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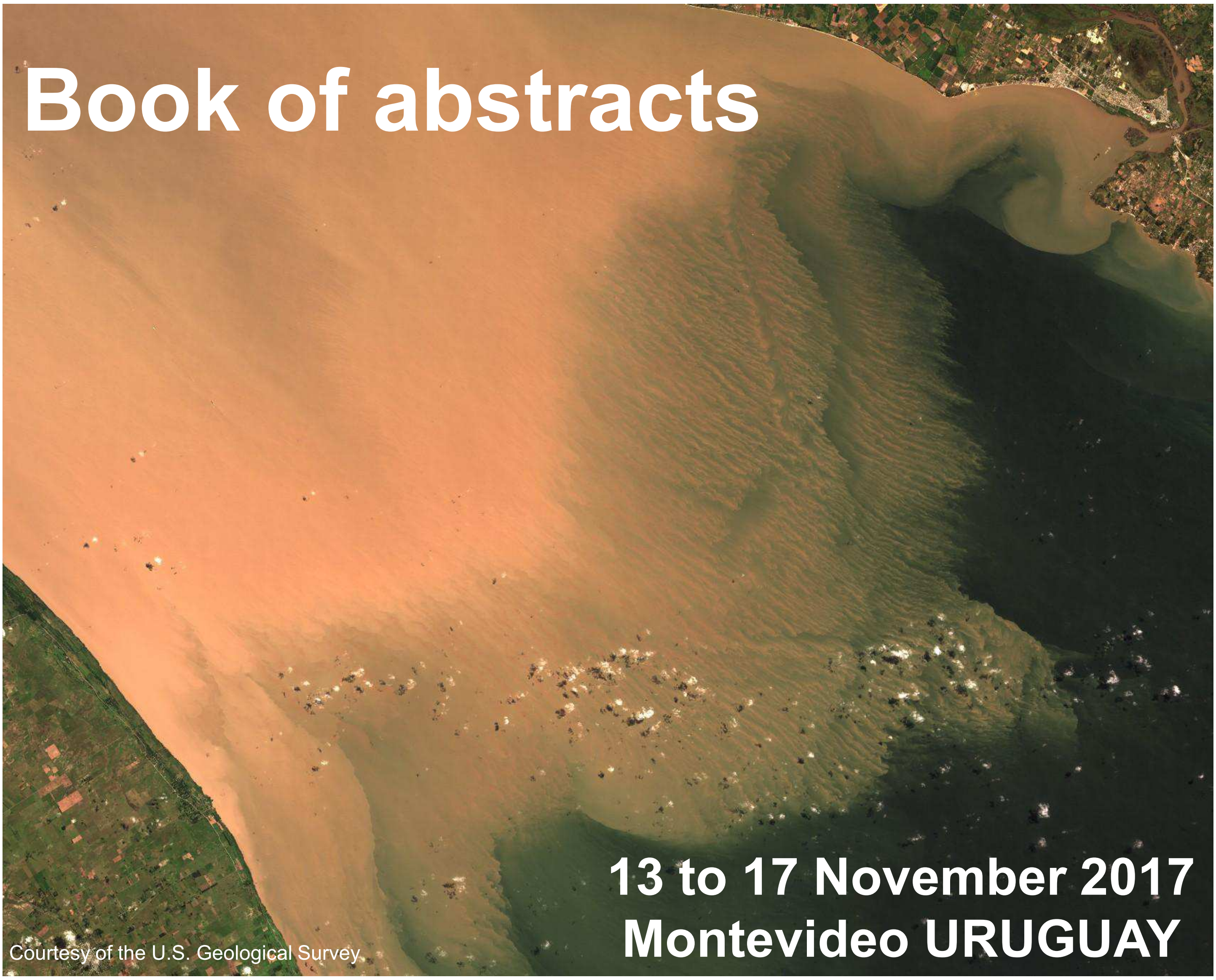

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The Importance of Wind-induced Sediment Fluxes on Tidal Flats

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Background & Research Question

Port maintenance and nature preservation are two often conflicting aspects of coastal management. Within a *Pilot Project* in the Western Wadden Sea (the Netherlands - see Figure1a) we test a win-win solution that could reduce harbour siltation while simultaneously stimulate saltmarsh development. For this purpose, fine material, dredged in the Port of Harlingen, is used to increase the bed level of the intertidal flats at North-East of the harbour. The sediment is not disposed directly *on* the mudflat but at the North-East edge of the Kimstergat Channel (Figure1b).

