

Contribution of waves and currents to observed suspended sediment distribution patterns in a macro-tidal beach

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Introduction

Near-bed sediment and turbulence interaction is one of the challenging issues in understanding sediment transport dynamics. The objective of this paper is to present our findings about the relative contribution of waves and currents to the distribution of suspended sediment based on field measurements obtained under both wave and (tidal) current dominated conditions. Near-bed single point measurements of 3D flow velocities and velocity profiles were obtained simultaneously with suspended sediment concentration and free surface elevation. Based on these data, shear stress and turbulent kinetic energy (TKE) are calculated for two different periods of 35h during spring tide: one characterized by significant wave heights exceeding 2m (Nov. 14-15, 2013), and a second period, during which mild waves not exceeding 0.5m height were measured (Nov. 16-18, 2013). Based on these measurements, we examined wave and current contribution to shear-stresses and TKE magnitudes and established relations with sediment (re)suspension patterns. Results suggest the presence of a specific mechanism responsible for reducing the efficiency of the flow in bringing and keeping sediment in suspension under energetic wave and current conditions.

Field measurements

The study area, located at the Southern North Sea in Mariakerke (Oostende, Belgium), is a rectilinear beach presenting a fairly constant slope and exposed to spring tides exceeding 5m and waves mostly from West-Northwest. Littoral drift coincides with flood direction going from Southwest to Northeast. Sediment is considered as fine sand with a high content in finer material.

Field data was collected in the framework of the ARGONAUTS project financed by the Flemish government. The deployment consisted on an up-looking AWAC at 1.7m above the bottom measuring waves at 2Hz and 5 minutes time-averaged current profiles, a down-looking ADCP measuring velocity profiles at the lowest 1.5m of the water column, an ADV measuring at 16Hz at 0.3m above the bed and a vertical array of three OBS measuring suspended sediment at 4Hz at nominal heights of 0.3, 0.5 and 0.8m above the bottom. 10 to 20 minutes of simultaneous time-series were collected every two hours during six weeks in November and December 2013. In this paper results based on a small part of this dataset are presented.

Effect of wave energy and turbulence on SSC

Results for the two different periods during which spring tide is combined with energetic and mild wave condition are examined. Fig. 1 shows time series of water levels, wave heights, depth averaged velocities for the lowest 1.5m of the water column, the three spatial components of ADV near-bed velocities and OBS signal for suspended sediment concentration (SSC) at 0.5 and 0.8m above the bed. (The interpretation of the OBS data will be limited to qualitative aspects. Calibration will be completed end 2014). The figure shows, for spring tide with high waves, the dominant influence of waves on the range of near-bed and depth averaged velocities measured. High suspended sediment concentrations are found during the first half of the flood period also under high waves. However, it is under moderate wave conditions and not under the most energetic waves when the highest concentrations are observed. Highest shear stresses (not in figure) are found to be maximum during low water, before and after the most energetic conditions occur. This could be explained by the fact that the transfer of energy from waves to the bed is most limited by the water depth during high water. However, suspended sediment concentrations become persistently low during most of the two tidal cycles during which more energetic conditions and this suggests the possibility of a mechanism preventing the sediment to be brought in suspension higher in the water column.

Under mild waves, (right side of Fig. 1), flow velocity variations are clearly influenced by tidal periodicity. Maximum SSC signals are detected again mostly during the first half of flood but also at the end of the ebb phase of the tide. This is not the case under the presence of energetic waves, where no high concentrations are observed during the ebb period in the presence of high waves.

