Storm Classification and the Investigation of Impacts on Beach/Dune

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Abstract: A two-step framework is developed and verified for the investigation of storm impacted beach and dune morphodynamics, using the field data for the barrier island Norderney in the East Frisian Wadden Sea. Probabilistic analyses are performed for the simultaneous occurrence of high offshore wave height and tidal anomaly (water level-astronomical tide) to establish a classification of storm events. The established and existing classifications are used to identify storm events enclosing a period of profile measurements. The developed approach captures more events with longer durations than the existing classifications. Numerical simulations (XBeach: 1D) are carried out by forcing with the derived storm events. Analyses on profile evolution and erosion volume conclude that the proposed framework is able to capture the measured storm impact on Norderney. This framework is independent from tidal range, and therefore widely applicable for other beach and dune systems for a comprehensive investigation of storm impact, supporting to formulate sustainable management strategies.

Keywords: beach and dune erosion, Norderney, XBeach, storm classification, East Frisian Wadden Sea

1 Introduction

1.1 Background

Storm events are extreme marine forcing and provide high erosion risk at the beach and dune systems. Even during the impact of a single event, a catastrophic erosion can occur compared with the chronic erosion along a coastal stretch (Harley et al., 2017). The beach and dune systems have high socio-economic and environmental values, and provide the safety for the hinterland areas from the coastal flooding (Hanley et al., 2014). Sustainable use of these coastal systems and to implement suitable mitigation measures, a comprehensive understanding of storm driven erosion is a prerequisite. In this context, the occurrence of storm events and the corresponding erosion risk at the beach and dune systems need to be accurately estimated using reliable methods.

Different approaches have been proposed to identify the occurrence of storm events. Tidal Anomaly (hereafter $TA$), which is Total Water Level (TWL) less the astronomical tide, or offshore significant wave height ($H_s$) is commonly used for storm classifications. For example, Pye and Blott (2006) determined severe storm events on the Suffolk coast, when $TA > 1$ m, and Masselink et al. (2016) used 1% exceedance of $H_s$ for the Dorset coast in UK. For the Italian coasts, Corsini et al. (2004) defined that $H_s$ should be higher than 1 m for at least 12 hours in storm events. Both $H_s$ and $TA$ have also been employed using two separate thresholds to define the storm occurrence at the Dutch coast (Li et al., 2014). This study, however, has used an arbitrary threshold for $H_s$ and the threshold for $TA$ was based on bar-migration (Quartel et al., 2007). The erosion risk at the beach and dune systems is sensitive to even low wave heights during high water levels and increases markedly during high water levels and high wave heights (Pye and Blott, 2016; Dissanayake et al., 2019). Therefore, a
classification of storm occurrence using $H_s$ and $TA$ could be able to accurately capture the erosion prone storm events.

The numerical model XBeach is widely used to investigate the storm impacted erosion at the beach and dune systems. XBeach is an open-source coastal morphodynamic model (Roelvink et al., 2018). The 1D modelling of Dissanayake et al. (2015) presented the impacts of storm clustering by increasing the vulnerability to the beach and dune erosion. The impacts of a buried sea wall on the resilience of a beach and dune system were simulated during Hurricane Sandy (Smallegan et al., 2016). A comparison of the hydrodynamics and morphodynamics influencing dune response using laboratory experiments and the XBeach models was carried out in Berard et al. (2017). Results indicated the sensitivity of the dune erosion to the parameter settings in XBeach. These example studies show the competence of XBeach in simulating storm driven erosion at the beach and dune systems. However, XBeach cannot reliably produce the beach and dune recovery (Bart, 2017).

We use the two-step framework, which was developed by Dissanayake et al. (2019) based on a macro-tidal environment, to classify the occurrence of storm events and to estimate the potential erosion risk at the barrier island Norderney, East Frisian Wadden Sea. This framework classifies storm events based on the occurrence of high $H_s$ and $TA$, and estimates the erosion risk using XBeach.

