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Geostrophic turbulence on a beta-plane: a laboratory investigation of "How the planets got their stripes..."

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The banded patterns of cloud and wind are among the most striking features of the atmospheres of Jupiter and Saturn, but their dynamical origin remains poorly understood. It is also intriguing that there is increasing evidence from both eddy-permitting model simulations and actual observations in the Earth's oceans that similar zonally-banded circulation patterns occur on latitudinal scales of a few degrees, or even smaller scales in the presence of strongly sloping bottom topography. Most approaches towards understanding zonation so far have used highly idealized models to show that it might originate from dynamical anisotropy in a shallow turbulent fluid layer due to the planetary β-effect. Here we report the results of laboratory experiments, conducted on the 14-m diameter Coriolis turntable in Grenoble (France), which quantitatively confirm that multiple quasi-barotropic zonal jets may indeed be generated and maintained by this mechanism in the presence of deep convection and a topographic β-effect. At the very small values of Ekman number ($\sim 2 \times 10^{-5}$) and large local Reynolds numbers ($\sim$2000, based on jet scales) achieved, the kinetic energy spectra suggest the possible presence of both energy cascading and enstrophy-cascading inertial ranges in addition to the zonation at around twice the Rhines wave number. The latter is also associated with significant spectral anisotropy at low wavenumbers. Such jets are not found with a flat bottom, however. Implications of these results will be discussed in the context of various geophysical problems, including the atmospheres of the outer planets and the Earth's oceans.