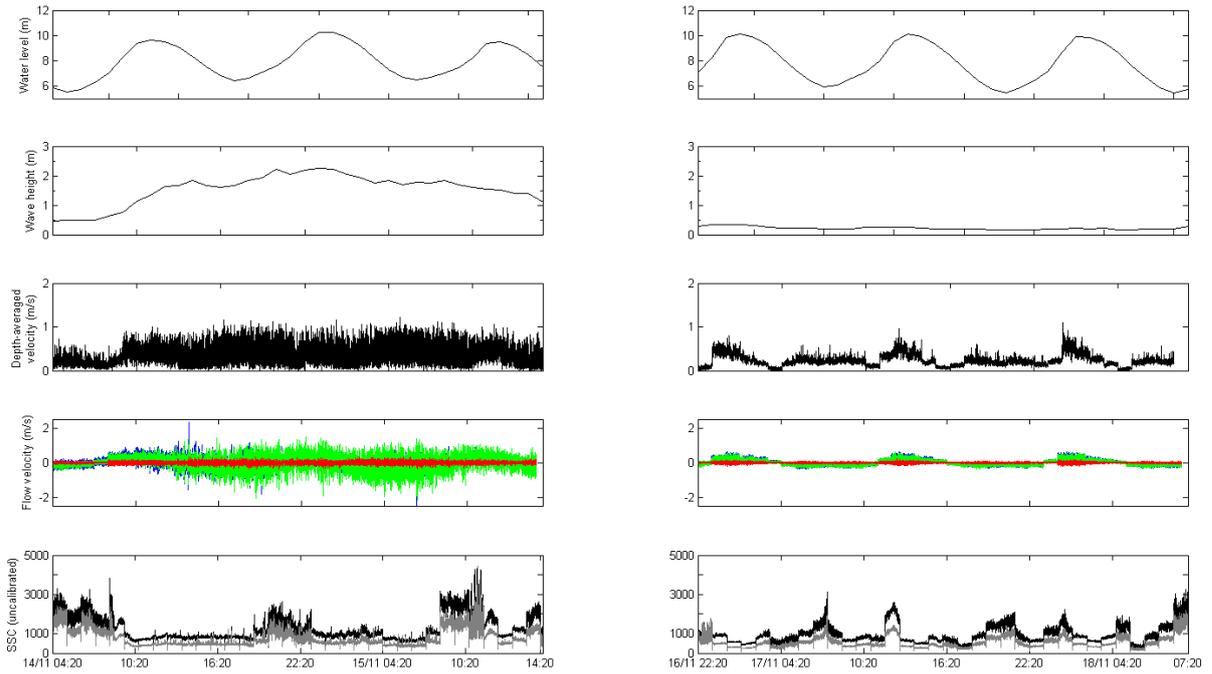


Fig. 1. Time series of a spring tide with energetic waves (left), and with mild waves (right). From top to bottom: water level, wave height, depth-averaged velocity, near-bed flow velocity u (blue), v (green) and w (red) and, signal for SSC in Volts at 0.5m (black) and 0.8m (grey) above the bed.

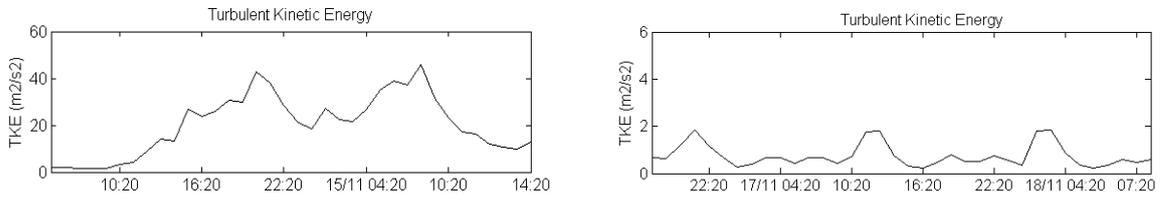


Fig. 2. TKE under energetic wave conditions (left) and under mild wave conditions (right).

Fig. 2 shows ten minutes averaged time series of TKE for the two cases. TKE is obtained by extracting turbulent normal stresses of the 3D near-bed velocities and applying the expression:

$$TKE = \frac{1}{2} \left(\overline{u'^2} + \overline{v'^2} + \overline{w'^2} \right) \quad (1)$$

Under mild waves, maximum TKE is found during high water. Maximal re-suspension occurs however during low water and in some cases during slack water. For high waves, TKE results are one order of magnitude larger than for the case with mild waves suggesting the relevance of the contribution of the oscillatory flow to producing near-bed turbulence. However, the time variation of TKE is not consistent with the variation of SSC as observed in the mild waves case where in addition much less turbulent energy seems to be more efficient in triggering (re)suspension events. With energetic wave conditions a reduction of TKE takes place under high water together with a persistently low SSC signal until close to slack water, when SSC maxima are observed. At this point, current velocities are minimal and waves dominate the generation of near-bed turbulence. During ebb and the following low water however, wave generated turbulence seems to be much less efficient in bringing and keeping sediment up in the water column.

Conclusions

Results suggest that a specific mechanism limiting the efficiency of the flow in suspending sediment is triggered under certain energetic wave-current conditions. This makes it necessary to investigate alternative models to understand and define the relationships between turbulence generation and re-suspension of sediment under the combined action of currents and waves.