1.2 Study area

Norderney is an East Frisian barrier island in the Southern German Bight, North Sea, which extends about 13 km in alongshore and has a maximum width of about 2 km (Fig. 1). Tidal inlets at both ends significantly influence on the barrier island morphology (Fitzgerald et al., 1984). The western part of the island is heavily protected by coastal structures. The eastern part is populated with dunes covering about 2/3 of the island coastline. This beach and dune system is exposed to storms approaching from W to N directions (Herman et al., 2009). Water level data for this study is used from the Norderney tidal gauge (NR in Fig. 1). Mean tidal range at NR varies $2.3 – 2.7$ m (meso-tidal: Herman et al., 2009) and extreme $TA$ has reached up to about $3$ m (Streicher et al., 2015). Wave and Wind data are used from the Fino1 research platform (F1 in Fig. 1) of German Weather Service (DWD: www.dwd.de). Additionally, the predicted wave and wind of CoastDat from Helmholtz-Centre Geesthacht (www.coastdat.de), and the measured wave data at an offshore buoy (FW in Fig. 1) from the local coastal research station (NLWKN-CRS) are also used for the analysis. Mean $H_s$ at FW varies from $1.1$ to $1.2$ m while extremes reaching above $6$ m (Herman et al., 2009). Beach profiles are routinely measured at the predefined locations around the island by NLWKN-CRS. Sand from eastern beaches is mechanically removed and dumped at the middle beaches to reshape the beach and dune topography and to withstand the storm impacted erosion during winter (Kunz, 1990).

In German administration, storm events are presently classified using $TA$ and wind speed. The Federal Maritime and Hydrographic agency (BSH: www.bsh.de) classifies a storm event at the North Sea coast when $TA \geq 1.5$ m. According to the German Weather Service (DWD), a storm event is defined,
if the wind speed (10 m above the ground) is higher than 20 m/s. These definitions, however, may not necessarily capture all events, which are relevant for the beach and dune erosion.

2 Objective

The objective of this study is to establish a classification of storm events, which can be used to identify the storm occurrence from the field data \( (Hs \text{ and } TA) \), and to develop a numerical morphodynamic model, which supports to understand the beach and dune erosion processes during a storm event.

3 Approach

The approach follows a two-step framework. In the first step, statistical analyses are performed to define a combined threshold with \( Hs \) and \( TA \), which can be used to identify the storm occurrence. Numerical modelling is carried out in the second step to investigate the erosion risk forcing with the derived storm events enclosing a profile measurement period. Results are analysed with the measured beach and dune profiles to assess the proficiency of the proposed framework.

3.1 Statistical analyses

The basis for the statistical analyses is the occurrence of high \( TA \) and high \( Hs \) from 2005 to 2018. \( TA \) is estimated by deducting the astronomical tide from the observed TWL at NR (Fig. 1), while \( Hs \) is used from the offshore platform at F1. A threshold for classifying storm events is established using a combined approach of the univariate function (Bernardara et al., 2014) and the bivariate analysis (Mazas and Hamm, 2017). The storm impact parameter \( X \) is given by,

\[
X(t) = TA(t) + Hs(t)
\]

where \( t \): time series from 2005 to 2018.

For the statistical analyses, meteorologically independent sets of storm events, which result from different low-pressure systems, are first estimated for a range of percentile values from 90% to 99%. Minimum duration of a storm event is set to be more than 1 hour, and the spacing from the end to the beginning of the subsequent event is set at least 12 hours (see Fig. 2 in Dissanayake et al., 2015), which provides a sufficient time span to differentiate meteorologically independent storm events.

The optimised threshold to identify the storm occurrence is defined by comparing the maximum value of \( X \) (Eq. 1) of the sample events with the extreme value probability distribution: Generalized Pareto Distribution \( (GPD) \). The cumulative distribution function of the \( GPD \) follows Eq. (2).

\[
F(x) = 1 - \left[ 1 + k\left(\frac{x-\mu}{\sigma}\right) \right]^{-\frac{1}{\xi}}
\]

where, \( k \): shape parameter, \( \sigma \): scale parameter and \( \mu \): location parameter, \( x: X_{\text{max}} \) (Eq. 1) during each storm event.

The location parameter \( (\mu) \) is set to zero following the Pickland’s theorem (Bernardara et al., 2014). Then, both shape \( (k) \) and scale \( (\sigma) \) parameters describe the behavior of the \( GPD \). For the selected sample sets of storm events, these two parameters are separately estimated using the method of L-moments (Hosking and Wallis, 1997). The \( GPD \) has the characteristics that \( k \) and the modified scale parameter \( (\sigma^* = \sigma - ku, u: \text{the percentile value of } X) \) will remain constant when the threshold increases (Jane et al., 2016). Therefore, the selection of the \( GPD \) parameters is independent from the threshold limits. This criterion (‘stability domain’) is used to identify the optimised value of \( u \) enabling to establish a classification of storm events at Norderney.

