BEHAVIOR OF SUSPENDED SEDIMENT FLOCS IN TIDAL BASINS
A CASE STUDY FROM THE BACKBARRIER AREA OF SPIEKEROOG ISLAND, GERMAN NORTH SEA

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Introduction
The Wadden Sea is a complex ecosystem in the transition zone from land to sea. This ecosystem consists in the area of the East Frisian Islands of various environments ranging from salt marshes at the foot of the dyke as landward margin, over a network of tidal flats and tidal creeks to barrier islands, which form the seaward margin of the Wadden Sea (FLEMMING, B.W. & DAVIS, R.A. JR., 1994). Permanent fluctuation between draining and flooding characterises and even more establishes this coastal environment. Driving forces in this area are tides. These tidal currents do not only exchange large volumes of water with the open sea and are thus forming the local morphology they transport large volumes of needful and harmful substances in solution into and out of the Wadden Sea. The here presented subproject "Hydrodynamic of the Wadden Sea" is dealing with another way of exchanging large amounts of material: the transport of suspended matter. We survey the net transport of suspended matter in the hydrodynamic context for understanding the different processes involved in suspended matter transport.

Study area
The East Frisian Wadden Sea is characterised by a line of seven major barrier islands at the seaward margin and backbarrier tidal flats. Investigations are carried out in the backbarrier tidal basin of Spiekeroog Island, German North Sea (Fig. 1). The Spiekeroog tidal basin covers an area of about 75 km². The tidal setting is semidiurnal with a tidal range of approximately 2.6 to 2.8 m (FLEMMING, B.W. & DAVIS, R.A. JR., 1994). Most of the water exchange is carried out through the Otzum Inlet situated W of the island. Exchange over the tidal watershed with neighbouring tidal basins occurs due to wind forcing and is omitted in this study.

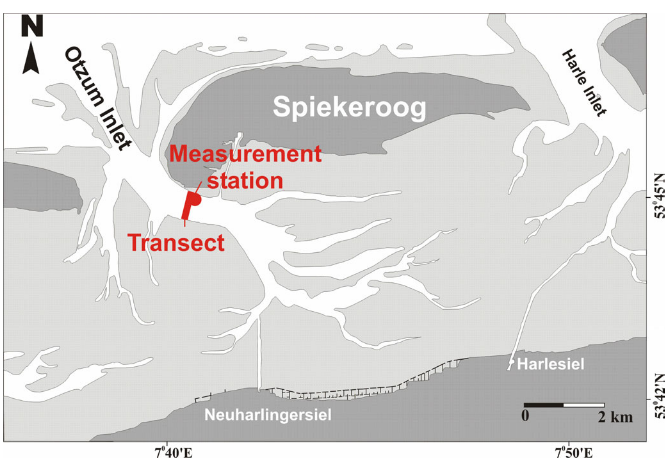

Fig. 1: Study area Spiekeroog tidal basin. Locations of the permanent measurement station and ADCP transects are marked.

Methods
Field measurements are carried out in the inner part of the Otzum Inlet covering nearly all the water and material exchange. For the hydrodynamic and suspended sediment survey we combine acoustical and optical instrumentation. Tidal currents are surveyed over the entire water column using "Acoustic Doppler Current Profiler" (ADCP). The instrument is mounted on a boat to cover complete main tidal channel transects during tidal cycles (Fig. 1). Suspended sediment concentrations are calculated based on the ADCPs backscatter signal (SANTAMARINA CUNEO, P. & FLEMMING, B.W., 2000).
A "Laser In-Situ Scattering and Transmissiometry" (LISST) system is used for surveying the suspended sediment at an anchor station 50 m SW of the measurement station successively at several water depths. By means of optical diffraction in-situ floc sizes are estimated. Suspended sediment concentration is calculated based on optical transmission (AGRAWAL, Y.C. & POTTSMITH, H.C., 2000). A pump centrifuge system is used to obtain suspended sediment samples for analysing grain size distributions and suspension concentrations. This direct approach to suspended sediment concentration is used to calibrate the acoustical and optical methods. Additionally floc sizes are recorded by a photogrammetric system by the subproject "Ecology of Suspended Particles". Comparison of the photogrammetric and LISST methods for estimating in-situ floc sizes will be presented soon.

Results
Suspended matter in coastal waters within the North Sea comprises mainly of mineral particles. Total organic matter content lies within 6 to 11% of the suspended matter. This contribution varies seasonally reaching higher organic content in spring and early summer due to higher primary production.
Comparing pump samples and LISST data shows that 85% of the single grains are smaller than 63 µm compared to only 25% of the in-situ particles contributing to the mud size (Fig. 2). Suspended sediment is thus mainly transported in complex, highly changeable flocs. These consist of single grains as well as smaller flocs.

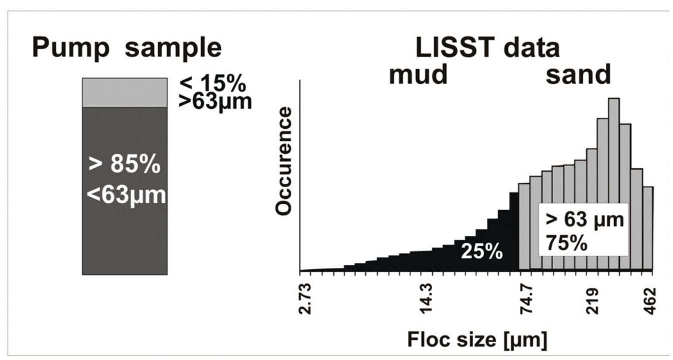

Fig. 2: Comparison of particle sizes, left side displays single grain sizes in pump samples. In-situ floc size distributions obtained by the LISST are shown on the right.

