Title: 'The nonlinear interaction between geostrophic and ageostrophic zonal flows'
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Zonal flows on rapidly rotating objects, such as the Gas or the Ice giants, form in a variety of surface patterns and amplitudes. It is thought that equatorial prograde surface zonal flows are created by Reynolds-stress in rotation-dominated convection, whereas the equatorial retrograde jets form in an inertia-dominated regime due to turbulent angular momentum mixing. As far as numerical simulations can reach, simple Boussinesq-models predict only minor variation in the interior zonal flow structure along the axis of rotation according to the Taylor-Proudman-Theorem.

Further solar or stellar irradiation might cause a latitudinal variation pattern of the surface temperature. The heat flux is then expectably higher at the cooler poles and smaller at the hotter equatorial region. If such a latitudinal temperature/heat flux anomaly at the surface affects also the interior of the fluid, thermal winds will introduce ageostrophic variations of the geostrophic zonal flow structure along the axis of rotation.

To investigate the interaction between thermal wind driven ageostrophic and Reynolds-stress driven geostrophic zonal flows, we conduct a series of hydrodynamical simulations using a rotating and convecting spherical fluid shell in the limit of the Boussinesq-approximation. The fluid is heated by a homogeneously distributed interior heat source and cooled by a prescribed mean heat flux at the outer boundary, which additionally varies smoothly with latitude as a axisymmetric spherical harmonic degree two of variable amplitude.

Our results suggest, that for weak perturbation amplitudes the flow tends to be the more ageostrophic the stronger the heat flux nomaly. This results from increasing ageostrophic and decreasing geostrophic zonal flows. Since the introduced thermal wind defines the zonal flow variation along the axis of rotation, the equatoral jet decreases its prograde amplitude. If the anomaly reaches a critical strength, the equatorial jet crosses zero amplitude and can even be reverted into retrograde direction. For perturbation amplitudes stronger than critical, the reverted jet gains in amplitude due to re-established, but reverted Reynolds-stress. Even though the ageostrophic flow is linearly amplified with the anomaly amplitude, the geostrophic flow contributions dominate at maximal heat flux perturbation. We therefore propose a nonlinear backreaction of the thermal wind onto the Reynolds-stress driven zonal flows. Analysis of the main force balance and parameter studies further foster this result.