Klimafolgenforschung in Niedersachsen

Effect of Leyhörn Peninsula on the Ley Bay Morphology in the Osterems basin, East Frisian Wadden Sea

Pushpa Kumara Dissanayake, Andreas Wurpts, Heiko Knaack, Hanz Dieter Niemeyer

Coastal Research Station

Lower Saxony Water Management, Coastal Defence and Nature Conservation Agency

Norderney, Germany, Ph (0049) 4932-916147, FAX (0049) 4932-1394,

email: Pushpa.Dissanayake@nlwkn-ny.niedersachsen.de

Introduction

Anthropogenic effects significantly govern the morphological evolution of some tidal basins. Ley Bay is a part of such a tidal basin, namely the Osterems basin in the East Frisian Wadden Sea.

Resulting morphological processes of erosion after dyke breaching during storm surges, silting up and successive land reclamations accelerated sedimentation in the Ley Bay. This inturn affected the inland drainage and navigational requirements which cost millions of Euros annually in order to execute these activities by pumping and dredging respectively.

As an alternative, the Leyhörn peninsula was constructed in 1984 facilitating inland drainage and navigational access.

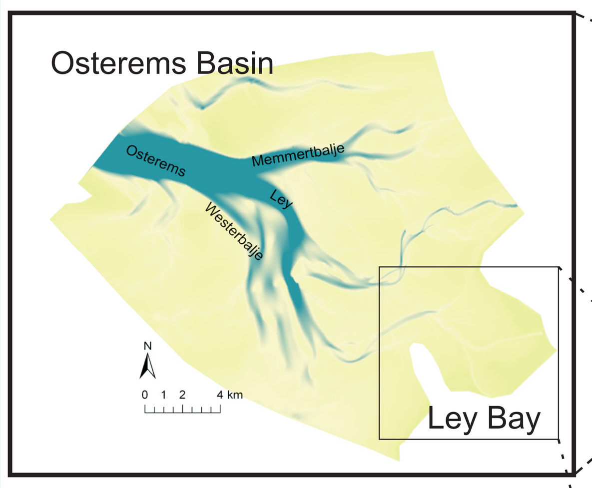
Objective

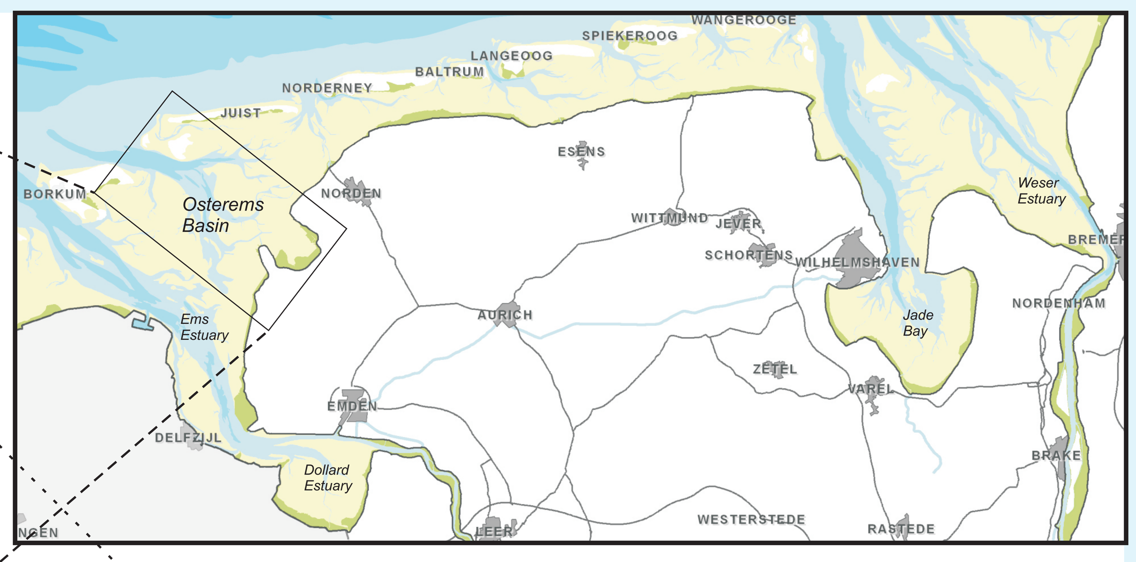
The overarching aim of this study is to investigate the effect of the Leyhörn peninsula on the Ley Bay morphology by elaborating the underlying physical processes with the emphasis of climate change and sea level rise scenarios.

