MG14A-1914

Observations of Waves and Currents on an Inundated Barrier Island: the Role of the Back-Barrier Basin

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Introduction

Overwash and inundation can cause large-scale coastal changes that range from the breaching of islands to vertical accretion of sediments. Vertical sediment accretion might aid in mitigating the effects of sea level rise and subsidence, and therefore the restoration of washovers on Wadden islands is being considered. However, not much is known about the hydrodynamic processes during overwash and inundation in mesotidal systems, and crucial field data is missing. Within this project we aim to characterize the hydrodynamic conditions during overwash and inundation on barrier islands in the Wadden Sea.

Research Questions

- What are the local inundation depths during a typical winter season?
- What is the strength and direction of the cross-shore currents?
- What are the wave characteristics and how do they transform across the island?
- What is the influence of the back barrier area (Wadden Sea) on the hydrodynamics during island inundation?

Field site

Figure 1. The barrier island of Schiermonnikoog is located in the North Sea and is separated from the Dutch coast by the Wadden Sea. The field site was located on the eastern tip of the island. The Huibertgat buoy is located in the North Sea, the Schiermonnikoog station in the Wadden Sea.

Instruments

measured continuously for 3 months in the winter 2014/2015

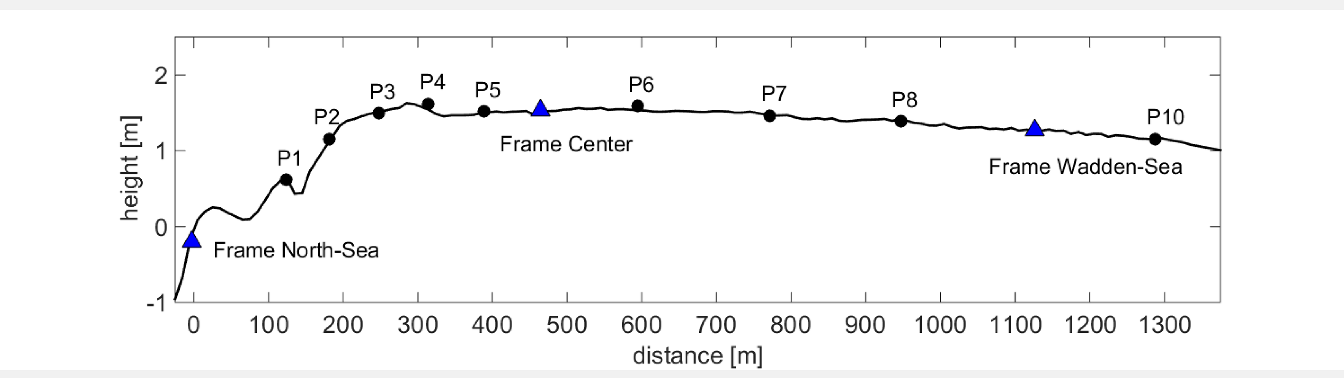

Figure 2. The cross-island profile (black line) is shown with the North Sea to the left and the back barrier area (Wadden Sea) to the right. The stand-alone pressure sensors (black dots) measured at 10 Hz, while the ADVs (pressure and currents) on the instrument frames (blue triangles) measured at 16 Hz.

Results

Boundary conditions

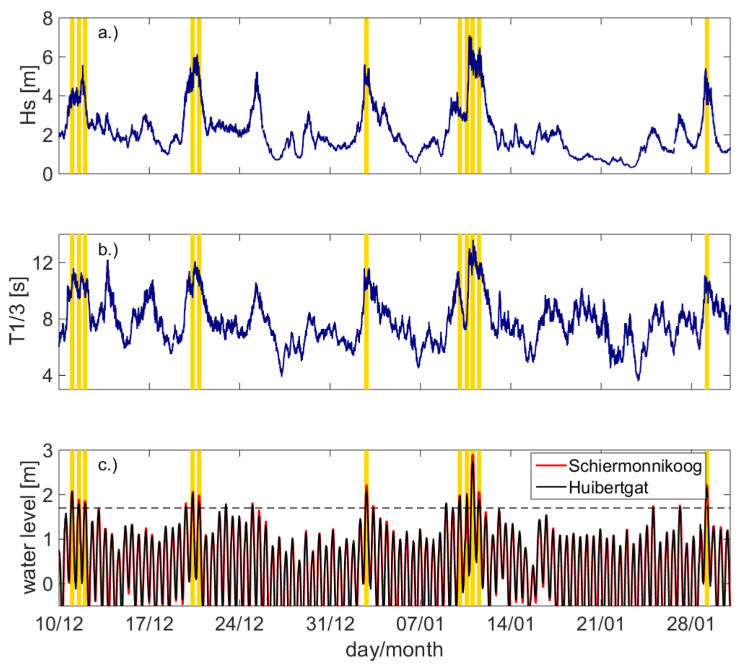

Figure 3. Offshore significant wave heights (a.) and -periods (b.). Water level variations (c.) are shown for the North Sea (Huibertgat) and the Wadden Sea (Schiermonnikoog station). The black dashed line indicates the highest elevation of the transect. Note that the water level is often higher in the Wadden Sea during storms. The yellow background indicates the times when the field site was completely inundated.

