The effect of tides and storm surges on the sediment transport during overwash events

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Introduction

- Large parts of the Wadden Islands are closed off by artificial sand-drift dikes (Figure 1).
- We hypothesize that during overwash and inundation the barrier islands experience an influx of sediment.
- Partial re-opening of the sand-drift dikes is considered.
- Most research on overwash has focused on US systems, however for the Wadden Sea the tide-induced dynamics of the back-barrier is also important.

Figure 1. Two German barrier islands (Spiekeroog on the left, Wangeroog on the right). The eastern part of Spiekeroog can be flooded during storms and this has resulted in a gradual transition from beach to dune to washovers. At Wangeroog, washovers have been closed off by sand-drift dikes.

Research questions

- How much sediment can be transported across a barrier island and how is this influenced by wave, tide and storm surge conditions?
- How does the presence of a back-barrier basin (Wadden Sea) influence the sediment transport?

Methods

- The model XBeach is used in 1D mode to simulate different combinations of waves, tides and storm surges.
- 25 years of water level data (combination of tide and storm surge) in the North Sea and Wadden Sea, and wave data in the North Sea are used to make a storm classification. This is used as model input.
- The input-profile is based on Schiermonnikoog with a beach crest of 1.70 m.
- XBeach is validated with field data, gathered during a campaign at Schiermonnikoog in the winter of 2014-2015 (not shown here).

Model input – Storm classification

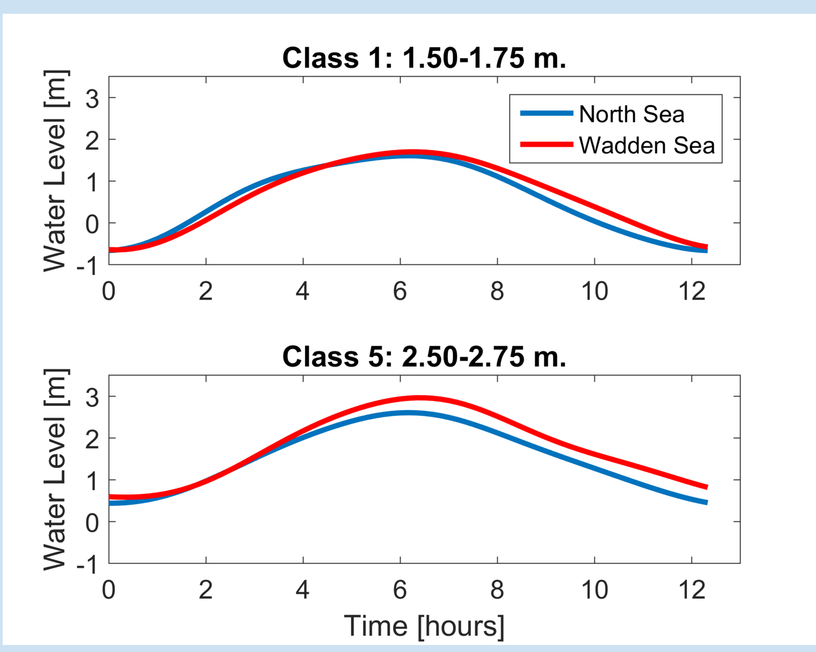

Figure 2. Six storm classes (only class 1 and 5 are shown), based on 25 years of water level data in the North Sea and Wadden Sea. The classes are separated by the peak water level during one tidal cycle in the North Sea. It increases with 25 cm for every class. Note the tidal phase difference for milder storms and the higher water levels in the Wadden Sea during larger storms.

Class	Hm0 [m]	Mean Wave Period [s]	Occurrence [in 25 years]
1	2.4	5.6	574 - 66%
2	3.2	6.3	184 - 21%
3	3.8	6.8	66 - 8%
4	4.2	7.1	21 - 2%
5	5.2	8.1	12 - 1%
6	5.3	8.4	8 - 1%

Table 1. Wave forcing for the six storm classes, also based on 25 years of data. Note that the significant wave height and mean wave period increase for larger storms. The occurrence – mentioned in absolute numbers and as a percentage – exponentially decreases with storm magnitude.

