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Dynamical constraint for tropopause height in an idealized model

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Using idealized dynamical models we explore the factors determining the tropopause height and how this affects the equilibration of baroclinic eddies. The troposphere may be regarded as a lower boundary layer for the atmosphere: it is that region in which significant dynamical lateral and vertical transfer of energy occurs, with the tropopause acting as a front that separates the troposphere from a stratosphere that is more nearly in radiative equilibrium. The determination of the tropopause is thus intimately related to the question of baroclinic eddy equilibration in the non-quasigeostrophic context, when the eddies are free to determine their own height. If energetic constraints (i.e., the so-called radiative constraint) apply, then the tropopause height and stratification cannot be independently determined by the dynamics and must be related through a ‘dynamical constraint’(Held, 1982).

The question of what is the most relevant dynamical constraint is still unclear. One possibility widely discussed in the literature is that the tropopause height were given by the ’Charney height’, $Sf^2/(\beta N^2)$ where $S = dU/dz$ is the shear. In this case the criticality to baroclinic instability would also be constrained. However, the stratification in rigid-lid primitive equation models (i.e., with fixed tropopause) seems to obey a different dynamical constraint, which may be explicitly expressed in terms of the heating using quasi-geostrophic turbulence theory. These models can also become supercritical in some parameter regimes. A fair question is whether the rigid-lid and unbounded models equilibrate in fundamentally different ways, and are thus constricted by different dynamical constraints. We report on a series of simulations with an idealized primitive equation model that explores these issues.