3.2 Numerical modelling

Storm impacted beach and dune erosion is simulated using XBeach along a cross-shore profile from the natural coastline (P in Fig. 1: profile 215 according to numbering of NLWKN-CRS). The
simulation period spans from 21.02 to 10.04.2007 considering the availability of field data within a storm period. The model domain (Fig. 5a) is set up combining the measured profile segments on 21.02 and 26.02.2007. The profile segment on 21.02 extends from -1 m at the beach to -13.5 m MSL at offshore, while the other on 26.02 covers from 14 m at the dunes to -1 m MSL to the beach. Existing offshore profile slope is then extended up to -20 m, where a constant depth is used at the offshore boundary for the accurate application of the wave boundary forcing. The final measured profile on 10.04 spans only from the dune (12.5 m) to the beach (-1.2 m MSL). At the beach and dune area, a high resolution grid (< 5 m) is used to accurately represent the topography, while a coarse-grid (50 m) is used at offshore to minimize the computational time.

Using the established storm classification, 3 storm events are identified for the simulation period (Tab. 1). Wave and wind at F1, and tide at NR (Fig. 1) are used to develop the boundary forcing for the durations of each event. For the missing wave data of F1, the predicted $H_s$ from CoastDat are used. A comparison of $H_s$ is carried out between CoastDat and FW, and between CoastDat and F1. Model simulations are carried out in two series representing the beach recovery processes during the inter-storm calm periods. In the first series, it is assumed that the profile is fully recovered when the subsequent event occurs. Therefore, the same initial profile is used for the simulation of each storm event (i.e. isolated impact of events). In the second series, the profile is not recovered during the inter-storm calm period. Therefore, the final simulated profile of the previous event is used as the initial profile for the subsequent event (i.e. cumulative impact of events). For the DWD and BSH storm events, XBeach is simulated for the observed storm periods.

We use the XBeach version 1.23.5387 with the surf-beat mode, which includes wave-driven currents (alongshore current, rip currents), long (infragravity) waves, and runup and rundown of long waves (swash). The surf-beat mode is relevant for the swash-zone processes and fully valid for the dissipative beaches (e.g. Norderney). Bed sediment composition is applied using a median sediment size ($D_{50}$) for an average single sand fraction.

### 4 Results

#### 4.1 Identifying storm occurrence

Occurrence of $TA$ and $H_s$ of the selected independent storm events is shown in Fig. 2 for the range of percentile values from 90% to 99%. Scatter plots of storm events generally show that there is a linear relation between $TA$ and $H_s$. $H_s$ tends to increase for the increase of both positive and negative values of $TA$. The value of the lowest percentile (a) encounters the highest number of storm events. The lowest $H_s$ of these events is about 1.8 m, whereas the corresponding $TA$ is higher than 2 m. Storm events of the highest percentile indicate that the lowest $H_s$ is higher than 4 m, while $TA$ ranges between 0 and 3.1 m. These are extremely high severity events, which have been captured in all percentiles. Therefore, capturing of storm events with low $H_s$ but high $TA$ depends on the percentile value.

The optimised value for $u$ is selected by analysing the stability domains of the variations of $k$ and $\sigma^*$ of the GPD. These two parameters are estimated for the $u$ values from 2.9 to 5.7 m. Both parameters show one stability domain ($k$~0 and $\sigma^*$~0.28) spanning from 3.4 to 4.0 m. The bias minimization requires to select the highest domain stability, while the variance minimization needs more data. Our attempt is herein to estimate a threshold, which results in a good fit between the sample storm events and the GPD, rather than fitting with the very extreme events only. The latter will provide an increased fit with the GPD. However, the number of storm events decreases significantly causing to neglect events, which are of importance for the beach and dune erosion. Therefore, we select the optimised threshold ($u_{opt}$) 3.4 m considering the lowest $u$ of the stability domain.
Fig. 2. Selection of independent sample sets of storm events from 2005 to 2018 using a range of percentile values of $X$. ‘+’ indicates the independent events of the samples and ‘o’ shows the selected events exceeding the corresponding percentile values.

