IMPACTS OF SLR-UPSCALED NOURISHMENT SCENARIOS ON DECADAL CROSS-SHORE DYNAMICS

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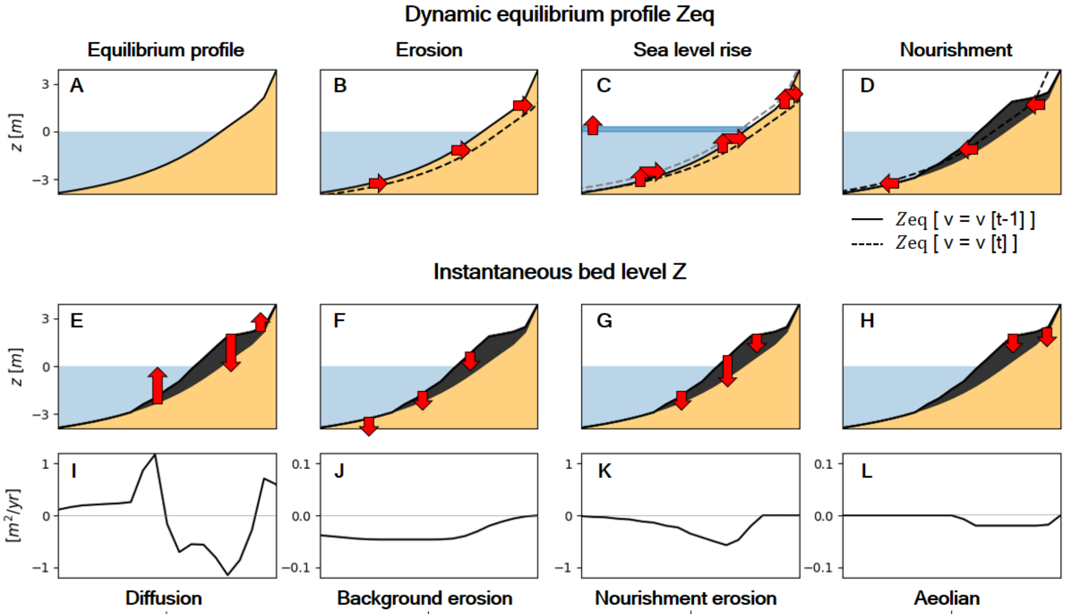
CONTEXT

Projections of high rates of sea level rise have stimulated proposals for adaptation strategies with increasingly high nourishment volumes. Nourishment strategies involving higher sand volumes can be accomplished by increasing the volume of individual nourishments or by decreasing the time interval between successive nourishments. The optimal placement of the sediment volumes in the cross-shore and alongshore to attain our coastal management goals is still under debate. From a long term, large scale perspective only the added sediment volume may be considered, regardless of the placement. A widely accepted perception is that coastal profiles respond to nourishment by rapid equilibration to an equilibrium shape including the added sand volume. However, the timescale of the redistribution of the sediment may be slower than the desired spreading rate of the added sediment, causing sediment to accumulate at some parts of the profile, while leaving other elevations sediment starved.

METHOD

This research aims to examine decadal-scale coastal profile response to nourishment strategies upscaled with sea level rise (SLR) whereby potential nourishment strategy impacts for beach width (fluctuations), dune growth potential and momentary coastline are mapped. Analysis of decadal morphological response to man-made interventions requires a level of detail that can typically not be obtained from existing (semi-)empirical models, while process-based models are computationally too expensive to arrive at the decadal time horizon. Therefore, a numerical, diffusion-type behavioural model has been developed which combines inductive assumptions on dynamic profile response and current state-of-the art knowledge on long-term nourishment behaviour in a predictive tool. The model computes an 'instantaneous' profile response with a time-dependent profile evolution approaching a 'dynamic' equilibrium profile (assuming the wave climate forcing is invariant).

Changes in the coastal system (e.g. SLR, erosion or implementation of nourishment(s)) lead to horizontal and vertical translation of the dynamic equilibrium profile as given by a sediment volume balance (figure 1 A-D). The SLR translation component follows the 'Bruun rule', whereby the active profile is raised by the change in sea level and shifted onshore to balance total sediment volume. Sediment gains and losses (e.g. alongshore transport gradients, sediment exchange with the onshore and offshore boundaries of the active profile, nourishment) lead to respectively seaward and landward translation of the dynamic equilibrium profile. The introduction of a nourishment is considered as a perturbation to this dynamic equilibrium profile. The nourishment shape and position are added to the 'instantaneous' profile, and the time-dependent evolution is calculated following a diffusion-type approach inspired by Stive et al. (1991). In this approach, the rate and extent of sediment dispersion



$$\frac{d(z-zeq)}{dt} = \frac{d}{dx}\left\{D(z)\frac{d(z-zeq)}{dx}\right\} + E(z) + F(z-zeq) + W(z-zeq) + Source(t) \quad (1)$$

Figure 1 - Upper row: Translation of the dynamic equilibrium profile (A) as a response to erosion (B), sea level rise (C) and nourishment (D). Red arrows indicate the direction of translation.
Middle row: Instantaneous bed level response to nourishment per model subcomponents diffusion (E), background erosion (F), nourishment erosion (G) and aeolian (H). Direction and magnitude of bed level change are indicated by red arrows.
Lower row: Magnitude of model subcomponents diffusion (I), background erosion (J), nourishment erosion (K) and aeolian (L) directly after nourishment application. Note different scales.