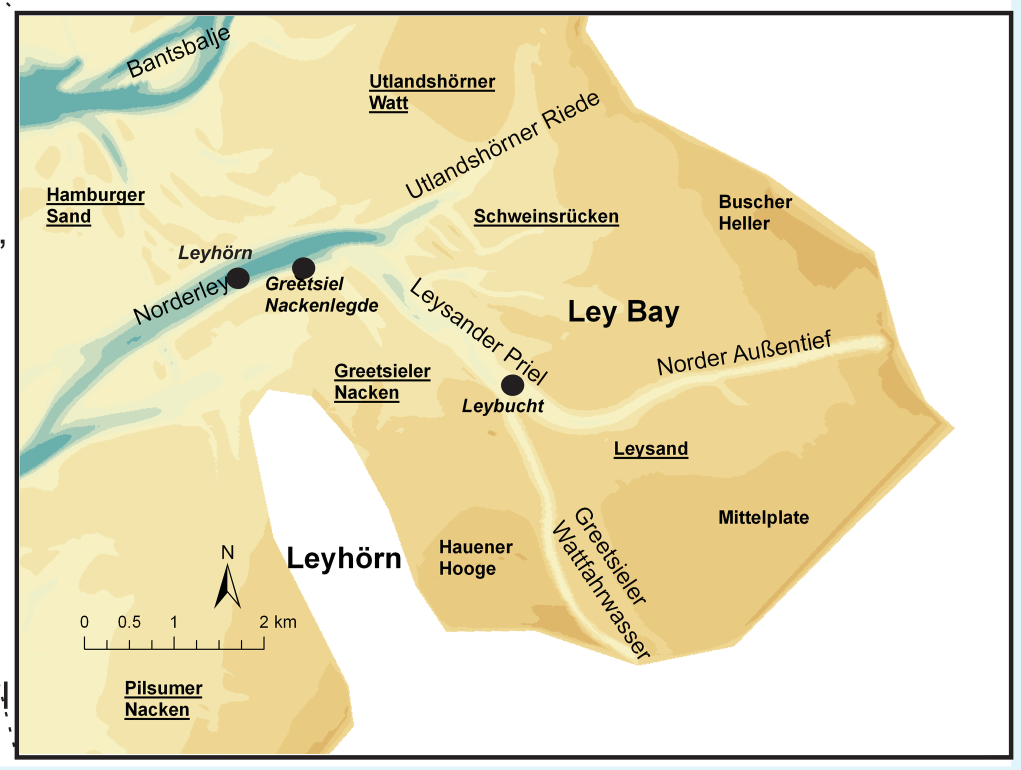
Approach

Approach undertakes 2DH version of the process-based model, Delft3D, with online morphology technique (Zanke, 2008; Roelvink, 2006). Present results show bed evolution from 1975 to 1990 applying different boundary forcings (tidal and wave) and bed compositions (single and multiple sediment fractions) with spatially varying bed roughness.

Study area







Relevance

Following functions are mainly related to morphological evolution in the study area,

- Safety of the coastal area against storm surges
- Conservation of the Ley Bay area as a unique ecological area
- Re-establishing of free-flow inland drainage due to hadraulic gradient
- Maintaining access channel to Greetsiel harbour without maintenance dredging

Scenarios

Study used different scenarios to investigate the bed evolution in the Ley Bay area. Only following three scenarios are hereon discussed.

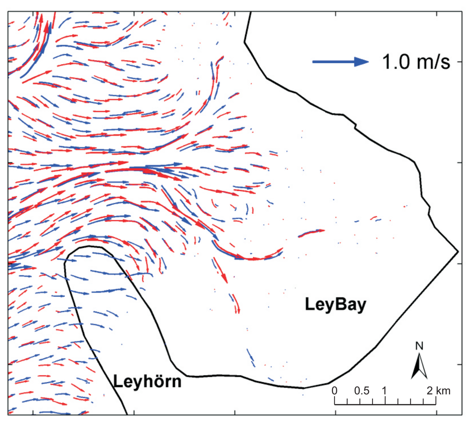
Scenario	Boundary	Bed Composition
S1	Tide only	Spatially uniform single sediment fraction (D_{50} = 0.2 mm)
S2	Tide only	Spatially varying multiple sediment fractions (mud, 0.25, 0.60)
S3	Tide and Wave	Similar to S2 (intermediate results)

Tidal boundary

Offshore tidal forcings are transformed into the Osterems basin via nesting with a large model that covers entire East Frisian Wadden Sea and forced by astronomical tidal constituents (Knaack et al., 2003).

