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Investigating the water-bed exchange of fine sediments

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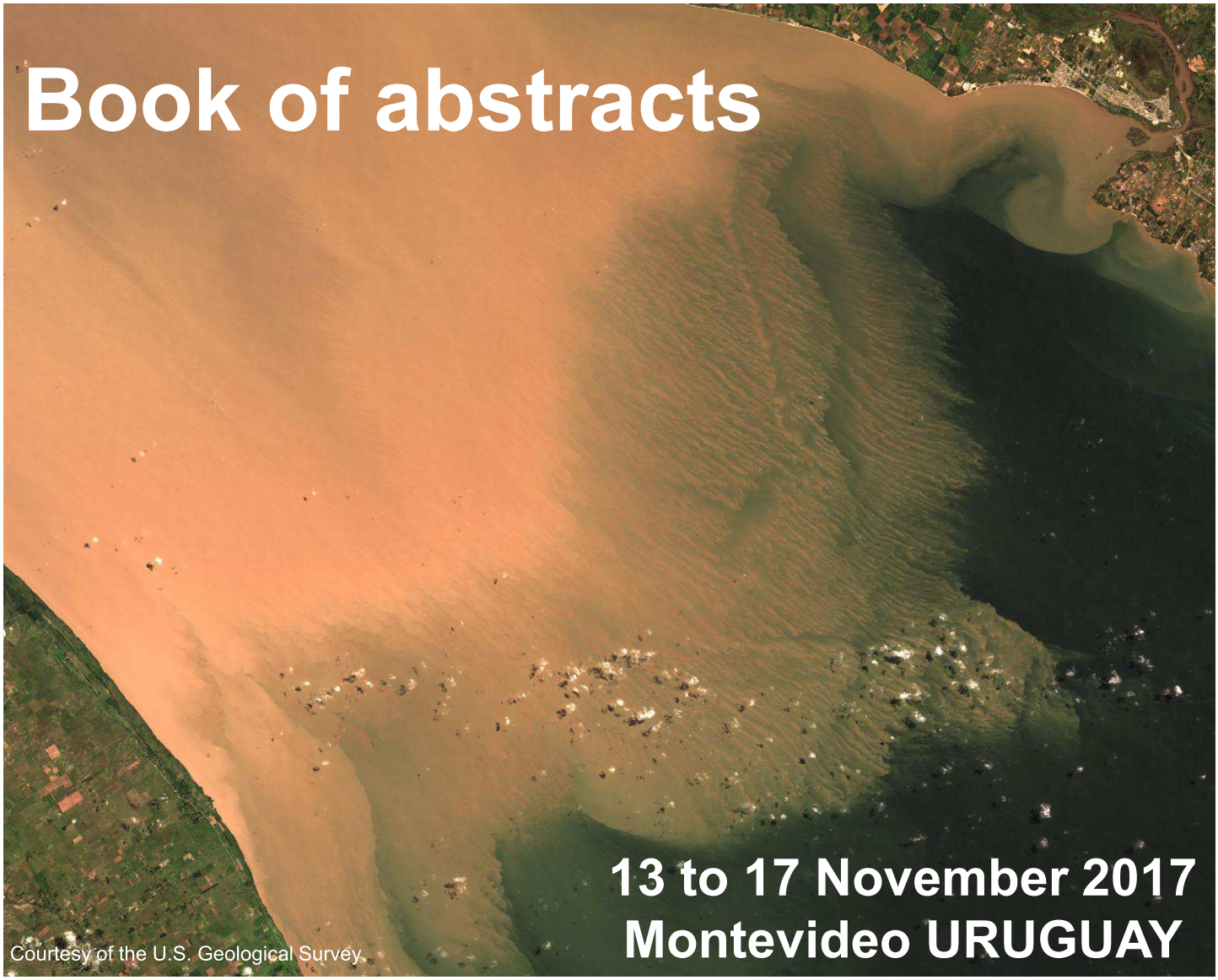
Publication date
2017

Citation (APA)
Hendriks, E., van Prooijen, B., Winterwerp, H., Aarninkhof, S., van der Hout, CM., & Witbaard, R. (2017). *Response of SPM concentrations to storms in the North Sea: Investigating the water-bed exchange of fine sediments*. 71-72. Abstract from INTERCOH 2017, Montevideo, Uruguay.

