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Drivers of residual sediment transport in a stratified estuarine channel

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1. Introduction

The bed stability of an estuary is determined by the net import or export of sediment, which in turn is controlled by multiple processes. Apart from the upstream riverine sediment supply, the net sediment flux is largely controlled by tidal hydrodynamics and the associated sediment exchange with the sea. In general, flood dominance causes landward residual sediment transport (sediment import from the sea), and ebb dominance causes seaward residual sediment export to the sea (Guo et al., 2014). In the New Waterway, The Netherlands, , residual fluxes are mainly associated with upstream and downstream advective transport in the salt wedge and in the fresh water layer, respectively. The associated processes have been well documented (De Nijs et al., 2010; Dronkers, 2017), which result in accumulation of sediment near the tip of the salt wedge (De Nijs et al., 2010). While it is known that mixing between freshwater and saltwater layers plays an important role in the residual salinity flux, little is known however about the exchange of sediment between both layers. We aim to quantify and understand the exchange of sediment across the freshwater-saltwater interface based on field data in a stratified tidal channel.

2. Methods

We set up a field campaign in the New Waterway, The Netherlands. We carried out two full 13-hour measuring campaigns: one covering a neap tidal cycle and one covering a spring tidal cycle. Continuous velocity and backscatter profile data were collected using a vessel-mounted ADCP over a longitudinal trajectory of 3~km. Two measuring locations were defined at both end points of the longitudinal trajectory. At both measuring locations, hourly casts were carried out collecting salinity, turbidity and sediment concentration data. ADCP velocity data are analysed with the recently developed method of Jongbloed et al. (2023), which removes turbulence and noise with a physics-based approach and therefore allows for more accurate estimates of velocity gradients and shear.

3. Results

The data collected offer a clear overview of the sediment dynamics in the channel. The neap tidal cycle is characterized by a strong salt-wedge type of flow. During the flood phase, suspended sediment is mostly confined in the saline layer below the pycnocline, resulting in a landward sediment flux. During the ebb phase, however, when stratification is strongest, maximum SSCs were observed just above the pycnocline (Figure 1). Considering the high interfacial shear, we hypothesize that these elevated SSC's are caused by entrainment of sediment-rich marine water into the upper fresh water layer.

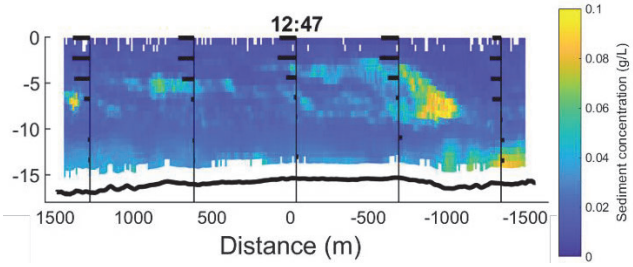

Figure 1. Suspended sediment collecting on top of the pycnocline during ebbing in the New Waterway.

The results of the spring tidal cycle indicate more mixing with SSCs being uniform throughout the vertical. SSCs in general are higher during the spring tidal cycle, resulting in large instantaneous sediment fluxes. The residual sediment flux of the spring tidal cycle and the neap tidal cycle however are of the same order of magnitude.

4. Conclusions

We identify estuarine circulation and mixing as main drivers of residual sediment transport in a stratified estuarine channel. Entrainment-induced sediment transport increases the seaward flux of suspended sediment, but is small compared to the total flux.

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