Results – Sediment transport across the barrier island

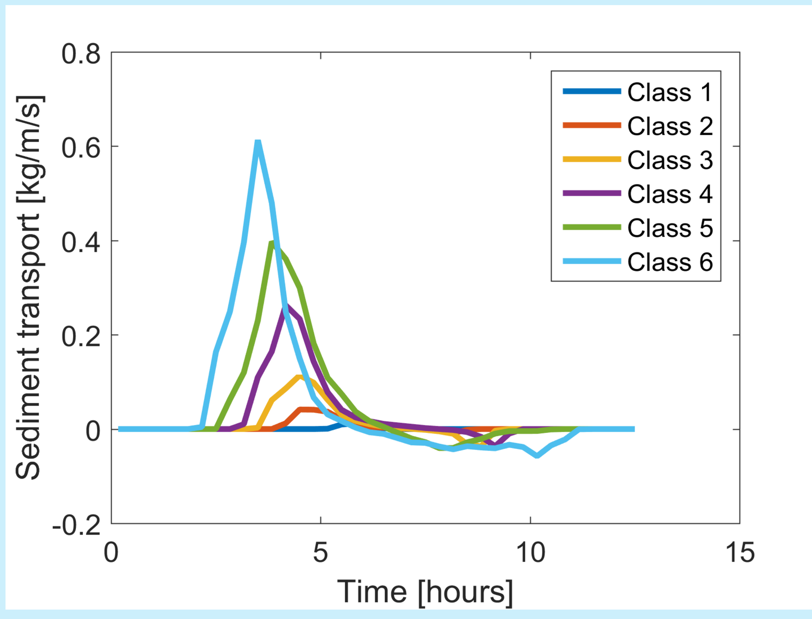

Figure 3. Sediment transport across the beach crest (the highest point of the profile, in this case 1.70 m) during one tidal cycle for all six classes. Positive transport (in Wadden Sea direction) occurs during rising tide, negative transport occurs during falling tide. The transport increases in both directions with storm magnitude.

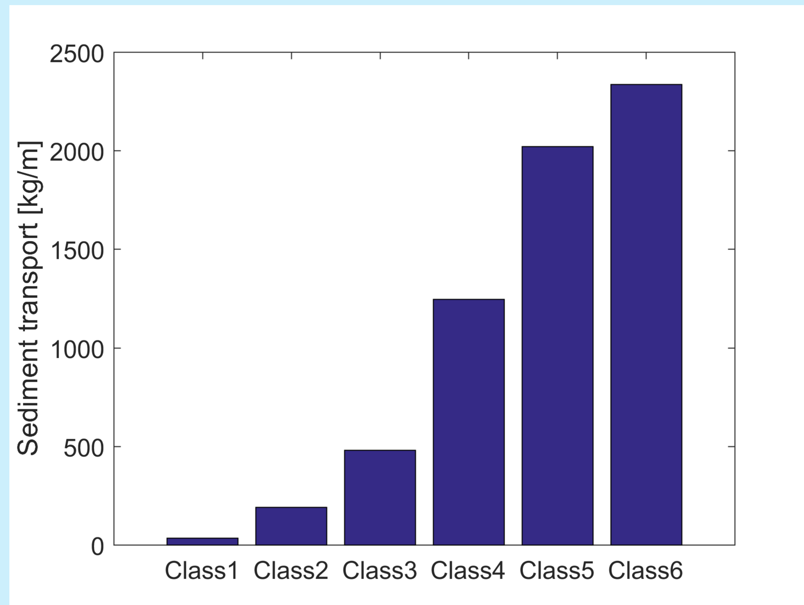

Figure 4. Total sediment transport across the beach crest for one tidal cycle for all classes. The net transport is always in Wadden Sea direction. The total transport increases with storm magnitude. However, the relative increase decreases with storm magnitude.

