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Sediment dynamics in the Coastal Turbidity Maximum of the Scheldt estuary

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Abstract

Turbidity Maxima are common in many estuaries and coastal seas worldwide, featuring areas with relatively high levels of Suspended Sediment Concentration (SSC). These enlarged SSC levels are often the result of sediment convergence mechanisms, such as salinity-driven gravitational circulation and flocculation, tidal asymmetry, and turbulence modulation by sediment-induced density effects. Estuaries also provide access to inland ports and waterways, and with ever-increasing ship size, the existing tidal channels are frequently deepened through dredging operations. Deepening often contributes to sedimentation, requiring larger dredging requirements in time. Siltation rates may be reduced and dredging schemes optimised through a sound knowledge of the mechanisms responsible for the presence and dynamics of the turbidity maximum. An example of a port located in a turbidity maximum, and suffering from very large siltation rates, is the Belgian Port of Zeebrugge, located in at the mouth of the Scheldt estuary. We refer to this turbidity maximum as a Coastal Turbidity Maximum (CTM).

Approximately six million tons of sediment are annually removed from the Port of Zeebrugge and disposed at nearby dumping grounds. But despite the large economic interest related to the local CTM, the mechanisms responsible for its formation are poorly known. Previous work highlighted the importance of residual circulation cells (Fettweis and van den Eynde, 2003). The proximity of the Scheldt estuary also suggests that salinity-induced effects may lead to sediment convergence, strengthened by a small fresh water source discharging into the Port of Zeebrugge. Tidal asymmetry also supports sediment accumulation, being located on a transition from ebb- to flood-dominant sediment transport. The continuous dredging and nearby disposal of sediment has often been hypothesized to increase SSC levels in the estuary. In addition to these hydrodynamically-driven mechanisms, the seafloor substrate may also contribute to elevated SSC levels. Large parts of seafloor in the area of the CTM consist of Holocene mud, deposited thousands of years ago (Fettweis et al., 2010). The change on currents resulting from the construction of the Port of Zeebrugge has led to erosion of the seafloor, estimated at around 3 million ton/year (Fettweis and van den Eynde, 2003), potentially also contributing to elevated SSC levels. This bed sediment may be resuspended especially during storm conditions, and in combination with sediment-induced buoyancy effects, lead to large deposition rates in the port (as in Winterwerp and van Kessel, 2003).

In order to better understand the contribution of these various mechanisms to the formation of the CTM and siltation rates in the port, a complex 3D numerical sediment transport model has been setup. The model is forced with tides, fresh water flows, and waves, and accounts for fine sediment buffering in the bed (following van Kessel et al., 2011), sediment-induced buoyancy effects (as in e.g. Winterwerp and van Kessel, 2003) and dredging and disposal routines. This model is calibrated to first reproduce the available observed sediment dynamics in the area (such as *in situ* measured SSC (Figure 1) and satellite-derived SSC fields, morphological changes, and dredging rates), and to be subsequently applied to investigate the relative role of sediment transport mechanisms to the formation of the CTM. This reveals that the in the recent past, the largest contributor is the Holocene muddy substrate. The role of salinity-driven flows, but also dredging and dumping, appears to be relatively small.

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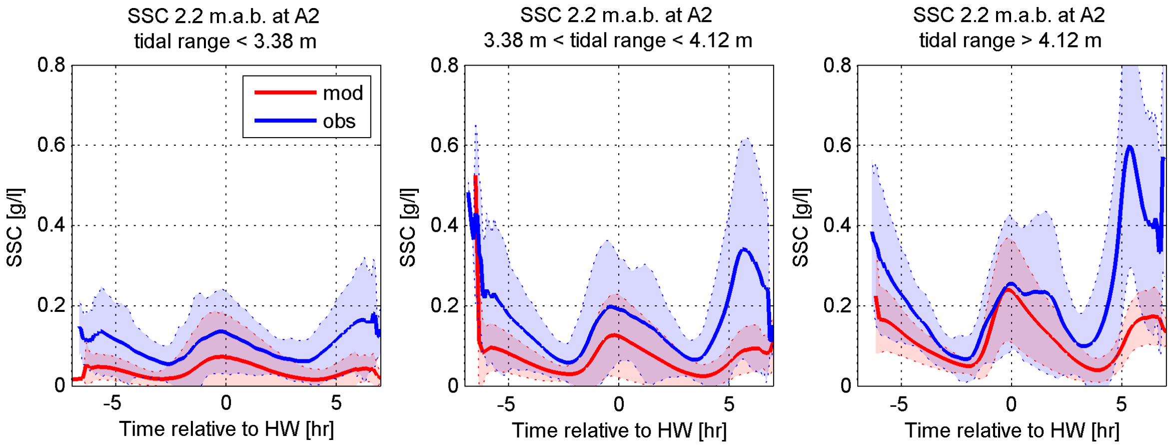

Figure 1. Observed (blue) and modelled (red) suspended sediment concentration at a location (MOW1/A2) nearby the port of Zeebrugge as function of the time relative to high water (HW) for neap tides (left, average tides (middle) and spring tides (right).Solid lines defines the average concentration, shading indicates the standard deviation.

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