Maximum tidal flow occurs at mid-tidal water level in the Wadden Sea tidal basins (Dissanayake et al., 2009)

Apparently, tidal flow at mid-flood condition shows strong velocities in the Ley Bay channels (red) compared to the situation prior to the construction of the Leyhörn peninsula (blue)



Wave boundary

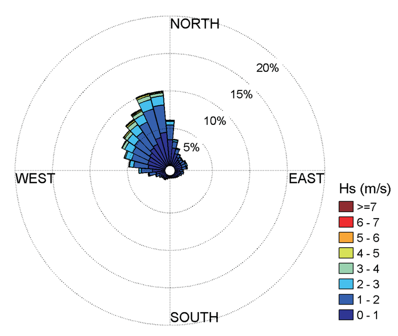
Measured wave data at an offshore location (close to Norderney) from 1975 to 1990 were used in this analysis. It was assumed that there is no climate change driven variations during this period. Selected wave climate was reduced to a few number of wave conditions based on two reduction criteria,

1) Neglecting wave conditions with a probablity < 1%

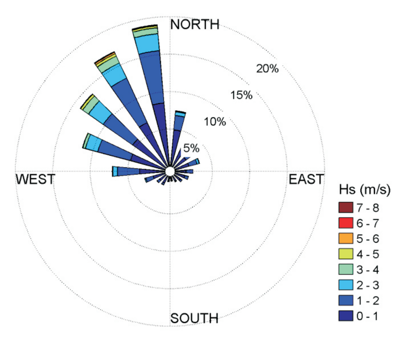
This is based on the fact that rare occurrence and was performed after constructing a scatter diagram of wave height and directional classes (i.e. indicated in red). 73 wave conditions remained.

Hs (m)	Directional Classes (deg. Nau.) 0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160	160-180	180-200	200-220	220-240	240-260	260-280	280-300	300-320	320-340	340-360	Prob.
0 - 1	4.895	2.637	1.956	1.942	1.462	1.390	1.037	0.781	0.568	0.620	1.062	1.062	1.665	3.409	4.806	5.439	6.533	8.505	49.77
1 - 2	1.933	0.935	0.971	1.119	0.923	0.496	0.274	0.106	0.085	0.098	0.257	0.393	1.015	2.942	4.535	4.805	6.527	6.995	34.41
2 - 3	0.497	0.146	0.206	0.309	0.111	0.014	0.001	0.002	0.001	0.004	0.019	0.036	0.148	0.643	1.713	2.406	2.249	2.284	10.79
3 - 4	0.098	0.031	0.024	0.051	0.003	0	0	0	0	0	0	0	0.012	0.056	0.353	0.944	1.003	0.783	3.36
4 - 5	0.040	0	0.005	0.010	0	0	0	0	0	0	0	0	0.001	0.001	0.059	0.324	0.343	0.272	1.06
5 - 6	0.007	0	0	0.006	0	0	0	0	0	0	0	0	0	0	0.009	0.086	0.218	0.098	0.42
6 - 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.032	0.083	0.032	0.15
7 - 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	0.025	0.015	0.04
8 - 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.004	0.00
Prob.	7.47	3.75	3.16	3.44	2.50	1.90	1.31	0.89	0.65	0.72	1.34	1.49	2.84	7.05	11.47	14.04	16.98	18.99	100

Measured wave climate from 1975 to 1990



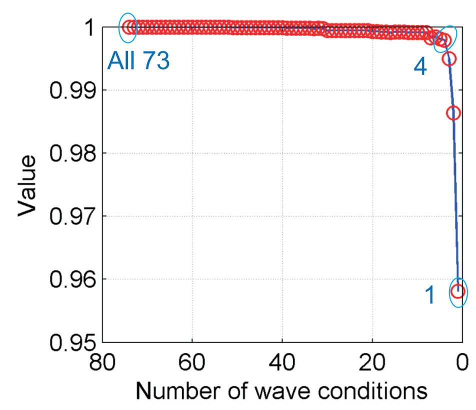
Schematised wave climate up to 73 conditions



2) Relative contribution of each wave condition to the overall bed level change of the Ley Bay area

Short-term (i.e. one day) simulations were separately undertaken for the selectd 73 wave conditions applying online coupling of Delft3D and SWAN models. With resulting sedimentation/erosion patterns, an iterative method was used to remove the wave condition which has the lowest contribution to the overall bed level change of the 73 wave conditions. Relative contribution of each wave is given by a weight factor. A few number of wave conditions can be selected based on statistical parameters (i.e. RMS error, R^2) which indicate, how bed levels of reduced number of wave conditions resemble with that of the 73 wave conditions.

