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Sea level rise impacts on the nearshore wave climate and dune erosion

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Introduction

Coastal safety in the Netherlands is threatened by severe dune erosion (Fig 1). If dunes breach, the low-lying hinterland will flood. Dune erosion results from storm surges and waves generated by storms in the North Sea basin. The wave climate consists out short-waves and infragravity waves (period >30 sec). Dune erosion is caused by short- and infragravity wave breaking on the dunes.

Here, we study the impact of the **steepness of the profile** on the **near-shore wave climate under different sea levels**. Subsequently, the impact of **sea level rise (SLR) on dune erosion** volumes is discussed.

Fig 1. Example of dune erosion at Egmond (January 2012)

Methods

All simulations are executed with XBeach, a process-based model, calibrated for the Dutch coast. Safety standards in the Netherlands require a primary defence to withstand a 1:10,000 year event. These standards are here used as offshore boundary conditions.

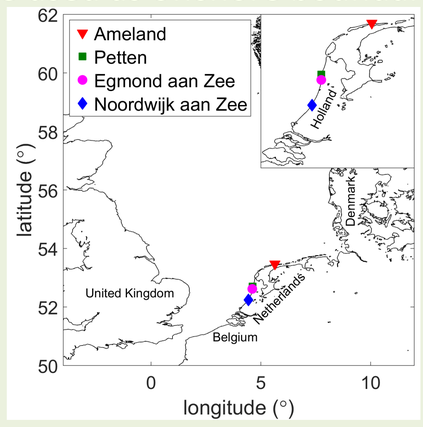

Fig 2. North Sea basin, with close-up of the Netherlands. 3 locations are used to analyse impact of SLR on near-shore waves (Ameland, Petten and Egmond). 2 locations are used to analyse the impact of SLR on dune erosion (Egmond and Noordwijk).

Waves and sea level rise:

- 3 locations (Fig 2, Egmond, Petten and Ameland) with different slopes (Fig 3h-i)
- Offshore wave conditions are the same for these simulation: wave height (Hs) = 9.55 m, wave period (Tp) = 16.1 s
- See Table 1 for offshore water levels
- Topography remains unaltered during the simulations

SLR scenario	Storm surge level*	Offshore water level (storm surge + SLR)
0	3.5	3.5
0	5.5	5.5
0.4	5.5	5.9
0.8	5.5	6.3
3.5	5.5	9.0

Tab 1. Analysed SLR scenarios and storm surge levels. * A +5.5 m storm surge level is the 1:10,000 year storm surge level in the present day climate.

Dune erosion and sea level rise

- The impact of SLR on dune erosion is analyzed for 2 locations (Fig 2, Egmond and Noordwijk) with varying offshore boundary conditions:
- Egmond: storm surge = +5.5 m, Hs = 9.55 m, Tp = 16.1 s
- Noordwijk: storm surge = +5.8 m, Hs = 8.55 m, Tp = 14.3 s
- See Table 2 for offshore water levels
- Topography changes during simulations, morphology active

SLR scenario	Egmond Offshore water level (storm surge + SLR)	Noordwijk Offshore water level (storm surge + SLR)
0	5.5	5.8
0.2	5.7	6.0
0.4	5.9	6.2
1.3	6.8	7.1
2.5	8.0	8.3

Tab 2. Analysed SLR scenarios and storm surge levels.. The 1:10,000 year storm surge level in the present day climate is 5.5 m and 5.8 m for Egmond and Noordwijk, respectively.

Waves and sea level rise

- Short wave are higher under an increase sea level (Fig 3 a-c, 4a).
- Infragravity waves are similar under all SLR-scenarios (Fig3 d-f, 4b).
- Short waves are highest for the steepest profile (Petten), while for the moderate sloping profile (Ameland) most of the short wave energy is dissipated in the near-shore zone.
- Infragravity wave heights increase with lower bed slope, but are independent of SLR.

