Convective properties of rotating, stratified atmospheres at low and high Mach number

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Abstract goes here.

INTRODUCTION

Papers on rotating RB convection that might matter: [1–5]. Papers on rotating stratified f-planes that might matter: [6–8]. Honestly, most stratified, rotating sims seem to avoid simplicities (like the f-plane) as though they were the plague.

EXPERIMENT

We study a plane-parallel atmosphere whose initial stratification is polytropic,

$$\begin{aligned} \rho_0(z) &= \rho_t(1 + L_z - z)^m, \\ T_0(z) &= T_t(1 + L_z - z), \end{aligned} \tag{1}$$

We utilize a localized f-plane model in which the domain is subject to a constant, unidirectional rotation, $\boldsymbol{\Omega} = (0, \Omega_0 \sin\theta, \Omega_0 \cos\theta)$. This is similar to the approached used in [6], and implies that the domain represents an area of relatively small extent near the surface of a planet or star, such that the rotation vector does not change appreciably over the domain. This assumption means that the centripetal force, $\boldsymbol{F}_{\text{cent}} \propto \boldsymbol{\Omega} \times (\boldsymbol{\Omega} \times \boldsymbol{r})$, is uniform across any given slice of the atmosphere, and thus it only modifies the initial pressure profile. If $\theta \neq 0$, then the upwards component of the centripetal force acts to weaken the effects of gravity.

We evolve the Fully Compressible Navier-Stokes equations,

$$\frac{\partial \ln\rho}{\partial t} + \nabla\cdot\boldsymbol{u} = -\boldsymbol{u}\cdot\nabla\ln\rho, \tag{2}$$

$$\begin{aligned} \frac{\partial \boldsymbol{u}}{\partial t} + 2\boldsymbol{\Omega}\times\boldsymbol{u} + \nabla T - \nu\nabla\cdot\bar{\bar{\boldsymbol{\sigma}}} - \bar{\bar{\boldsymbol{\sigma}}}\cdot\nabla\nu = \\ -\boldsymbol{u}\cdot\nabla\boldsymbol{u} - T\nabla\ln\rho + \boldsymbol{g} + \nu\bar{\bar{\boldsymbol{\sigma}}}\cdot\nabla\ln\rho, \end{aligned} \tag{3}$$

$$\begin{aligned} \frac{\partial T}{\partial t} - \frac{1}{c_V}\left(\chi\,\nabla^2 T + \nabla T\cdot\nabla\chi\right) = \\ -\boldsymbol{u}\cdot\nabla T - (\gamma-1)T\nabla\cdot\boldsymbol{u} \\ + \frac{1}{c_V}\left(\chi\nabla T\cdot\nabla\ln\rho + \nu\left[\bar{\bar{\boldsymbol{\sigma}}}\cdot\nabla\right]\cdot\boldsymbol{u}\right), \end{aligned} \tag{4}$$

with the viscous stress tensor given by

$$\sigma_{ij} \equiv \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} - \frac{2}{3}\delta_{ij}\nabla\cdot\boldsymbol{u}\right). \tag{5}$$

We have previously shown that the superadiabaticity of a polytropic atmosphere, ϵ, is the primary control parameter of the Mach number of the evolved atmosphere. Here we study two values of $\epsilon = (10^{-4}, 0.5)$ in order to study low at high Mach number flows. We study the behavior of convection near onset and with a supercriticality parameter up to 10^3. We examine three different values of the Convective Rossby number ($\text{Ro}_c = (0.1, 1, 10)$) in order to understand the behavior of atmospheres in which convective driving dominates over rotation, in which those forces are equal, and in which the rotation dominates over convective driving.

We measure the resulting Rossby number, Nusselt number, and Reynolds number of all flows in order to understand the various regimes of convection which are open to us.

RESULTS & DISCUSSION

This is where figures go and other important things that we like to talk about.

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