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The intra-tidal evolution of currents, stratification, and turbulence in a near- to mid-field river plume and the local effects of topography

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River plumes transport large quantities of freshwater along our coastlines, affecting coastal dynamics and the movement of sediment and fish larvae. This study focuses on describing the local intra-tidal evolution of currents, stratification, and turbulence in the Rhine River plume in The Netherlands. While the mid to far-field Rhine River plume has been subject to a number of field campaigns and detailed modelling studies, e.g. on tidal straining, very little data exist in the near-mid field region. However, this region is particularly interesting due to the occurrence of plume fronts and internal waves and their influence on coastal dynamics. Moreover, river plume regions are often highly engineered. In the Dutch coastal region, several topographic depressions, sand pits, are present. Their number is expected to further grow as beach nourishments are increasingly used as a coastal protection measure against sea level rise. Yet we lack information about the impacts of such topography changes on the hydrodynamics within this system.

In this study, we present unique observations of the turbulent kinetic energy (TKE) dissipation rate in the near-mid field Rhine River plume and a sand pit, along with salinity, temperature, and current measurements. The novel field data was acquired in April 2024 during a cruise of the RV *Pelagia* and covers a tidal cycle over two days during neap tide. The campaign happened to take place after a storm event. Two moorings with CTDs and an upward-looking ADCP were deployed outside and inside the sand pit and were complemented by ship-based CTD, microstructure profiler, and ADCP measurements at the mooring sites and close to the sand pit edges.

An analysis of the currents and TKE dissipation rate outside the pit reveals enhanced surface-layer shear and turbulence during higher wind speeds on the first day. At the same time, the density measurements show strong stratification that almost constantly withstands wind-induced mixing. However, a few disruption events in stratification are observed. These events indicate the advection of fresher and saltier surface water due to wind-generated currents. Furthermore, our observations show strong cross-shore shear emerging in the mid-to-bottom layers as a result of the stratification-induced modification of the tidal ellipse. We present how this shear reduces the stability and increases vertical mixing in the aforementioned layers. Additionally, we show events of increased turbulence, which we attribute to the passage of a tidal plume front. This front is indicated by higher surface stratification with simultaneously increased surface and bed shear

stress.

Presently, we are comparing the measurements in- and outside the pit. While we expect an increase in mean stability due to the deeper water column and unchanged mixing input, local mixing may be significantly enhanced. Particularly around the steep edges of the sand pit as well as within the mid-to-surface layers, we hypothesize finding increased turbulence due to eddy formation and topographic internal wave generation. Furthermore, we are looking into internal waves generated ahead of the tidal plume fronts, which may increase mixing levels throughout the river plume.