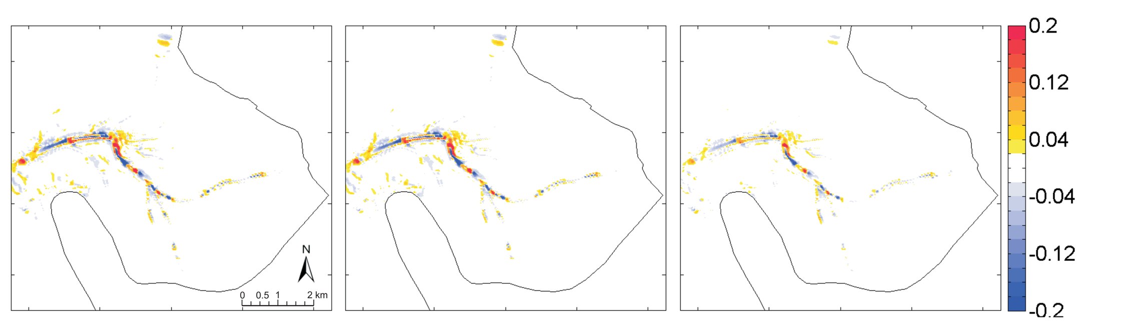
Variation of R^2



Selected four wave conditions

Hs (m)	Tm02 (s)	Dir (deg. Nau)	Wind Speed (m/s)	Wind dir. (deg. Nau)	Weight factor
0.6	3.9	90	6.8	108	0.451
1.4	5.3	271	10.2	219	0.243
3.4	9.0	330	12.9	293	0.109
1.4	6.8	331	6.9	270	0.118

