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Shallow-water flow circulation in a closed basin with topography

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The large-scale ocean circulation in a closed basin with topography is studied by means of numerical simulations and theoretical considerations. We analyze the nonlinear problem on the beta-plane both with and without external wind forcing. The basin is shallow near the lateral boundaries (the "coastline") and has a maximum depth at the center. It is well-known that, according to statistical fluid mechanics, a steady equilibrium state in the free-evolution case is a cyclonic flow with shallow water to the right (in the Northern Hemisphere), which follows closed contours of f/h, where f is the Coriolis parameter and h the fluid depth. However, under appropriate forcing conditions and considering a flat bottom, the flow is characterized by an anticyclonic gyre intensified at the western boundary (equivalent to the model of Stommel). In this study we investigate whether the Stommel circulation persists, it is modified or even reversed due to topographic effects. It is found that the anticyclonic gyre is strongly deformed and displaced towards southern latitudes due to the topographic beta-effect associated with the western bottom slope, which is a result that has been discussed previously by other authors. One of the novel aspects we present is the final steady state reached by the flow regardless of the initial condition. We also discuss the relationship of the flow with open and closed f/h contours, for different forcing configurations. Another relevant result concerns the generation of topographic Rossby waves over the coastal bottom slopes. We found that the eastward topographic waves generated at the southern slope are inhibited, while the westward waves at the northern slope are enhanced. It is argued that these observations are associated with the competition of the topographic and the planetary beta-effect: at the southern boundary both mechanisms are canceled, while at the northern slope they are mutually reinforced. Finally, we discuss some oceanographic cases in which these phenomena might be present.