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Coexistence of Jets and Vortices in Anelastic Numerical Models of Deep Convection in Giant Planets

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Observations of cloud motions reveal strong zonal flows and vortices on all four giant planets. Jupiter and Saturn feature a strong prograde equatorial flow and higher latitude jets that alternate in latitude between prograde and retrograde flow directions. These higher latitude zonal flows seem to be stable over long timescales, and exhibit a rough symmetry between cyclonic and anticyclonic shear zones. In contrast to this shear zone symmetry, vortices on Jupiter show a clear asymmetry between cyclones and anticyclones, and both Jupiter and Saturn have vortices with a large range of observed sizes and lifetimes. We have used the benchmarked 3D spherical anelastic convection code MagIC to investigate the relationship between zonal jets and vortices. Rotating deep convection is modelled for relatively thin spherical shells. We study the effect of varying the radial background density variation and the thermal boundary conditions on the formation of jets and vortices. We find that, whereas the formation of jets is relatively insensitive to these conditions, vortex formation and dynamics depends strongly on them. For constant entropy difference between top and bottom boundaries, models with strong radial density gradients form alternating, zonal flows, and very small-scale flow and vorticity structures at the outer boundary. Models driven by constant convective entropy flux at the bottom, and small convective, or reversed entropy flux at the top, also can produce multiple zonal jets. However, these models, with a nearly neutral or stably stratified background vertical thermal structure near the outer boundary, can produce vortices of larger scale and lifetime. In particular, anticyclonic vortices with large lateral scales tend to form in the first anticyclonic shear zone, away from the equatorial jet. These model results have implications for the formation of of Jupiter's Great Red Spot.