The strategy is based on the presumption that the flood dominant system results in an extra net sediment transport onto the Koehool Mudflat (Figure1b). The imposed higher mud supply will gradually feed the mudflat (hence the name of the project: *The Mud Motor*) and is expected to accelerate the rate of bed level increase and, as consequence, the switch from a bare to a vegetated mudflat state.

The success of the Pilot Project *Mud Motor* relies on the sediment transport capacity from the channel to the mudflats. We therefore carried out a field campaign to unravel the role of the various hydrodynamic forcing that determine the fate of the disposed sediment.

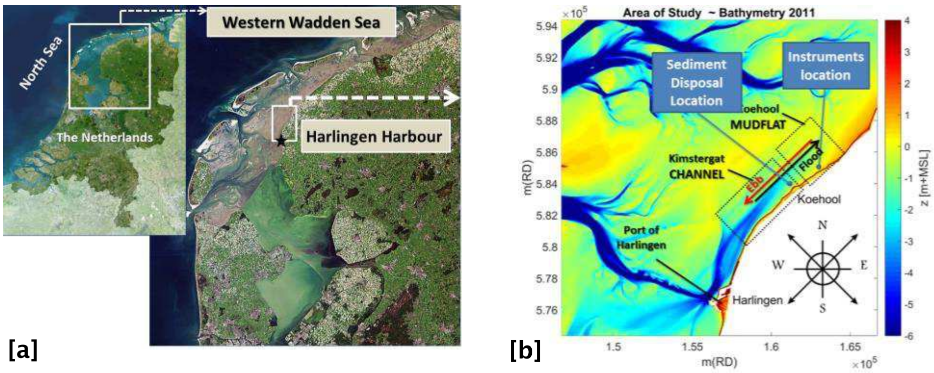

Figure 1: a) Frame of reference of the investigated area: Western Wadden Sea (the Netherlands). b) Study Area: Kimstergat CHANNEL - Koehool MUDFLAT System. The definitions for the flood direction (towards northeast) and ebb direction (towards southwest) are indicated.

Method

In Spring 2016, a 30 days' field campaign was carried out. Wave, flow and sediment concentration data were collected, at high frequency, using Wave Loggers, Acoustic Doppler Velocimeters (ADVs) and Optical Back Scatter sensors (OBSs). The instruments were installed on two frames, located at 900m from each other, along a cross-section in the southern Koehool mudflat (Figure 1b).

Results and Interpretation

The dataset covers a variety of combinations of wind, waves and tidal conditions. Despite the meteorological variations, most tides show the following trends (see for example the second tide in Figure 2):

- The tides are flood-dominant, with larger flow velocities during flood (from channel to mudflat) than during ebb (from mudflat to channel).
- The Suspended Solid Concentrations (SSC) are highest during conditions with very shallow water, i.e. when the bed is more exposed to the effect of waves and when flow velocities are relatively high; SSC values are very low (often close to zero) during high water slack, when waves do not penetrate to the bed and when the flow velocity is close to zero.

The weather during the full measurement period was overall calm, but wind events showed that the above-mentioned flow and concentration patterns can drastically change. Such a different behaviour is observed in the first tidal cycle of Figure 2. The weak wind from the South during the rising tide did not result in sediment resuspension. During the falling tide, the wind changed in southwestern direction. This led to: (i) reversal of the flow, with the velocity flow remaining in flood direction during the full tidal cycle (Figure 2c); (ii) a slight water level set up (Figure 2a); (iii) relatively high wave height over depth ratios (Figure 2a, 2c). The consequence was that the falling tide phase resulted in a significant sediment flux towards the mudflat. Figure 2d shows that the accumulated flux of the "atypical" first tide, is more than 3 times larger than the accumulated sediment flux of the "typical" second tidal cycle.