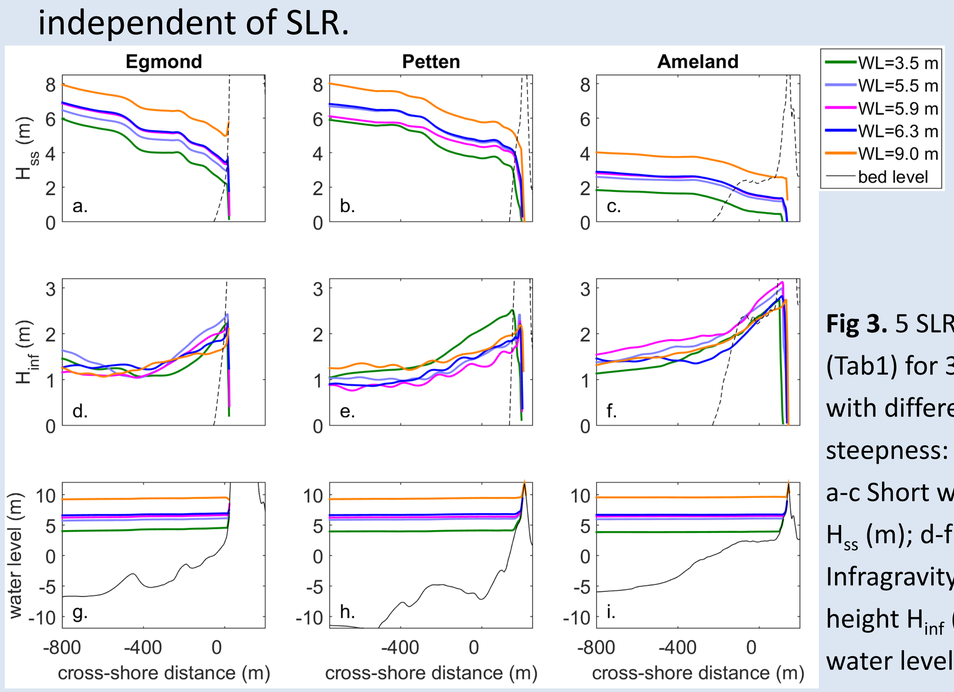

Fig 3. 5 SLR scenarios (Tab1) for 3 profiles with different steepness: a-c Short wave height H_{ss} (m); d-f Infragravity wave height H_{inf} (m); and water level (m).

Dune erosion and sea level rise

- Erosion volumes increase by approx. 25% with 0.8 m SLR (Fig 5).
- Model runs show a linear relation between the increase in dune erosion volumes and SLR (Fig 5).
- This relation is site specific, since hydroynamical boundary conditions vary per site.
- Retreat distance is unrelated to SLR (Bruun-rule not applicable) (Fig 4d).
- Increase in erosion volumes are the result of higher point of impact (higher water levels) of the waves on the dune front due to SLR.

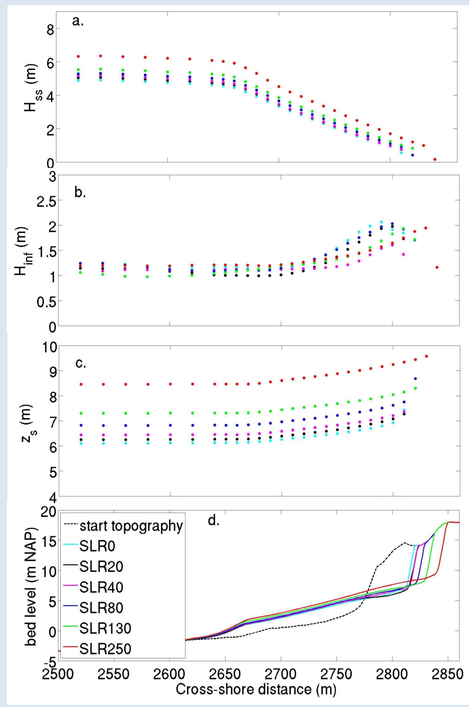

Fig 4. Hydrodynamical conditions at Noordwijk: a. Significant short-waves height Hss (m); b. significant infragravity wave height Hinf (m); c. total water level zs (m); d. initial and final profiles

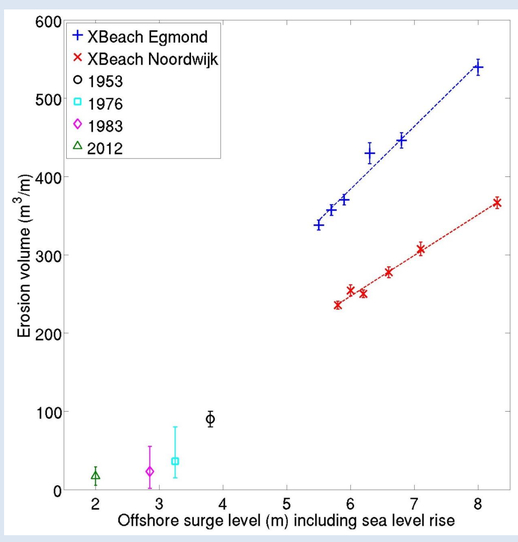

Fig 5. Erosion volume as a function of offshore surge level + SLR. Blue and red represent XBeach projections under different SLR conditions. The dotted line are the best-fit linear regression lines. Other symbols are observations from the Dutch coast (de Vries et al. 2012 and de Winter et al. 2015)

Conclusions

- Height of near-shore, short waves increase with sea level rise, for all profile slopes
- Infragravity wave height is independent of SLR.
- Level of attack (water level) is dominant for increase in dune erosion, not the increase in short waves.
- Linear relation between SLR and erosion volume (approx. 25% more dune erosion with 0.8 m SLR).
- Retreat distance and SLR are uncorrelated. Bruun-rule not applicable

De Winter, R.C. and Ruessink, B. G. (2017). Sensitivity analysis of climate change impacts on dune erosion: case study for the Dutch Holland coast. Climatic Change