Erosion/Sedimentation pattern

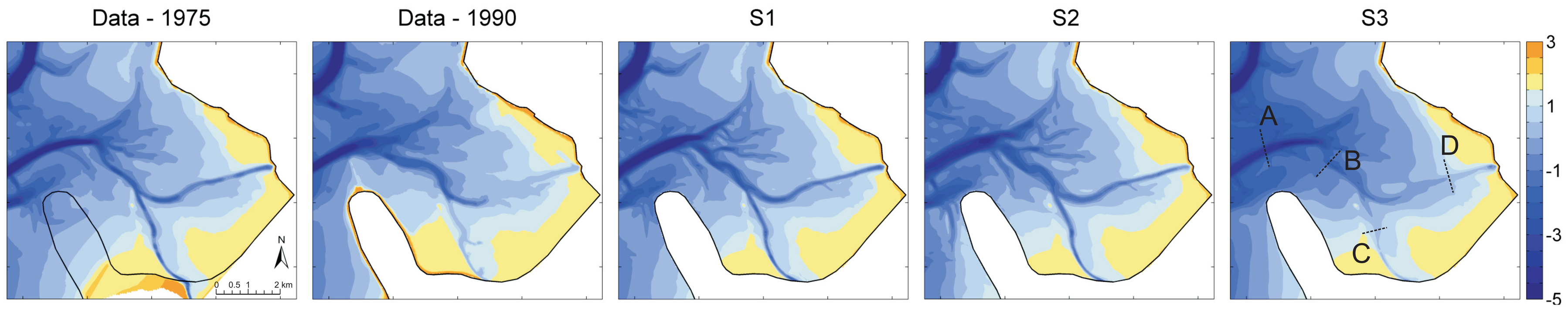


Morphological evolution of the Ley Bay

Bed evolution

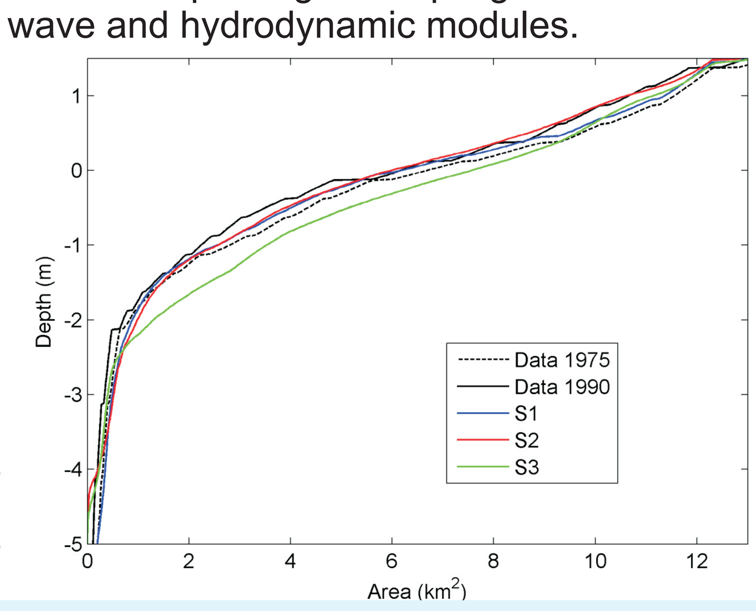
Data at 1990 show strong sedimentation in the Ley Bay, disappearing Norder Außentief and Greetsieler Wattfahrwasser channels while pronouncing Leysander Priel channel.

Models with tidal boundary forcing only (S1 and S2) predict stronger channel pattern compared to the data. However, including both tidal and wave boundary forcings (S3) has resulted in strong sedimentation in the channels while deepening middle of the bay. Furthermore, strong sedimentation is apparent at the west of Leyhörn and on Utlandshörner Watt under S3. Predicted Mittelplate areas (> 1.5 m+NN) are similar to that of the 1975 bed whereas it is wider on the 1990 bed implying the growth of salt marsh areas in nature. Application of a single sediment fraction (S1) shows the deepest channels in the bay compared to the cases of applying multiple sediment fractions with initially distributed bed composition (S2 and S3).



Basin area-depth hypsometry

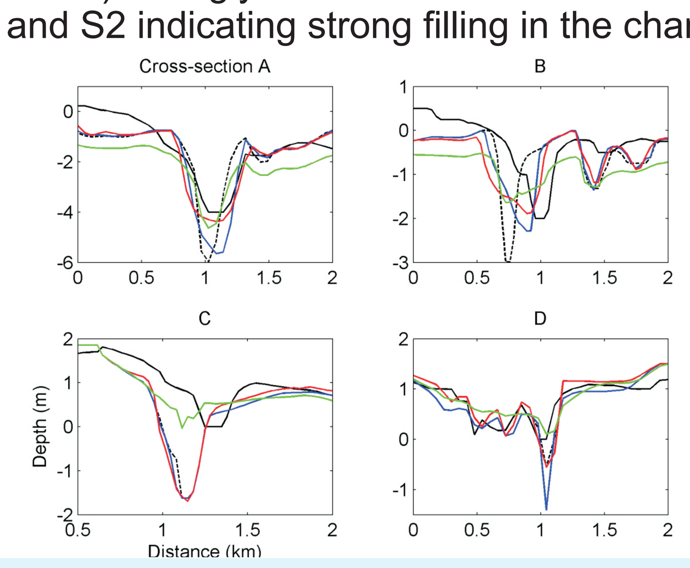
Hypsometry indicates the overall morphology in the Ley Bay area. S2 reasonably agrees with the 1990 data while S3 shows larger basin area implying sediment import and losing respectively. Wave effect generally deepens the bay area. This is under investigation and expected due to strong bed level updating or coupling interval between wave and hydrodynamic modules.



Evolution of channel cross-sections

From 1975 to 1990, channel sections have significantly become shallow. B and C have shifted away from Leyhörn indicating possible effect of dumping on the left-bank.

Deep sections (A and B) show agreement with the 1990 bed in all cases. Under S3, shallow sections (C and D) strongly resemble to the data than that of S1 and S2 indicating strong filling in the channels.



Preliminary Conclusions

Data indicate that strong sedimentation in the Ley Bay area has resulted in decreasing the channel pattern while growing the salt marsh areas (i.e. Hauener Hooge, Mittelplate).

Major channels in the Ley Bay are resonably re-produced by the model while secondary channels are overestimated compared to the data. Only under S3, the basin channels show strong sedimentation as observed on the 1990 bed though middle part of the bay deepens.

Work is currently in progress to optimise the wave inclusion, bed composition and to include the effect of dredging and dumping activities prior and after construction of the Leyhörn peninsula.

References

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