Occurrence included

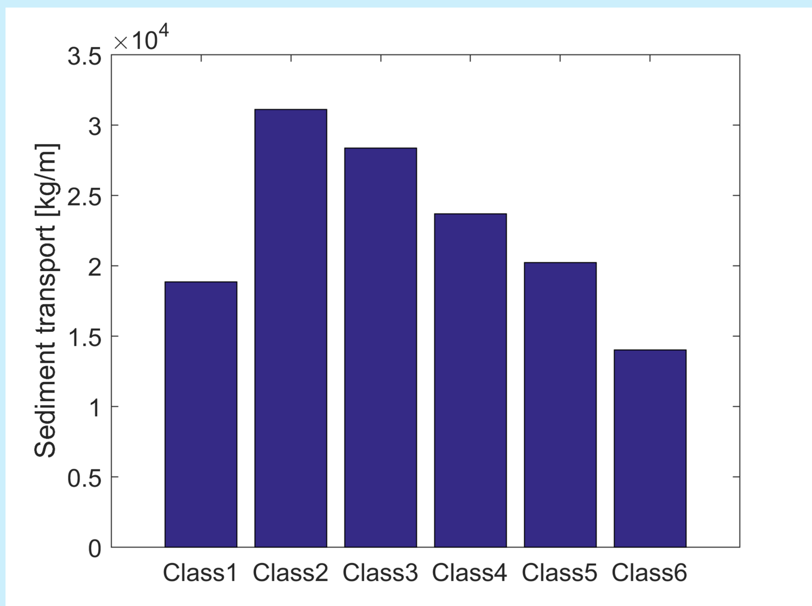

Figure 5. Total sediment transport across the beach crest in 25 years for all six classes. The accumulated effect of gentle storms is more important than the accumulated effect of larger storms.

Water level difference excluded

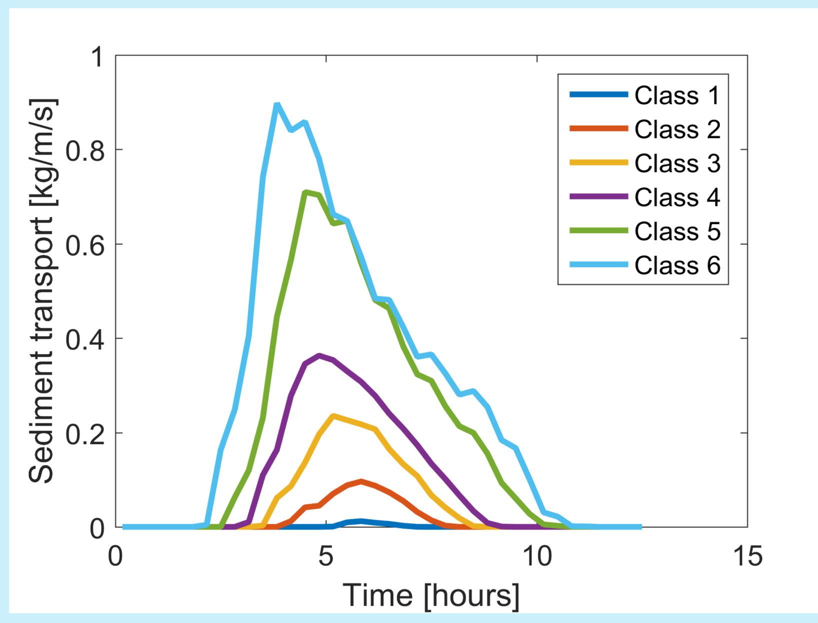

Figure 6. Sediment transport across the beach crest during one tidal cycle for all six classes. For these simulations, the water level difference is not taken into account. Instead, the North Sea water levels are also used for the Wadden Sea. Note that transport is only in Wadden Sea direction and that the net transport is much larger compared to Figure 3.

Analysis of results

Suspended sediment transport (S) is a function of flow velocity (u) and sediment concentration (c).

$$S = u * c \qquad (1)$$

The influence of a larger storm (higher storm class) is summarized in Table 2.

	Flow velocity	Orbital velocity	Sediment concentration	Sediment transport
Larger waves	+	+	+	+
Higher water level in general	+ -	+	+ -	+ -
Higher mean water level in Wadden Sea	-	0	-	-
+ means an increase, - means a decrease and 0 means no change. + - is first an increase and then a decrease				

Table 2. Processes that influence the sediment transport across the Wadden Islands.

Conclusions

- The accumulated effect of gentle storms on sediment transport is more important than the accumulated effect of larger storms.
- For meso-tidal barrier systems like the Wadden Sea, the dynamics of the back-barrier have to be taken into account.