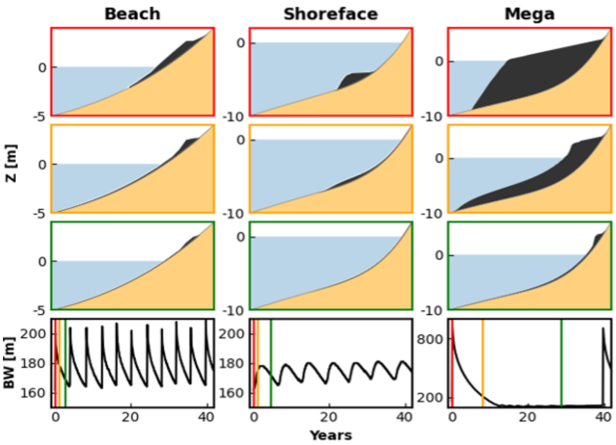


Figure 2 - Snapshots of the coastal profile (top three rows) and the computed beach width (BW, bottom row) for three different repetitive nourishment scenarios (left to right).

are calculated as the sum of four components that depend on the scale of the nourishment relative to the static profile (equation 1). The first component describes cross-shore diffusion (figure 1 E, I) whereby a depth-dependent coefficient D(z) is prescribed depending on the local hydrodynamic climate. The shape of D(z) represents the sediment redistribution capacity along the profile, and thereby regulates the morphological time-scale of response. Two other components describe longshore sediment losses, whereby nourishment lateral loss F(z-zeq) (figure 1 G, K) is discriminated from 'background erosion' E(z) (figure 1 F, J). F(z-zeq) is a function of instantaneous nourishment volume and acts upon the nourished region exclusively, E(z) subtracts nourishment-independent sediment losses from the active profile following the shape of D(z). The fourth component describes aeolian losses (figure 1 H, L) from the intertidal zone and dry beach as a function of beach width inspired by de Vries (2011). Resulting simulations of the 'instantaneous' bed level are translated to the temporal evolution of active profile volume, beach width, momentary coastline and dune growth potential. The impact of different repetitive nourishment scenarios on beach width is given as an example in figure 2.

To validate the model it is applied to hindcast profile volume, beach width and duneward sand supply on case study locations that vary in morphology and nourishment history. Morphological model set-up modifications per case study location are the initial profile shape and background erosion E(z), that are based on profile bathymetric measurements from an unnourished period. Nourishment application in the model follows the nourishment history of the case study location in volume, timing and cross-shore position. Model outcomes are compared to observations in terms of trends and fluctuations (as observations reflect stochastic aspects of hydroclimatic forcing that are not reproduced by the model, which is stationary forced), to review the model's performance to reproduce relations between coastal indicator behaviour and nourishment application.

RESULTS

Hindcast results show that the model is capable to simulate relations between coastal indicator behaviour and nourishment application in terms of trends, trend reversals and variability for regular beach and nearshore nourishments (figure 3 C, D) as well as mega nourishments (figure 3 A, B). Both nourishment cross-shore position and nourishment size affect the speed and location of cross-shore sediment redistribution conform to observations. For instance, larger or more frequent beach nourishments induce widening of the beach with larger beach width maxima, steepening of the coastal profile and seaward migration of the momentary coast line (figure 3). In case of shoreface nourishments, limited feeding of the upper profile can lead to too beach narrowing at erosive locations.

OUTLOOK

To investigate coastal profile response to SLR-upscaled nourishment strategies, different nourishment scenarios are simulated on these case study locations that vary in rate of SLR, whereby amount of applied sand is upscaled such that the coastal profile can grow along. Compared to the present-day nourishment scheme, these scenarios include larger nourishment volumes or shorter time intervals. SLR-upscaled simulations with the model have potential to investigate how nourishment strategies under high SLR scenarios become affected by the sediment redistribution capacity along the profile. This research may become a stepping stone towards improved design of future shoreline maintenance schemes.

REFERENCES

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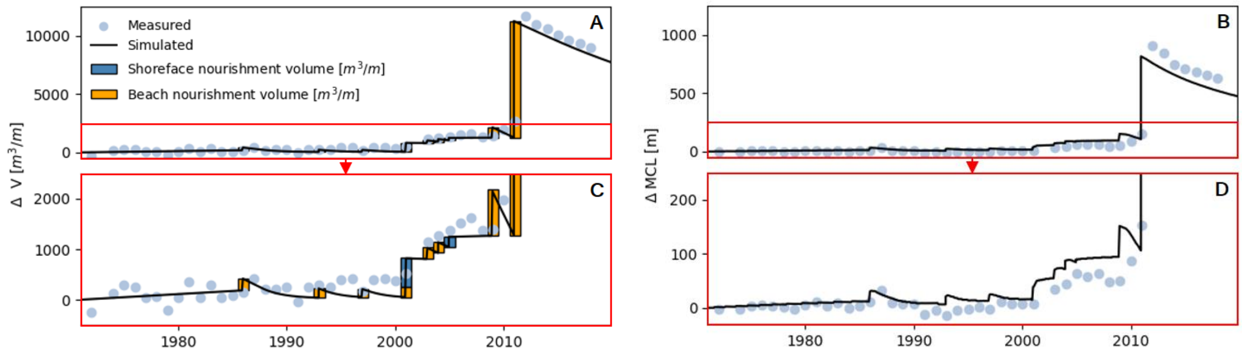

Figure 3 - Hindcast and measurements of active profile volume change ΔV and momentary coastline change ΔMCL at Monster (the Netherlands). Vertical close ups of panel A and B are displayed in panel C and D respectively.