Flocculation is resulting in different orders. Flocs of higher order are generally less dense and more fragile. Thus floc sizes vary according to the tidal cycle (Fig. 3). Maximum floc sizes are reached half an hour after slack water.

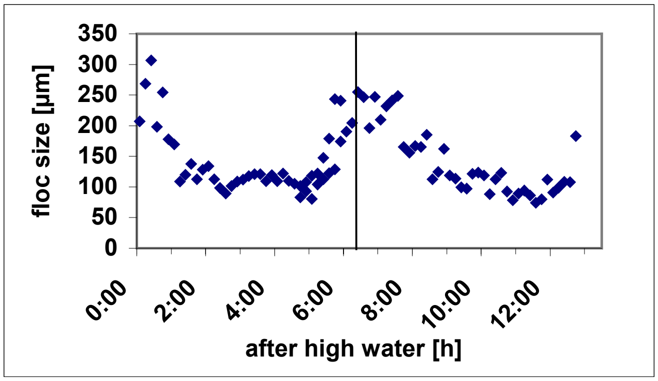

Fig. 3: Variation of in-situ floc sizes over tidal cycle.

Tidal variations of suspended sediment concentration are shown in figure 4. Minima in concentration occur after slack water. Analysing figures 3 & 4 shows differences between flood and ebb phases. During flood the concentration is higher and floc sizes are generally smaller than during ebb. This seems to be forced by resuspension of previously deposited sediment and disruption of flocs due to slop over of waves on tidal flats.

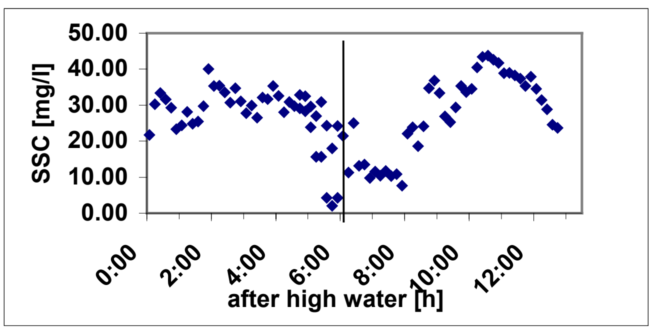

Fig. 4: Variation of suspended sediment concentration over tidal cycle.

Integrating ADCP data into the analysis documents that floc sizes are mainly controlled by combination of current velocity and suspended sediment concentration. Suspended sediment concentration increases proportionally with increasing current velocity (Fig. 5). The maximum floc size is limited by current velocity and shear stress in the bottom boundary layer (Fig. 6). A higher concentration of suspended sediment on the other hand aids faster flocculation and thus larger floc sizes.

Outlook

It is planned to mount an ADCP on the measurement station for surveying tidal currents and suspended sediment permanently and independent of weather conditions. Furthermore this instrument is capable of estimating the wave field. Thus we will be able to analyse suspended sediment transport processes including the influence of waves also during storm events.

Additionally we plan to expand measurements onto tidal flats near the landward margin. There we will obtain information about deposition and resuspension processes.

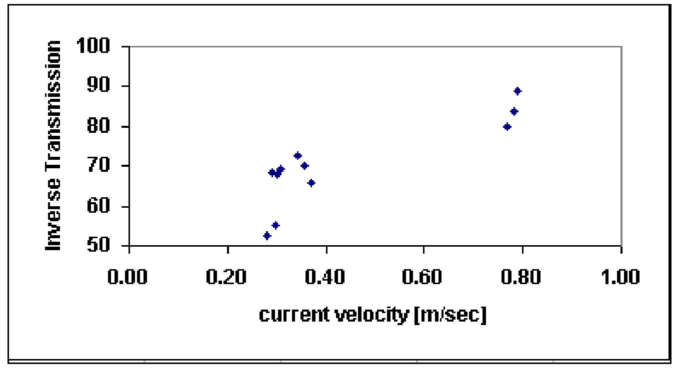

Fig. 5: Inverse transmission as a proxy for suspended sediment concentration in relation to current velocity.

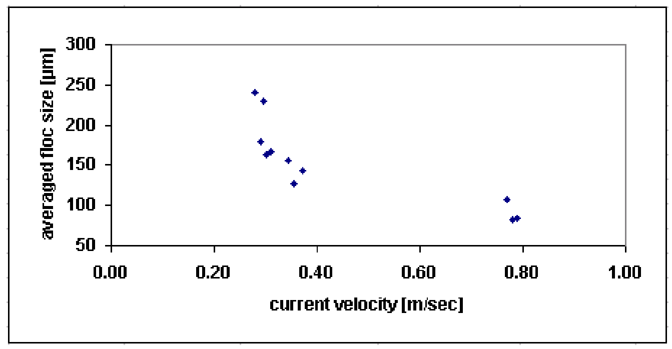

Fig. 6: Average in-situ floc sizes obtained by LISST in relation to current velocity measured by ADCP.

References

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