The $u_{opt}$ is then used to identify the occurrence of storm events from 2005 to 2018 (Fig. 3). The scatter plot (Fig. 3a) shows that only 33% of events has $X_{\text{max}}$ lower than 4 m, while there are only 5 events (<2%) higher than 10 m. Storm duration is defined as the period of $X$ exceeding $u_{opt}$. Storm durations of about 62% events are less than 24 h, and about 38% of events are less than 12 hours. It should be noted that there are 4 events, which have storm durations more than 5 days. Accordingly, $u_{opt}$ has captured a wide range of severity events based on the occurrence of $Hs$ and $TA$, and storm durations. Agreement between the classified storm events and the theoretical GPD ($k=-0.0091$ and $\sigma=0.3150$) is analysed using a probability plot (Fig. 3b). The sample points show a good agreement with the theoretical line of the GPD ($RMSE=0.028$ and $R^2=0.996$).

Fig. 3. $X_{\text{max}}$ (Eq. 1) of the selected storm events from 2005 to 2018 using the optimised threshold (a: colour-coding indicates storm duration in hours) and comparison of the agreement between the empirical GPD and the sample storm events using a probability (b).
The new established classification, and the DWD and BSH classifications are then used to identify the occurrence of storm events within a storm period (21.02 – 10.04.2007), which encloses the beach profile measurements. Variation of $H_s$ from the measured and CoastDat data at F1 is shown in Fig. 4a together with the wind speed, and the water level characteristics within the analysis period are shown in Fig. 4b.

![Fig. 4](image)

**Fig. 4.** Variation of $H_s$ from the measured data (black-cross) and the CoastDat predicted data (red-line), and wind speed (blue-circle) at the Fino 1 station (F1 in Fig. 1) (a), and total water level (TWL) and estimated tidal anomaly (TA) at Norderney (b: NR in Fig. 1). Blue-dash-line: days of the measured profiles (02.21 and 04.10) and black-dash-line: spans of derived storm events (S1, S2 and S3) for the numerical simulations using the established threshold. DWD and BSH storm classifications are shown by blue-line and black-line respectively.

Measured data at F1 do not cover the entire storm period. Similar observation is found with $H_s$ at FW (see location in Fig. 1). Comparison of $H_s$ from CoastDat with the measurements at F1 shows a good agreement (see red-line and black-cross; $RMSE=0.23$ and $R^2=0.82$). The agreement of $H_s$ between CoastDat and FW is also appreciable ($RMSE=0.21$ and $R^2=0.72$). Therefore, we use the CoastDat data as representative values to identify storm events.

Capturing of storm events and durations depends on the storm classification. According to the established classification, there are 3 storm events: S1, S2 and S3, of which S3 has the highest $H_s$ and also the longest storm duration (see vertical dash-line). DWD (wind speed $\geq 20$ m/s) is able to capture only one event, representing the occurrence of the storm peak of S3. Variation of TWL and TA indicates that the highest values occur during S3. BSH (TA $\geq 1.5$ m) has also captured only one event within the duration of S3. Therefore, all classifications are able to identify S3 with different durations.

Characteristics of the storm events for different storm classifications are summarized in Tab. 1. It is particularly found that the storm durations of the established classification are very long compared with DWD and BSH, and the low water of S1, S2 and S3 falls below MSL.

**Tab. 1.** Characteristics of the selected storm events based on the variation of $H_s$ at Fino 1 station (F1 in Fig. 1), and total water level (TWL) and tidal anomaly (TA) at Norderney (NR in Fig. 1) using the established, DWD and BSH storm classifications.

<table>
<thead>
<tr>
<th>Storm event</th>
<th>Duration (hours)</th>
<th>TWL (m)</th>
<th>TA (m)</th>
<th>$H_s$ (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>16</td>
<td>-0.7</td>
<td>1.3</td>
<td>0.2</td>
</tr>
<tr>
<td>S2</td>
<td>33</td>
<td>-0.7</td>
<td>1.8</td>
<td>0.4</td>
</tr>
<tr>
<td>S3</td>
<td>100</td>
<td>-1.3</td>
<td>3.4</td>
<td>0.4</td>
</tr>
<tr>
<td>$S3_{DWD}$</td>
<td>4</td>
<td>0.8</td>
<td>3.4</td>
<td>2.3</td>
</tr>
<tr>
<td>$S3_{BSH}$</td>
<td>14</td>
<td>0.8</td>
<td>3.4</td>
<td>1.5</td>
</tr>
</tbody>
</table>
4.2 Storm impacted evolution

Model calibration is first carried out to optimise the parameter setting in XBeach by comparing the measured and simulated final profiles. The calibrated model parameters are shown in Tab. 2.

