Geophysical Research Abstracts
Vol. 20, EGU2018-10899, 2018
EGU General Assembly 2018

Upwelling, downwelling and tidal straining in the Rhine ROFI

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The Rhine ROFI is a shallow, tidal, river plume dominated by tidal straining that has a major effect on the transport and dispersion of freshwater in the southern North Sea. We use a numerical model to explore the response of the Rhine ROFI to upwelling and downwelling winds. Using a potential energy anomaly (φ) analysis we find that as tidal straining moves the plume onshore during ebb tides it decreases the stratification and as it moves the plume offshore during flood tides it increases the stratification. We show that the overall effect of downwelling winds is to narrow the ROFI and decrease stratification, while upwelling winds spread the ROFI offshore and increase stratification. However, the plume does not continue to advect and disperse offshore during upwelling winds as in classic wind driven river plumes, but instead tidal straining limits the offshore displacement. This is due to a net onshore flux of freshwater caused by alongshore tidal straining the plume, as a result of which the plume is more fresh during the onshore phase of the tide, than during the offshore tidal phase. In contrast we show that the onshore displacement of the plume due to downwelling winds is enhanced by tidal straining. Using the volume integral of φ we show that upwelling favourable winds suppress the downwelling tidal straining phase of the tide during which convective mixing occurs. In contrast it enhances the upwelling phase during which straining increases stratification. The opposite happens for downwelling winds. Field data from the STRAINS experiments show the on and offshore advection of the plume during upwelling and downwelling favourable winds and are in reasonable agreement with the idealised model.