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Variations in the wind-driven response of the Rhine ROFI during a spring-neap cycle

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The position and properties of a river plume strongly depend on the wind conditions. Upwelling-favourable winds force the plume offshore, while the freshwater layer thins. Downwelling-favourable winds confine the plume against the coast, resulting in a thicker freshwater layer. The Rhine Region Of Freshwater Influence (ROFI) along the Dutch coast is not only modulated by winds, but also influenced by tides and bottom friction. The near-field region is dominated by tidal plume fronts, which are formed by the release of freshwater. The mid- to far-field region of the plume switches between stratified conditions on neap tide and well-mixed conditions on spring tide. Furthermore, tidal straining induces a semidiurnal cycle in the stratification. In this study, we investigate how winds influence this shallow frictional river plume. We use an unstructured high-resolution 3D model to perform idealized simulations of a spring-neap cycle, forced with constant upwelling- or downwelling-favourable winds. It is shown that the state of the ROFI depends on the combined effect of tides and winds. In the absence of winds, a multi-frontal system forms on neap tide, which is strongly stratified. On spring tide, however, stronger tidal currents in combination with stronger salinity gradients result in separate, buoyant fronts that propagate northwards. The background plume is well-mixed vertically, due to strong tidal mixing. Under downwelling winds, flood currents are aligned with the wind direction, resulting in faster propagating fronts. As a result, separate freshwater lenses arise on neap tide. In contrast, upwelling winds hinder the alongshore propagation of tidal plume fronts, which results in a multi-frontal system on spring tide. Furthermore, we show that winds change the semidiurnal cycle in the stratification, induced by tidal straining. Under downwelling winds, this cycle is enhanced due to stronger cross-shore salinity gradients. Under upwelling winds, there is less variability in the stratification within the tidal cycle. Understanding the dominant physical processes of this complex system is important for transport of, amongst others, sediments, nutrients and pollutants in coastal systems.