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Do buoyant plumes enhance cross-shelf transport in the Black Sea?

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Like many inland seas, the Black Sea is exposed to massive continental discharges on the one hand and significant anthropogenic stresses, including pollution, on the other. It is, therefore, important to understand mechanisms of advection of continental water into the sea and factors that may influence transport of such water across shelf areas.

In this study, we focus on the coastal segment of the Black Sea between the Feodosia Bay, which includes nature reserve and resort areas, and the Kerch Strait. The Sea of Azov outflow penetrates into the Black Sea through the latter, forming a plume of relatively fresh, light waters with elevated concentrations of suspended matter but also pollutants, especially hydrocarbons. This plume, which can be detected via satellite imagery of the region, extends on over 70 km from the Kerch Strait outfall along Crimea shore and reaches the Feodosia Bay, making that area the most polluted of the Crimea shoreline.

In situ velocity measurements were conducted at a mooring station deployed in the area at the depth of 5 and 21.5 meters during the period 17th-23rd of May 2015. These data demonstrated high correlation of the wind stress with the cross-shore component of the velocity in the surface layer and anti-correlation with that in the bottom layer during the periods when a two-layered stratification of the water column due to the occurrence of the Azov plume was present, and lack of such correlation otherwise.

In order to investigate whether the buoyant plume in the surface layer is capable of fortifying the wind-driven cross-shelf exchanges, we develop a dynamical model of current forming under the influence of wind tension, pressure gradient and Earth's rotation in a simple one- and a two- layer setups. Firstly, a 2D model was investigated that did not account Coriolis effect. Secondly, a 3D model with Coriolis effect was investigated. The main parameter of the problem is the eddy diffusivity coefficient, which we choose to be either constant and different within each layer or a linear function of depth. In each case we obtain an analytical solution and derive a relation between seaward/shoreward transport and eddy viscosity. Both 2D and 3D models indicate that the stratified conditions damping vertical mixing lead to an increase of transport in the surface layer. This result corresponds well with the in situ observations, showing that buoyant plumes may indeed enhance advection of plume waters across shelf areas.