Simulations of eddy-driven jets and circulation on gas giants

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Jupiter's atmosphere consists of three dynamical regimes: the equatorial eastward flow and retrograde jets surrounding it; the midlatitudes with alternating eddy-driven jets and circulation; and the turbulent poles. Despite intensive research conducted on each of these regimes over the past decades, they remain only partially understood. Saturn's atmosphere also encompasses similar distinguishable regimes, but evidence for deep meridional cells is lacking. Models offer a variety of explanations for each of these regions, and only a few are capable of simulating more than one of the regimes at once. This study presents new numerical simulations, using a 3D anelastic GCM, that can reproduce the equatorial flows as well as the midlatitudinal pattern of the mostly barotropic, alternating eddy-driven jets and the meridional circulation cells accompanying them. These simulations are consistent with recent gravity and microwave data coming from the Juno mission. The dynamics of the simulation are greatly influenced by varying the simulation's inner depth. As expected for a gas giant, we find that the vertical eddy momentum fluxes are just as important as the meridional eddy momentum fluxes, which drive the midlatitudinal circulation on Earth. The number of the jets/cells, their extent, strength, and location are directly related to the boundary conditions and the Ekman number. Studies have shown that the rotation rate, the forcing scheme, and the Rayleigh number are also responsible for the emergence of jets in simulations of gas giants, but we keep these constant in our simulations. Our simulations also capture the tilted convection columns outside of the tangent cylinder, leading to the superrotation at the equator and the adjacent subrotating jets. A combination of boundary conditions leads to a stacked circulation cell pattern that is aligned with numerous jets that are conceptually similar to the meridional circulation in Jupiter's midlatitudes, as suggested by several studies. This analysis provides another step toward understanding the deep atmospheres of gas giants.