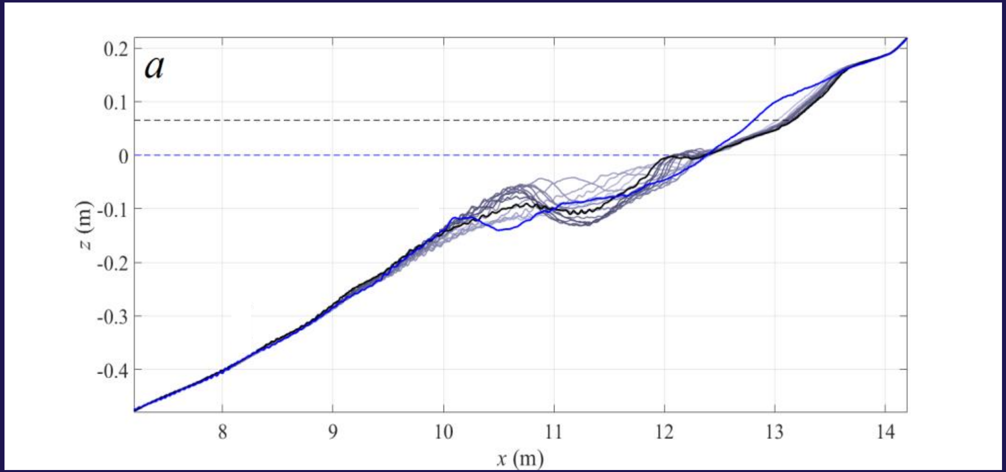
- Error in measured mean recession of the profile versus predictions by Bruun rule, profile translation model, R13 and (R13+DH16)

- Note large error for Bruun and R13 for NE3 since $R_{meas} \approx 0$.

Conclusions

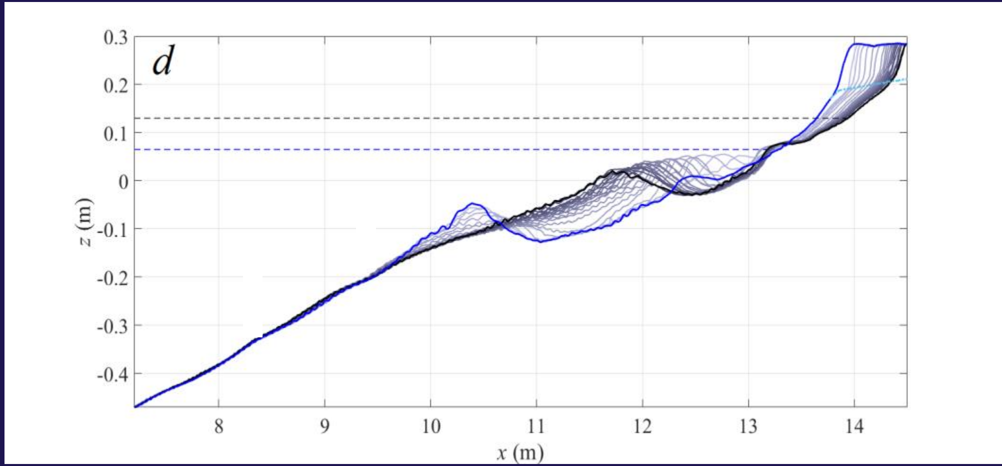
- Compared beach profiles run to equilibrium after *SLR* with and without nourishment
- Shoreline recession is generally reduced to a greater extent than the mean recession
- Recession is reduced by nourishment and can be prevented with sufficient sediment (obviously)
- Variants to the Bruun rule provide better estimates of recession (but require additional measured data)
- A profile translation model using the actual profile generally provides the best predictions of recession, but not always so

Results – profile evolution, bar degeneration-regeneration



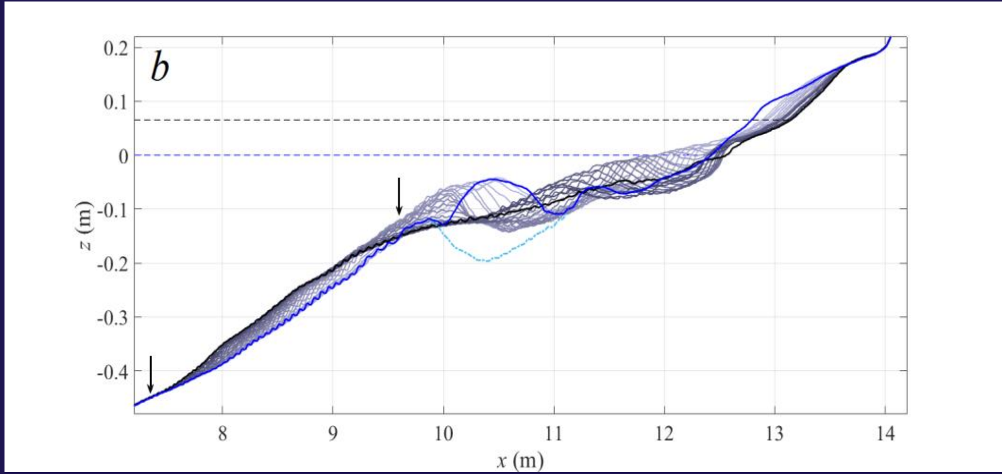
No nourishment

- Bar decay following rise in water level, new bar generated in inner surf zone propagates offshore



