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Emergence of coherent structures in convectively driven baroclinic flows

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Large-scale flows in the gaseous planets lacking a strong mean thermal gradient are believed to be sustained by thermally driven small scale turbulence. Despite the fact that the turbulence source can induce potential energy in the flow, the large scale structures are barotropic or nearly barotropic. We investigate turbulence self-organization in a quasi-geostrophic two layer model on a beta-plane with no imposed meridional thermal gradient and turbulence supported by an external random stirring. The goal is to address the emergence of large scale coherent structures for a wide range of parameters and their characteristics focusing on their baroclinicity. We employ a second order closure of the statistical state dynamics that allows the identification of statistical turbulent equilibria and the investigation of their stability. The bifurcation of the statistically homogeneous equilibrium state to inhomogeneous states comprising of coherent waves and/or jets is analytically studied. We find that if the scale of excitation is larger than the deformation radius, the emergent structures are barotropic. When the excitation is at scales much shorter that the deformation radius, mixed barotropic-baroclinic states with jets and/or waves arise with the baroclinic component of the flow being subdominant for low energy input rates and non-significant for higher energy input rates. When compared to direct numerical simulations of the turbulent flow, the statistical theory is found to accurately predict both the critical transition parameters and the characteristics of the emergent structures.