Numerical and theoretical results exploring the role of potential vorticity in coastal outflows.

*Sean Jamshidi[1], Ted Johnson[1]

1. University College, London

The influx of river water into the oceans brings nutrients, sediments and pollutants, as well as driving coastal currents, and as such is an important area of study. Previous works have largely investigated the impact that density differences have on the dynamics of these systems, and it is well understood that these play an important role. However, large-scale currents can also be driven by jumps in potential vorticity, and there are far fewer studies that investigate the impact that this has on river outflows. The present work isolates the effect of potential vorticity, and develops a mathematical model based on a 1 1/2 layer Boussinesq system with a long-wave scaling (the semi-geostrophic equations). The model depends on two physical quantities: the volume flux of river water, and the depth of the buoyant oceanic layer. Although the system is fully nonlinear, it allows theoretical predictions to be made, which are then compared with numerical experiments.

In particular, major qualitative differences occur depending on whether the potential vorticity depth of the river fluid is greater or less than the depth of the buoyant ocean layer. Two mechanisms contribute: flow driven by a nonlinear Kelvin wave, and flow driven by the jump in potential vorticity, the latter of which can drive fluid in either direction. The faster Kelvin wave disturbs oceanic fluid ahead of intruding river water, and causes a redistrubtion of the buoyant ocean layer along the coast. The model allows for the prediction of both the local fluid velocity and the speed of wave propagation in the river fluid and the oceanic Kelvin wave.

The different qualitative behaviours of the outflow can also be investigated using the method of characteristics. There are strong analogues between flows driven by jumps in density and those driven by gradients in potential vorticity. Depending on the values of the model parameters, solutions can feature coastal currents, anticyclonic gyres and plumes that expand offshore, as well as flows separating from the coast.

Keywords: potential vorticity, semi-geostrophic equations, coastal currents, Kelvin wave, river plumes