INTERCOH 2017
Montevideo - Uruguay
November 13 - 17

14th International Conference on Cohesive Sediment Transport Processes



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Response of SPM concentrations to storms in the North Sea: investigating the water-bed exchange of fine sediments

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Introduction

Shallow coastal seas are subject to an increasing pressure by offshore operations. Further to a direct influence these operations impose on benthic and pelagic organisms, an indirect influence is caused by changes in sediment dynamics and morphodynamics. Temporal variations in SPM have a large effect on the timing and rate of primary production, thereby also affecting higher trophic levels. Field measurements along the Dutch coast indicate significant seasonal variations in concentrations of SPM (Suijlen and Duin, 2001; Witbaard et al., 2015). These seasonal variations originate from a marked seasonality in wind climate and the occurrence of storms. During storms, increases in SPM occur simultaneously in large parts of the Dutch coastal zone of the North Sea (Suijlen & Duin 2001), demonstrating that on short timescales, the vertical exchange between the sea bed and the water column is dominant. Model concepts with two discrete seabed layers (a fluffy top layer and a sandy lower layer) turned out to capture these fine sediment dynamics, see van Kessel *et al.* (2011). However, the underlying physical processes resulting in the water-bed exchange of fines are still to be unravelled.

Therefore, this study aims to investigate the resuspension of fines from the bed during and after storms, accounting for the tidal variation due to the spring-neap tide cycle. This will lead to a more specific conceptualization and related parameterization of the water-bed exchange, thereby enabling to study both the direct and indirect impact of offshore operations.

Methods

To investigate the water-bed exchange of fines, data from a bottom lander is analysed. The lander was placed 1.2 km off the Dutch coast, at Egmond aan Zee (see Figure 1). It collected data on hydrodynamics and sediment concentrations continuously during a period of 21 months, from March 2011 until November 2012 (van der Hout *et al.*, submitted). The following data collected with the lander are analysed: (i) current velocity over the entire water column, measured by an upward looking RDI ADCP; (ii) near bed velocities, measured with a Nortek Vector current meter, positioned at 30cm above the seabed; (iii) SPM concentrations at four heights above the bottom, i.e. 30, 80, 140 and 200cm, measured with ALEC Compact-CLW's.

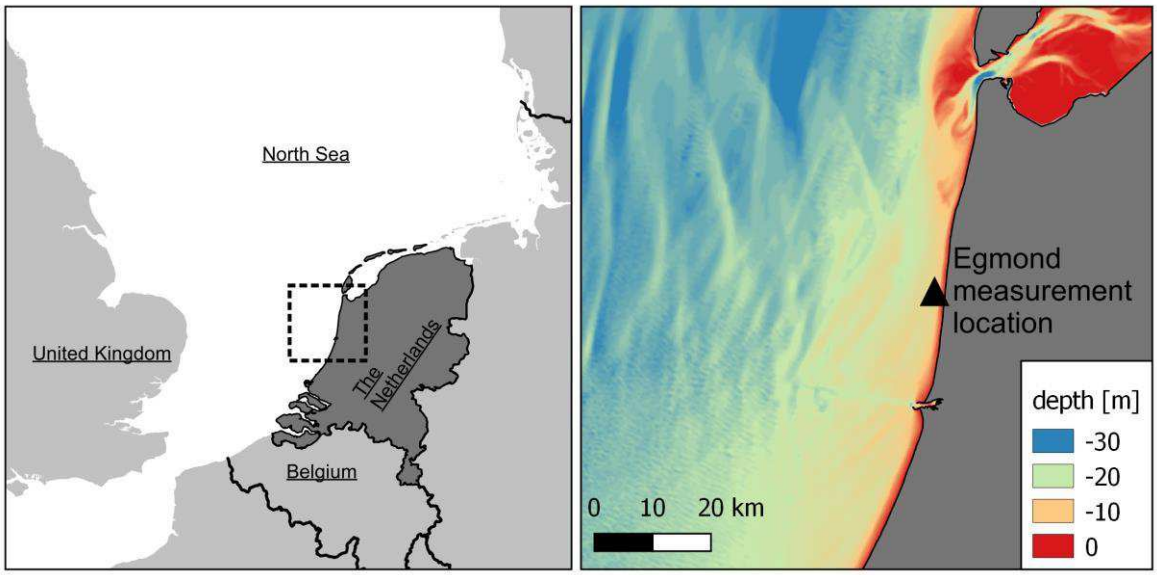

Figure 1: Location of the bottom lander, also showing the bathymetry of the study area

