Retrograde equatorial surface flows generated by thermal convection under a stably stratified layer in a rotaiting spherical shell

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Finite amplitude thermal convection in a rapidly rotating spherical shell associated with a stably stratified layer near the outer surface is investigated. Systematic numerical experiments show that existence of a strong upper stratified layer enhances generation of equatorial retrograde flows. For the Ekman number $E=10^{-3}$, the Prandtl number P=1 and the inner/outer radius ratio 0.4, mean zonal flows induced by the convection direct prograde at the outer surface of the equatorial region when the Rayleigh number is a few times as large as the critical value. However when the Rayleigh number is increased to ten times the critical, the equatorial surface flows tend to retrograde in the cases of strong stratified upper layers. Although the convective flows are turbulent in the deep region and the regular Taylor-column type vortices are destroyed, the convective flows still do not erode the stably stratified layer. The stratified layer inhibits convetive motions in the upper region, increases the radius ratio of the convective region, and causes the intermediate dynamical effect of the no-slip and free-slip conditions at the boundary between the stable and convective layers.