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# Mass and momentum transport across the sediment-water interface

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The sediment-water interface (SWI) is the site of strong gradients in physical, chemical and biological properties. As a consequence, the penetration of flow and turbulence across the SWI can have a significant impact on physical and ecological processes in aquatic systems, including particle entrainment, boundary resistance to the flow and organic matter cycling. Our understanding of the hydrodynamics across the SWI is, however, considerably restricted by the obstructive character of the SWI that makes it difficult to observe, and hence quantify, fluxes in this region. Through a series of experimental studies, we present a hydrodynamic framework that characterizes the transport of mass and momentum across the SWI. To obtain simultaneous observations of the flow above the interface and within the stationary sediment bed, an experimental methodology was used that combined refractive-index matching with particle-tracking velocimetry.

In this framework, the interfacial hydrodynamics are characterized by the permeability Reynolds number $Re_K$ which represents the ratio of the length scale of fluid motions in the interstices at the SWI (the square root of the permeability of the sediment bed) to the viscous length scale. The extent to which the flow and turbulence can pass across the SWI correlates strongly with $Re_K$. When $Re_K \ll 1$, the sediment bed is argued to be effectively impermeable as viscosity controls the hydrodynamics at the interface. For $Re_K \gg 1$ the interface is seen as highly permeable to the overlying flow and turbulence dictates the hydrodynamics at the SWI. We demonstrate that for $Re_K \geq O(1)$ the length scale of the interstitial fluid at the SWI is large enough to allow turbulence to persist across the SWI and observe that sweep events originating from the overlying flow can pass into the interstices of the underlying sediment bed. This causes the interfacial turbulent shear stress to become much larger than the viscous shear stress and turbulent stirring dominates the transport of mass and momentum. Hence, our results imply that for many aquatic sediments the permeability is a critical property for many physical and ecological processes in aquatic systems. Models to account for the additional turbulence-induced interfacial exchanges of mass and momentum (or flow resistance) are provided.