

# HIGH-RESOLUTION ADCP MEASUREMENTS OF TURBULENT FLOWS NEAR A LARGE STREAM GROUYNE

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## BACKGROUND

The tidal inlet ‘Harle’ is located at the German North Sea coast, intermediary to the barrier islands Wangerooge and Spiekeroog. In the highly complex natural system encompassing the North Sea, barrier islands, tidal flats and coastal foreshores, the pivotal role of tidal inlets become evident. These cross-sectional narrowings concentrate the exchange of water-bound matter between the backbarrier tidal flats and the open sea. Additionally, they are characterized by pronounced dynamics in both current patterns and sediment transport, owing to the influence of tidal forces.

Within this context, the ‘Harle’ inlet constitutes a distinctive significance, notably characterized by the presence of a large-scale stream groyne. As an integral component of the western coastal protection of Wangerooge, the extensive coverage of groyne H across large parts of the inlet’s cross-section imparts a consequential impact on the natural dynamics inherent to the system. One of the most dominating consequences of the structure are large scours at the tip of the groyne as well as along the groyne flanks. Given an advanced age, unclear structural condition, sizable dimensions and dynamical influence, plans for conversion and reconstruction are currently being discussed.

To provide a foundational basis for future proactive coastal protection strategies and to understand the prevailing near-field hydrodynamics the conducted study aims to reveal patterns of the current-structure interaction and provide insights into the turbulence characteristics in such a complex system.

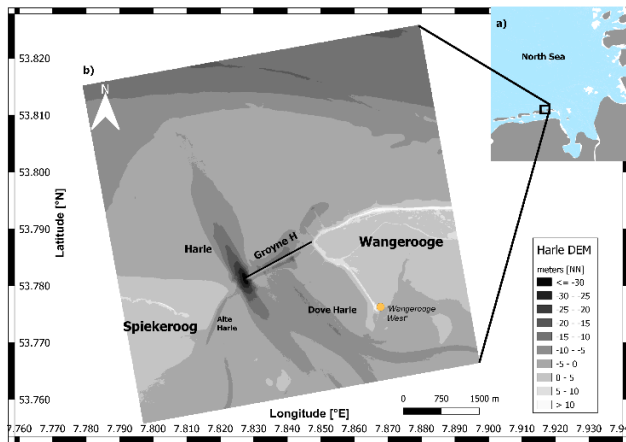


Figure 1: Location of the Study area of the Harle inlet between Spiekeroog and Wangerooge (German North Sea coast).

## METHODOLOGY

High-resolution Acoustic Doppler Current Profiler (ADCP) measurements were conducted in close proximity to the groyne. Simultaneous current recordings were executed both north and south of the structure, employing two last generation 5-beam ADCPs (Nortek Signature 1000 kHz). These instruments were securely affixed within weighted triangular frames, deployed from the research vessel to the seabed within the longitudinal scours. A total of five distinct measurement locations over five days and additional shipboard ADCP (RDI Sentinel Workhorse 600 kHz) transects were established to comprehensively capture the hydrodynamic conditions.

The deployment campaign was purposely designed to cover the peak spring tide expected on the 2<sup>nd</sup> and 3<sup>rd</sup> day of the measurements. Unexpectedly for the summer season, cyclone ‘Poly’ hit the study area on the 4<sup>th</sup> day with gust speeds above 100 km/h. Besides challenging working conditions, this incident adds another unique feature to the obtained data set.

