Self-organization of the atmospheric macroturbulence to critical states of weak nonlinearity

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If baroclinic eddies are efficient enough to influence the thermal stratification of an atmosphere, they adjust the stratification such that nonlinear eddy-eddy interactions of the atmospheric macroturbulence are weak. States of strong nonlinear eddy-eddy interactions and accompanying inverse energy cascades appear not to be attainable in the atmosphere, notwithstanding their attainability (and prominence) in quasigeostrophic models.

Simulations with an idealized general circulation model over wide range of climates show that the supercriticality, or nonlinearity, of atmospheric flows initially increases with increasing baroclinicity but levels off and remains nearly constant if the baroclinicity is increased beyond a critical value. The critical value of the baroclinicity at which the supercriticality reaches saturation is the value at which baroclinic eddies begin to exert a significant influence on the thermal stratification. For baroclinicities less than the critical value, the stratification is set by convection; for baroclinicities greater than the critical value, the stratification is set by baroclinic eddies. Turbulent fluxes, for example, of heat and momentum exhibit a phase transition at the critical value, with different power laws for the scaling of the fluxes on either side of the phase transition. In the phase in which baroclinic eddies set the stratification, one obtains a scaling theory for turbulent fluxes of heat and momentum by using the fact that eddy-eddy interactions are weakly nonlinear, paired with considerations of the energy cycle of the atmospheric circulation. The scaling theory is consistent with the results of simulations with the idealized GCM.