Tab. 2. Parameter setting of the calibrated model.

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bed roughness coefficient</td>
<td>C</td>
<td>45</td>
</tr>
<tr>
<td>Sediment transport formula</td>
<td>form</td>
<td>Van Rijn 2008 with modifications by Van Thiel:2</td>
</tr>
<tr>
<td>Median sediment size</td>
<td>D&lt;sub&gt;50&lt;/sub&gt;</td>
<td>0.0003 m</td>
</tr>
<tr>
<td>Maximum shield parameter</td>
<td>smax</td>
<td>0.8</td>
</tr>
<tr>
<td>Courant criterion</td>
<td>CFL</td>
<td>0.9</td>
</tr>
<tr>
<td>Wave breaking formula</td>
<td>break</td>
<td>Roelvink1: 1</td>
</tr>
<tr>
<td>Coefficient in Roller model</td>
<td>beta</td>
<td>0.25</td>
</tr>
</tbody>
</table>

The simulated final profile (from 12.5 m to -1.2 m MSL) is compared with the measured final profile in order to analyse the competence of the storm event classifications (Fig. 5). The initial profile is featured with a channel (at 300 m) and a sand bar (at 220 m distance). On the measured final profile, these features have migrated landwards, and their elevations and widths have considerably decreased. This indicates strong erosion on the sand bar, and sediment accumulation in the channel. The dune toe level is located around 3.6 m MSL on the initial profile. Storm impact above the dune toe level is marginal. The simulated final profiles are shown in Fig. 5b for the cumulative impact of 3 events, and the isolated occurrence of the last event (S3). In both cases, the final simulated profiles are fairly the same. Therefore, the impact of S3 on the beach erosion is significant compared with S1 and S2. S3 has higher TWL, TA and Hs, and also a longer duration than S1 and S2 (see Tab. 1). The sand bar and the channel completely disappear during the impact of S3. This suggests that XBeach has overestimated the profile evolution compared to the measured data.

Fig. 5. (a) Profile domain with the selected segment for the analysis, (b) the comparison of the simulated final profile with the measured final profile considering the cumulative effect of S1, S2 and S3 (green-line), and the isolated occurrence of S3 (black-dash-line), and (c) the different storm classifications: the new established (black-dash-line), DWD (black-dash-cross-line) and BSH (black-dash-circle-line).

Storm impact on the profile evolution during S3 of the 3 classifications is shown in Fig. 5c compared to the measured profiles. The simulated final profile of DWD shows a higher agreement with the initial profile rather than with the measured final profile, indicating low erosion at the sand bar and low sedimentation in the channel. In case of BSH, the simulated profile shows higher changes than DWD. However, erosion at the sand bar and sedimentation in the channel are lower compared with S3 of the established classification. No storm event of the classifications results in erosion above the dune toe level. Therefore, the dunes are not affected during the analysis period of storm events.

A statistical analysis is performed using Brier-Skill-Score (BSS) and RMSE to evaluate the agreements between the measured and simulated final profiles (Tab. 3). BSS is defined according to van Rijn et al. (2003) in Eq. (3).

\[
BSS = 1 - \frac{\langle (z_{mf} - z_{si})^2 \rangle}{\langle (z_{mi} - z_{mf})^2 \rangle}
\]  

(3)
where, $z$ is bed level along the beach and dune profile, $m$: measured, $s$: simulated, $i$: initial and $f$: final, and $\langle \rangle$: mean value. BSS provides a range of model skills, 0.3-0.0: Poor, 0.6-0.3: Reasonable/Fair, 0.8-0.6: Good and 1.0-0.8: Excellent.

Tab. 3. Statistical comparison of the measured and simulated final profiles forcing with S3 of 3 storm classifications.

<table>
<thead>
<tr>
<th>Storm Classification</th>
<th>BSS</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>New established</td>
<td>0.69</td>
<td>0.32</td>
</tr>
<tr>
<td>DWD</td>
<td>0.14</td>
<td>0.53</td>
</tr>
<tr>
<td>BSH</td>
<td>0.41</td>
<td>0.44</td>
</tr>
</tbody>
</table>

According to the statistical values, S3 of the established classification has the highest skill, which can be classified as good, in reproducing the measured final profile. Simulated final profile of DWD is poor and that of BSH is reasonable/fair compared to the BSS skills.

