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A generalized quasi-geostrophic model of thermal convection

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It is well known that, under the influence of planetary rotation, convective flows tend to have a two dimensional (2D) structure, with small variations along the direction of rotation. Because of the primary force balance between pressure gradients and the Coriolis force, such flows are termed geostrophic. Convective flows are never purely geostrophic because buoyancy (which powers convection) is necessarily present and so is viscous dissipation. Nevertheless, provided rotation is dominant, the first order 2D nature of convective flows is preserved and these flows are often referred to as quasi-geostrophic (QG). QG numerical models of thermal convection, in which only equatorial variations are tracked, have been developed to take advantage of the predominant 2D structure of QG flows. These models can reproduce faithfully some of the features of fully three-dimensional (3D) numerical models. The chief advantage of such QG models is that, because of their 2D nature, a much higher numerical resolution is achievable than for 3D models for the same computing cost and can thus be used to study aspects of convection under a regime not accessible to 3D models. In existing QG models, the buoyancy force is restricted to its component perpendicular to the rotation axis and the modelled region of convection is limited to that outside the tangent cylinder. Here, we present an extension on these models by incorporating the axial component of the buoyancy force and by modelling convection inside the tangent cylinder. Our model can reproduce the salient features of 3D numerical models near onset. Further, our model also captures features of well developed, fully turbulent convection, such as production of zonal jets.