



The dynamics of baroclinic zonal jets

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Multiple alternating zonal jets are a ubiquitous feature of planetary atmospheres and oceans. However, most studies to date have focused on the special case of barotropic jets. Here we investigate the dynamics of freely evolving baroclinic jets, using a two-layer quasi-geostrophic annulus model with sloping topography.

In a suite of 15 numerical simulations, the baroclinic Rossby radius and baroclinic Rhines scale are sampled by varying the stratification and root-mean-square eddy velocity, respectively. Small-scale eddies in the initial state evolve through geostrophic turbulence and accelerate zonally as they grow in horizontal scale, first isotropically and then anisotropically. This process leads ultimately to the formation of jets, which take about 2,500 rotation periods to equilibrate. The kinetic energy spectrum of the equilibrated baroclinic zonal flow steepens from a -3 power law at small scales to a -5 power law near the jet scale.

The conditions most favorable for producing multiple alternating baroclinic jets are large baroclinic Rossby radius (i.e., strong stratification) and small baroclinic Rhines scale (i.e., weak root-mean-square eddy velocity). The baroclinic jet width is diagnosed objectively and found to be 2.2–2.8 times larger than the baroclinic Rhines scale, with a best estimate of 2.5 times larger. This finding suggests that Rossby wave motions must be moving at speeds of approximately 6 times the turbulent eddy velocity in order to be capable of arresting the isotropic inverse energy cascade.

Reference

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