Erosion volume along the analysed profile segment is estimated for each simulation (Fig. 6). In the first group of bars (a), erosion volumes are shown for S1, S2 and S3 in the application of isolation (blue-bar) and cumulative (red-bar) impact of storm events. Results indicate that storm events cause higher erosion (~15%), while occurring in isolation rather than within a storm group (cumulative impact). The second group (b) shows the erosion volume during S3 in different storm classifications. The erosion volume of S3 in the established classification is higher by 80% than DWD, and by 34% than BSH. In comparison to the erosion volume of the measured profile (c), it is lower only by 2 m$^3$/m. These results clearly suggest that the DWD and BSH classifications underestimate the storm impact erosion at the beach and dune system. The new established classification using $TA$ and $Hs$ is able to reasonably capture the measured erosion, and therefore it is suitable to identify the morphologically relevant storm events.

Fig. 6. Erosion volume of the analysed profile segment from 12.5 m at the dune to -1.2 m MSL at the beach, simulating S1, S2 and S3 in isolation (a: group1: light-blue) and cumulative effect (a: group1: red), S3 in the 3 different storm classifications (b: group2: new established, DWD, BSH) and the measured profile data (c: group3).

5 Discussion

Occurrence of storm events at Norderney is presently identified using hydrodynamic ($TA \geq 1.5$ m: BSH) and meteorological parameters (wind speed $\geq 20$ m/s: DWD). However, for the storm impact beach and dune erosion, the utmost energetic condition is the simultaneous occurrence of high water levels and waves, which is not necessarily met if only one criterion is satisfied (Pye and Blott, 2016; Dissanayake et al., 2019). In the proposed probabilistic framework, we considered the occurrence of high $TA$ and $Hs$, and developed a single threshold using a univariate response function to establish a classification of storm events. These two parameters had already been employed using two separate thresholds to identify the storm occurrence (Li et al., 2014). However, there was no methodology presented to define the thresholds. As our storm classification was based on the probabilistic analyses,
it is explicitly applicable for the entire coast of Norderney providing a basis to investigate any interested location.

XBeach has proven skills in reproducing event-based storm impacted erosion at the beach and dune systems (Roelvink et al., 2018). Field data are available from the local agencies through the routine monitoring campaigns (e.g. twice a year), and they generally represent a storm period, which consists of several events. It can be expected partial recovery of beaches during the inter-storm calm periods (Pender and Karunarathna, 2013). These processes need to be considered by modelling a storm period with several events. However, Bart (2017) showed that XBeach is not able to produce the beach recovery after storm impacts. Therefore, we simulated the identified 3 events in isolation and cumulative impact representing the extreme scenarios of beach recovery.

S3 was the highest severity event of the established classification and produced fairly similar profile evolution, and erosion volume compared to the measured profile data. The profile evolution, however, showed an overestimation of storm impacts resulting a linear-shape profile below the dune toe level. It is a known phenomenon that XBeach tends to overestimate the storm impacted erosion (Elsayed and Oumeraci, 2017). On the measured final profile, sediment supply from the alongshore transport can also be expected, whereas the model (1D) simulated only the cross-shore transport during storm impact. Both profile evolution and erosion volume suggested that the established classification is highly suitable for the investigation of storm impact than the existing classifications of DWD and BSH.

6 Conclusions

A two-step framework was developed for the investigation of the storm impacted beach and dune erosion on the barrier island Norderney. In the first step, a new classification of storm events was established using probabilistic approaches considering the simultaneous occurrence of high wave heights and tidal anomalies of the measured data from 2005 to 2018. The established and the existing (DWD: wind speed ≥ 20 m/s and BSH: Tidal anomaly ≥ 1.5 m) classifications were used to identify the storm occurrence enclosing a profile measurement period from 21.02 to 10.04.2007. The new classification identified 3 events (S1, S2 and S3), of which S3 had the longest duration, and the highest wave height and water level. DWD and BSH however identified only partly S3, which includes a period of the peak storm wave of S3. In the second step, a morphodynamic model (XBeach: 1D) was set up to investigate the storm impact from the derived events of 3 classifications. Analyses on profile evolution and erosion volume showed that S3 of the established classification can reasonably reproduce the field data.

These results conclude that the developed two-step framework is suitable for a comprehensive investigation of storm impacted morphodynamics on Norderney. This framework is easily transferable for other beach and dune systems employing the local field data for the investigation of storm impacts.

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