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Hydrodynamics in the mid-field plume region of the Rhine ROFI

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Abstract

River plumes, also regions of freshwater influence , are important features to understand because of their impact on the current structure, stratification and the transport of fine sediments, nutrients and contaminants. One important river plume is the Rhine ROFI. Prior studies have sought to understand far-field dynamics where cross-shore straining is dominant (Simpson & Souza, 1995; Souza & Simpson,1995; De Boer et al., 2008). However, less is known about the mid-field region of this river plume, where fronts matter as well. Here we use field observations from a 6 week measurement campaign in fall 2014 to investigate the dynamics of the mid-field region of het Rhine ROFI. We will focus on the interaction between far-field processes, such as tidal straining, and near field processes, such as fronts. The Rhine ROFI is of interest because the Dutch coast has been modified by extending the Port of Rotterdam and the construction of the Sand Engine that extends into the southern North Sea. These perturbations might impact the currents, the ROFI and the distribution of fine sediment, nutrients and contaminants. Therefore, the understanding of this is of importance.

During September and October 2014, a large field observational campaign was conducted off the Dutch coast close to the sand Engine, 10 km north of the river outflow. Measurements were made at two locations, 2 and 5.5 km offshore (see Figure 1). Moorings, with Conductivity Temperature Depth (CTD) and Optical Backscatter (OBS) instruments at different depths, were deployed to obtain vertical profiles of salinity and suspended sediment concentrations (SSC). In addition, at each location a bottom-mounted Acoustic Doppler Current Profiler (ADCP) measured vertical velocity profiles. Radar images of the area were used to gain surface information, specifically about frontal propagation in the vicinity of the measurement locations. The weather conditions were highly variable during the six week period. There were very calm periods, but also storms, which completely destroyed stratification. The wind direction changed during the campaign as well. In addition to the data, numerical modelling with a 3D hydrostatic model will be used to gain information of the entire mid-field plume.

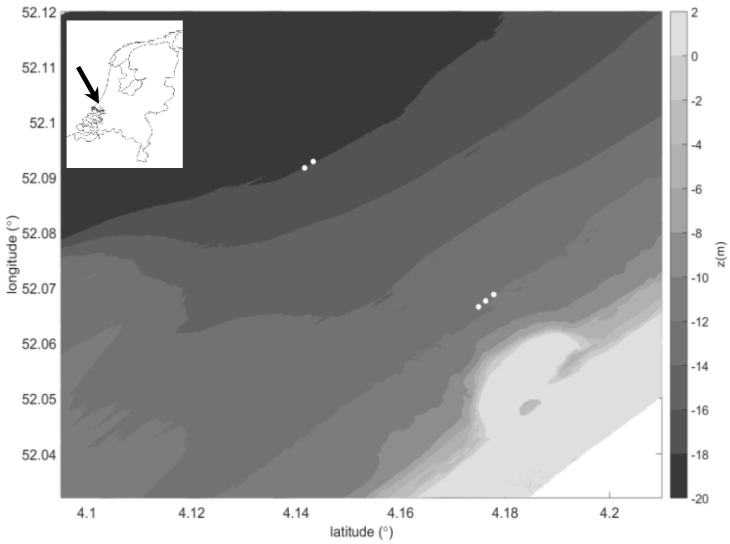

Figure 1. Measurement location. The upper left corner shows the Netherlands. The main figure shows the bottom topography, the Sand Engine and the 2 measurement sites, 2 and 5.5 km offshore which are 10 km north of the river outflow.

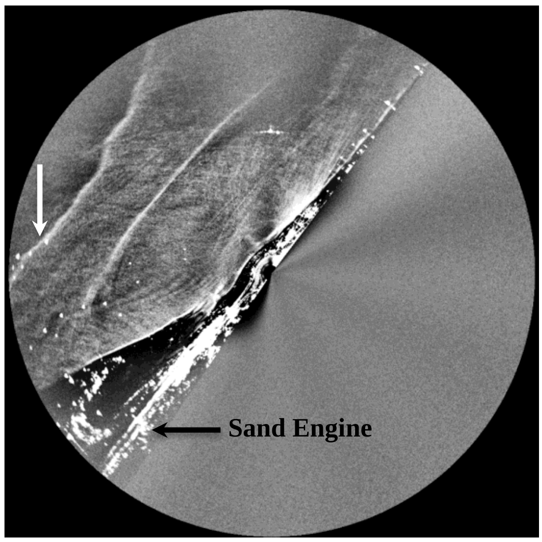

Figure 2. X-band radar image of the 1st of October 2014 at 19:10:00 UTC. The upper white dots are buoys and the measurements at 12m depth. At this moment a front passes through the measurement site.

The density and velocity data is used to investigate the behaviour of the freshwater plume. The data shows that cross-shore straining is not the only process controlling stratification. After high water there is a sudden decrease in

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salinity with an onshore surface velocity, which is a freshwater front. This is confirmed with radar images of that period (see Figure 2). Therefore, fronts play an important role at the two locations as well. They cause a sudden increase in stratification and a strong cross-shore shear. The fronts are moving onshore after passing the 5.5 and then the 2 km site. The front might be the inner edge of the plume, however it could be the edge of a freshwater lens as well. The data is limited in space. Therefore, numerical modelling will help us to gain more insight into the propagation of the fronts.

Distinct differences in stratification between spring and neap tide are observed. During neap tide the water column is always stratified, which is the background plume. The water column gets even more stratified after high water, when the front comes by. However, the timing of the front is 1,5 hours later during neap than during spring. During spring tide, there is almost no background stratification, the front comes close to high tide and shows a much higher cross-shore shear. In addition, the stratification due to the front is a sharp peak, which is different than during neap. It seems that the fronts are stronger during spring tide. From the above it is likely that the frontal passage modifies cross-shore straining. Analysis of the relative cross-shore displacement confirms these conclusions. The analysis shows that stratification is not only controlled by tidal straining but wind and fronts have a large contribution during different periods. However, the details are not fully understood yet. We aim to get a more detailed picture of the hydrodynamics in the Rhine ROFI with further analyses of in-situ data and numerical modelling.

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