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Rapidly rotating Rayleigh-Bénard convection with a tilted axis

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We numerically explore the dynamics of an incompressible fluid heated from below, bounded by free-slip horizontal plates and periodic lateral boundary conditions, subject to rapid rotation about a distant axis that is tilted with respect to the gravity vector (supposed vertical). The angle ϕ between the rotation axis and the horizontal plane measures the tilting of the rotation axis and it can be taken as a proxy for latitude, if we think of a local Cartesian representation of the convective dynamics in a rotating fluid shell. The results of the simulations indicate the existence of three different convective regimes, depending on the value of ϕ: (1) sheared, intermittent large-scale winds in the direction perpendicular to the plane defined by the gravity and rotation vectors, when rotation is "horizontal" ($\phi = 0$); (2) a large-scale cyclonic vortex tilted along the rotation axis, when the angle between the rotation axis and the gravity vector is relatively small (ϕ between about $45°$ and $90°$); (3) a new intermediate regime characterized by vertically sheared large-scale winds perpendicular to both gravity and rotation. In this regime, the winds are organized in bands that are tilted along the rotation axis, with unit horizontal wavenumber in the plane defined by gravity and rotation, at values of ϕ less than about $60°$. This intermediate solution, studied for the first time in this work, is characterized by weaker vertical heat transport than the cases with large-scale vortices. For intermediate values of ϕ (between about $45°$ and $60°$) the banded, sheared solution coexists with the large-scale vortex solution, and different initial conditions lead to one or the other dynamical behavior. A discussion of the possible implications of these results for the dynamics of rapidly-rotating planetary atmospheres is provided.