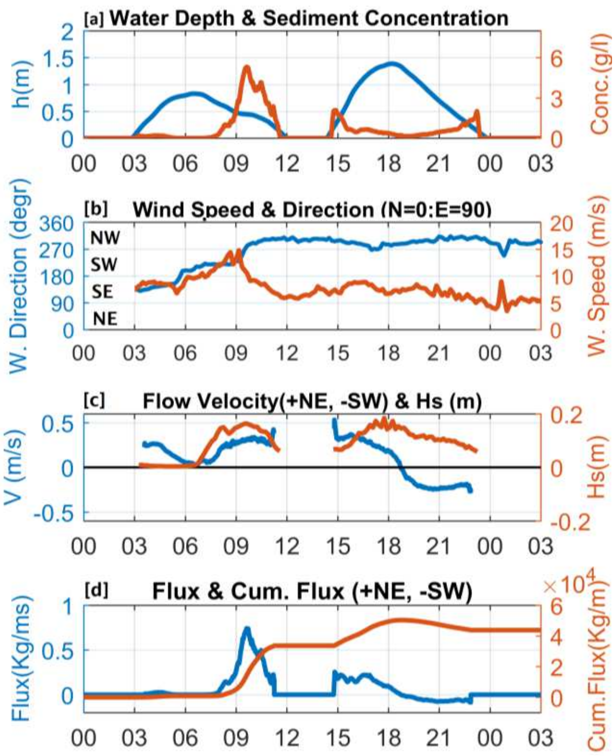

Figure 2 - Time series of : [a] Water Depth (m) and SSC (g/l); [b] Wind Speed (m/s) and Direction (degrees); [c] Flow Velocity Magnitude (m/s) and Significant Wave Height (m); [d] Fluxes (kg/ms) and Cumulative Fluxes (kg/m).

The first tide of Figure 2 is representative for the case of flux enhancement in the North-East direction, but other tidal cycles, with opposite wind (from North-East), show net sediment fluxes towards the channel (Figure 3).

The analysis of the full dataset (totally 56 tidal cycles) shows that for the majority of the time, the tide-induced sediment transport result in a net flux in the flood direction. This typical pattern can be modified by the wind, (i.e. by wave forcing and wind-driven flow) and can induce a significant net sediment flux towards one direction for the full tide (respectively: from channel to mudflat with south-western wind and from mudflat to channel with north-eastern wind). The six events highlighted by the green squares in Figure 3, show that the sediment fluxes towards the mudflat, cumulated in long periods, can be "lost" in a few tides if wind reverses the tidal flow in the channel direction. Over the full investigated period, in fact, a small net flux is observed ($0.5\text{x}10^4$ kg/m), due to 3 reversed tide in the South-West direction (3rd,5th and 6th wind events indicated by the green boxes in Figure 3).

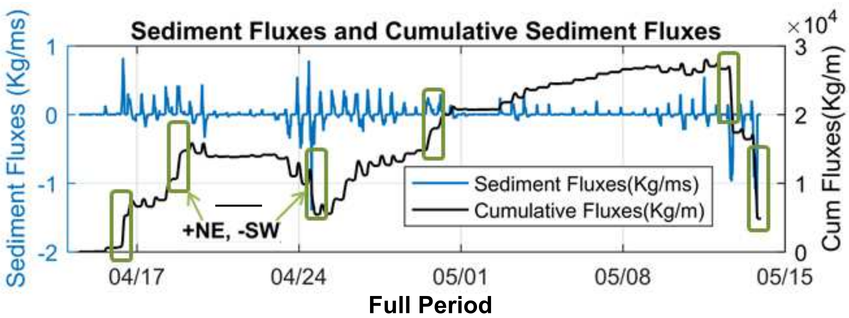

Figure 3 – Gross Fluxes (positive: N-E direction; negative: S-W direction) (kg/ms) and Cumulative Fluxes (kg/m) in the full measurement period. The boxes indicate wind events with speeds above 12 m/s.

Conclusions

This study shows that wind plays a major role on the sediment transport in shallow intertidal areas. It is therefore important to take this into account in the morphological modelling, especially in the shallower tidal flat zone. These relatively common wind-events (more than 10% of the tides in the measurement period presented a reversed velocity profile) are expected to influence the yearly averaged sediment transport and therefore, in the case of the *Mud Motor*, the effectiveness of a successful transport towards the mudflats.