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Multi-class modelling of suspended sediment transport in a hypertidal estuary: validation, physical study, and impacts.

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Estuaries are highly dynamic environments that are characterized by complex and competing physical processes both in terms of hydrodynamics and in terms of sediment dynamics. Suspended particulate matter is closely linked to estuarine turbidity; it impacts water quality and estuarine ecology; and it also contributes to the overall estuarine sediment budgets. Temporal variations in suspended sediment concentrations and their correlation with tidal currents are thus critical towards understanding and predicting net transport, pathways, and estuary health.

We investigate the dynamics of suspended sediment transport in a hypertidal estuarine channel which displays a vertically sheared exchange flow. We apply a three-dimensional process-based model coupling hydrodynamics, turbulence, and sediment transport to the Dee Estuary, in the north-west region of the UK. The sediment transport model has multi-class capability and flocculation processes are taken into account via a variable settling velocity that is a function of turbulence parameters.

The coupled numerical model is used to reproduce observations of suspended sediment and to assess physical processes responsible for the observed suspended sediment concentration patterns. The study period focuses on a calm period during which wave-current interactions can reasonably be neglected. The numerical domain extends over the entire Liverpool Bay region at a resolution of approximately 180 m. The bathymetry consists of digitized hydrographic charts combined with LIDAR and multibeam data. Three-dimensional baroclinic effects, river inputs, surface heating and offshore density structure are all considered.

Good agreement between model and observations has been obtained, both for hydrodynamics and for suspended sediment. A series of numerical experiments aims to isolate specific processes and confirms that the suspended sediment dynamics result primarily from advection of a longitudinal gradient in concentration during our study period, combined with resuspension and vertical exchange processes. Horizontal advection of sediment presents a strong semi-diurnal variability, while vertical exchange processes (including time-varying settling as a proxy for flocculation) exhibit a quarter-diurnal variability. Sediment input from the river is found to have very little importance and spatial gradients in suspended concentration are generated by spatial heterogeneity in bed sediment characteristics and spatial variations in turbulence and bed shear stress.

In addition of such study of physical processes responsible for observed sediment dynamics, the validated numerical model can be applied to investigate the long-term sediment transport in the Dee estuary and in Liverpool Bay.