Inundation depths

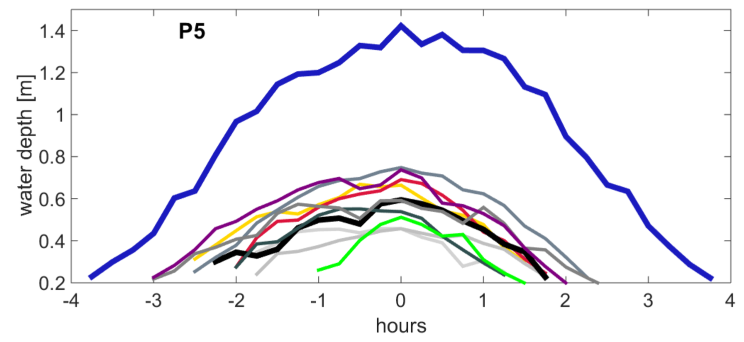

Figure 4. Water depths for all flooding events at P5 (see Figure 2). 0 hours indicates high tides. Inundation depths ranged between 0.4m and 1.4 m. The largest flooding event (thick blue line) corresponds to a 1 in a 3 year storm . This event and a shallow flooding event (thick black line) are investigated further in the wave plots.

Water level gradients and currents

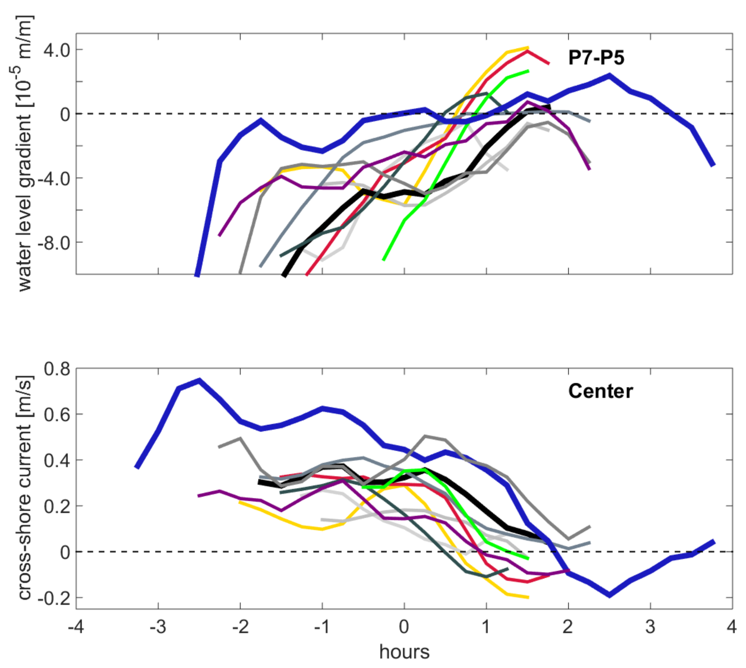

Figure 5. Water level gradients (a.) are calculated as (wl-P7-wl-P5)/d where wl is the water level at the respective sensor and d is the distance between the two sensors. Water level gradients are typically negative, indicating lower water levels at the Wadden Sea side of the profile; however, they occasionally reverses directions after high tide (positive values). Cross-shore currents are generally directed onshore (positive values), but occasionally also reverses (negative values). For a comparison with inundation depths refer to Figure 4, for instrument locations to Figure 2.

Waves

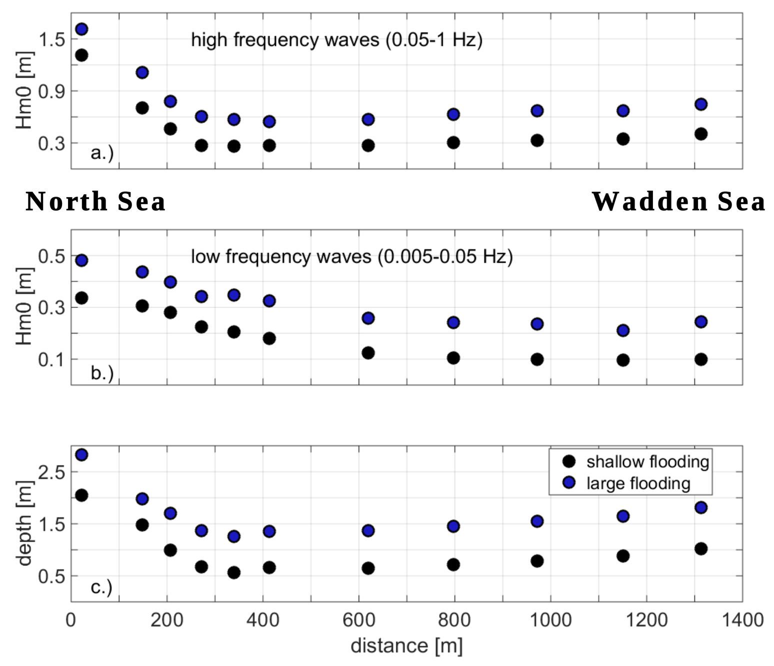

Figure 6. High frequency waves (a.) decrease consistent with a decrease in water depths (c.) from the North Sea towards the center. Remarkably, they increase again towards the Wadden Sea. Low frequency waves (b.) decrease over extended distances and then stay constant from ~ 800 m to the Wadden Sea.