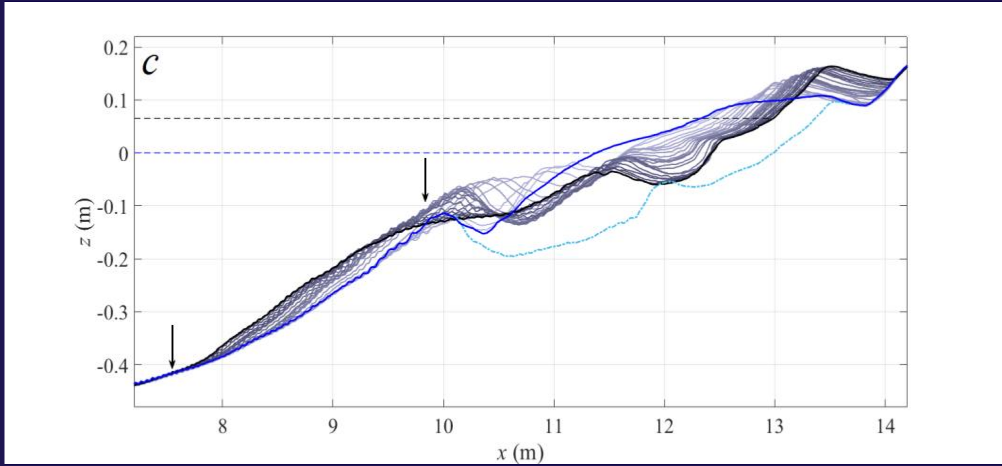
Nourishment

Results – profile evolution, movement of nourishment



Nourishment

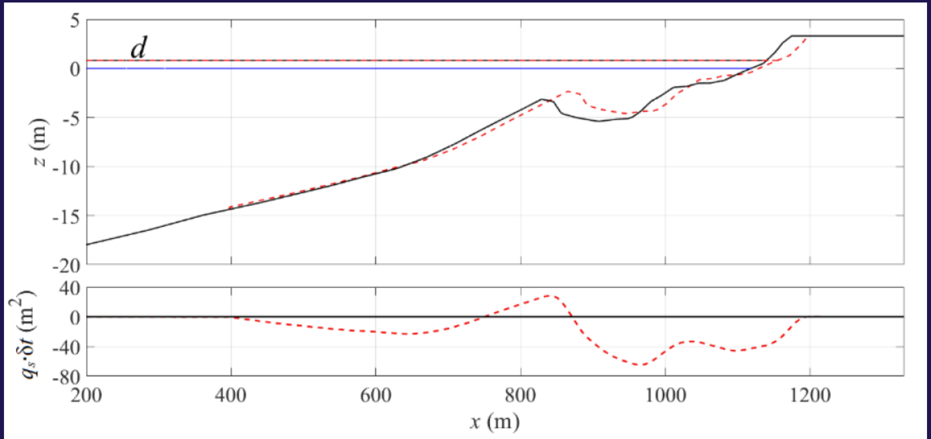
- Nourishment bar propagates offshore and decays following *SLR*

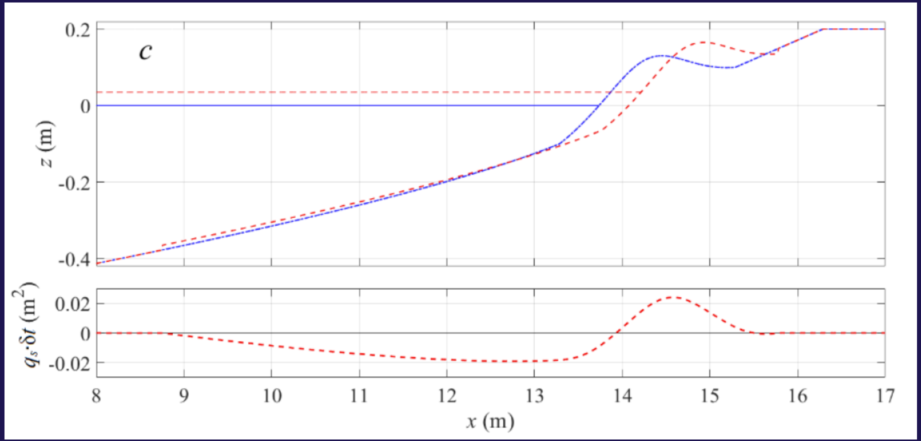


Nourishment

- Nourishment form a bar that propagates offshore and decays following *SLR*, plus berm formation

Profile Translation Model - PTM





- Maintains initial arbitrary profile shape and volume.
- Automatically accounts for added volume, overwash deposition etc.

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