Offshore spreading and mixing of a supercritical plume under upwelling wind forcing: a case study of the Winyah Bay outflow

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Abstract

Observations of the Winyah Bay outflow exposed to a moderate upwelling-favorable wind are presented. The resulting plume comprises a train of tidal sub-plumes undergoing rotational adjustment and being transported offshore by Ekman dynamics. The focus of this study is on the observations conducted in March 2020, when the freshwater discharge was high (close to 1000 m^3s^{-1}) and the wind was consistently upwelling-favorable, with offshore gusts. The Winyah Bay outflow is characterized by a low Kelvin number at the mouth, so that the near field plume is supercritical. Light wind extends this supercritical regime farther offshore. The plume is characterized by interior fronts associated with consecutive tidal pulses. Age of the buoyant water can be distinguished by the buoyant layer mixing (evident in the layer's thickness and salinity anomaly) along with the transformation of its *T-S* properties. However, relatively little transverse (lateral) spreading of buoyant water occurs: the equivalent freshwater layer thickness remains surprisingly consistent, approximately 0.7 m, over more than 20 km offshore distance. Microstructure measurements reveal higher dissipation rates at the base of the older (offshore) part of the plume. In particular, the interior front has a dissipation rate maximum at mid-depth just below the plume. This may be due to the internal wave (IW) radiation from a newly discharged tidal plume into an older plume, with the buoyant layer acting as a waveguide. Theoretical estimations of the IW properties show that the interior front is highly supercritical, while the observed dissipation maximum agrees with the theoretical IW structure.