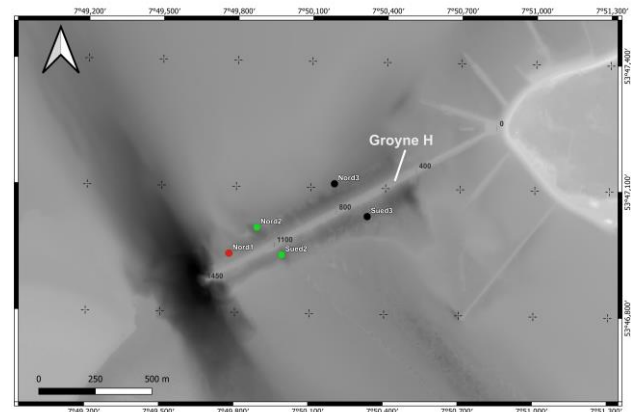


Figure 2: Detailed view of the northwestern tip of Wangerooge and groyne H (labeled). Colored dots represent the individual measurement locations of ADCP measurements.

In order to understand the groyne’s impact on local hydrodynamics and regional sediment transport processes, this study focuses on turbulence characteristics derived from the simultaneous measurements on both the upstream and downstream side. It is believed that the massive obstruction in the tidal inlet plays a major role in mixing processes and energy dissipation which is still to be resolved quantitatively, also to improve proper parametrization in regional numerical models. Here, the variance method (e.g. Burchard et al. (2008)) is applied to estimate the Reynolds stresses and total turbulent kinetic energy budget (TKE) from the velocity measurements. While the ADCP yields average and fluctuating velocity components  $u$ ,  $v$  and  $w$  in all three directions, these cannot be correlated directly to establish

estimates of the full Reynolds stress tensor, since the four diverging beams would be too far apart at the water surface. Instead, it is assumed that the turbulence statistics are homogeneously distributed over the area covered and hence derived within each beam individually following the approach by Dewey and Stringer (2007).

### PRELIMINARY RESULTS

Results suggest that different distinctive flow patterns develop depending on the tidal time as well as the position along the groyne flank. The emergence of a breach within the structure gives rise to particular characteristics in the ambient flow and sediment dynamics. Patterns that lead to the generation and maintenance of the large-scale longitudinal scours along the groyne flanks and at the groyne tip are examined.

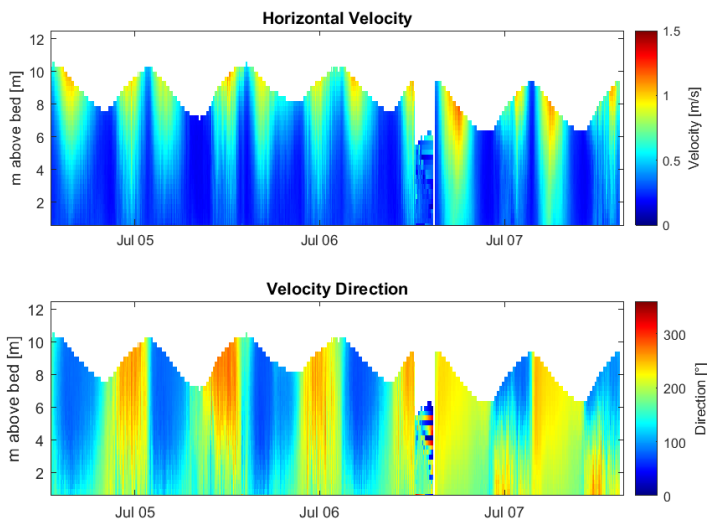


Figure 3: Horizontal flow velocities a) and velocity directions b) at the longitudinal groyne scour resolved over depth and time.

This study offers a distinct context for the analysis of turbulent characteristics. Existing literature is mostly focused on turbulence generated at a channel bottom within e.g. a river. In the present study area, findings related to turbulent kinetic energy and Reynolds stresses are investigated in a much more complex dynamic system with a unique external driver in the form of a large-scale stream groyne.

### REFERENCES

Burchard et al. (2008): Observational and numerical modeling methods for quantifying coastal ocean turbulence and mixing, *Progress in oceanography* 76.4: 399-442.

Dewey and Stringer (2007): Reynolds stresses and turbulent kinetic energy estimates from various ADCP beam configurations: Theory, *J. of Phys. Ocean*: 1-35.