Results

The 21-month deployment allows comparing high-energetic conditions with low energetic conditions. Here, we highlight a period of 25 days: 10 August 2011 until 4 September 2011. Figure 2a shows the water depth variation with a dominant semi-diurnal tide and spring-neap cycle. Panel 2b shows the computed variation in bed shear stress by waves and currents, whereas panel 2c shows measured SPM concentrations at 0.3 and 2.0 meters above the bed (mab). Two storm events can be distinguished, and are indicated by grey bands. During these storms, the bed shear stress increases due to wave action. An increase in SPM concentration is also observed during this storm period. A quarterly diurnal cycle can be identified, which can be related to increased mixing during higher tidal flow velocities. After the storm events, the bed shear stress decreases, but the SPM concentrations remained high for approximately a week. During the period from 12 August – 26 August (i.e. between the storm events) similar bed shear stresses lead to large differences in SPM concentrations. The first week after the storm event is characterized by generally high SPM concentrations, whereas SPM concentrations are low throughout the second week after the storm event. This indicates that more fine sediment is available for resuspension in the study area after the storm event. After approximately a week, the response of SPM concentrations to the computed bed shear stress is similar to pre-storm response. Before the onset of the second storm, around the 28th of August, SPM concentrations at 0.3 mab are lower than 100 mg/l. After the storm event, similar bed shear stresses lead to SPM concentrations of almost 500 mg/l at 0.3 mab.

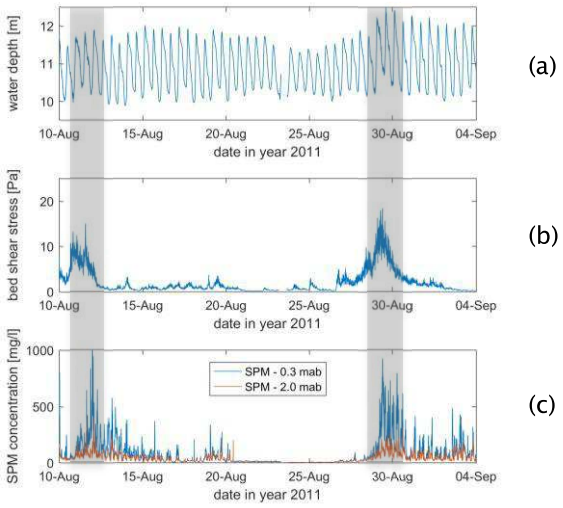

Figure 2: Measured water levels (a), computed bed shear stress (b) and measured SPM concentrations at 0.3 and 2.0 meters above the bed (c), from 10 August 2011 until 04 September 2011.

Interpretation and Conclusions

The variations in SPM concentration indicate that waves play a crucial role in remobilizing fine sediment from the mostly sandy seabed. After remobilization, tidal flow is essential for mixing the sediment higher up in the water column. The resulting SPM-time series show a semidiurnal cycle (mixing by the flow) modulated by the wave-induced bed shear stress. Before and shortly after storms, the response of SPM concentrations to similar bed shear stresses is clearly different. This difference can be attributed to the burial of fines into the seabed. However, this burial is not instantaneous but takes approximately one week of calm conditions. Hence, the predominant processes that lead to the burial of fine sediments in the seabed should work on these timescales as well.

In conclusion, the North Seabed depicts a profound memory to previous meteorological (and seasonal) conditions, which needs to be captured in any model describing the water-bed exchange processes in this sandy system.

Acknowledgements

This work is part of the SANDBOX project, funded by NWO-ALW. The additional funding by Boskalis is also appreciated. Data collection has been made possible by financial support of the LaMer foundation and a grant of Ecoshape within the framework of Building with Nature.

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