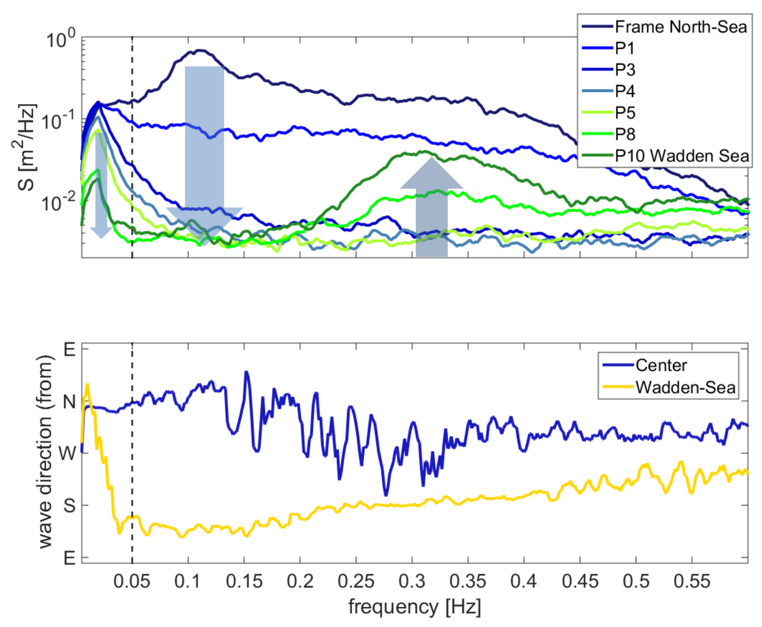

Figure 7 . Spectral densities (upper panels) are shown at locations along the transect for the shallow flooding event (the large flooding event produces similar results). The downward looking arrows indicate high-frequency and swell waves from the North Sea. The upward looking arrow indicates waves coming from the Wadden Sea. The frequency band around 0.3 Hz and the wave direction (also compare spectral wave directions in the lower panel) indicate that these waves were locally generated in the Wadden Sea. The black dashed lines at 0.05 Hz indicate the cut-off between low- and high frequencies.

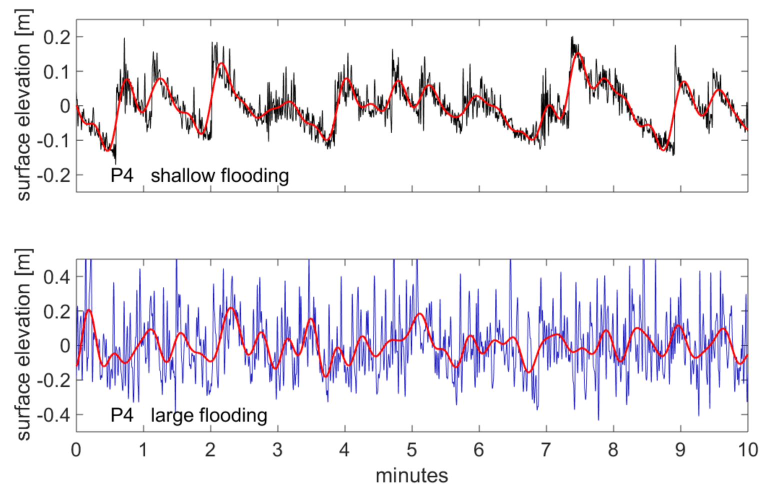

Figure 8. Variations in surface elevation are shown for the two flooding events at P4 at high tide. Low-pass band filtered surface elevations (red) indicate that low-frequency waves propagate as bores when water depths are shallow.

Main findings

- Inundation depths ranged between 0.4 -1.4 meter.
- Currents are generally directed onshore; however, the occasional reversal of water level gradients between the center of the island and the Wadden Sea, due to increased water level s in the Wadden Sea (Figure 3), forces flows in the offshore direction.
- Waves in the swell and infragravity bands enter the field site from the North Sea while from the Wadden Sea primarily locally generated wind waves enter.
- Infragravity waves are frequently observed to propagate as bores in shallow inundation depths.

Discussion

The back-barrier area (Wadden Sea) plays a significant role during island inundation. Increased water levels in the Wadden Sea not only reverse the flows occasionally, but are also likely to slow the flows. This will impact sediment transport greatly.
Waves entering from the back-barrier area and infragravity waves propagation across the island might play a crucial role in sediment stirring and transport.

Begin of an overwash event on Schiermonnikoog. This is not the field site.

Acknowledgements

We couldn't have done it without the technical support of Marcel van Maarseveen, Henk Markies, Chris Roosendaal and Arjan van Eijk. We would also like to thank Natuurmonumenten for their assistance during the field work. This work is supported by NWO.