Extension of a Cartesian Geometry MHD Boussinesq Code to the Anelastic Approximation

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Abstract

Most numerical simulations use the framework of the Boussinesq approximation for modeling the turbulent convective flows in the planetary interiors of our solar system. Typically, the planets' density varies considerably with radius. Such background density variations have a large impact on the interior flow dynamics and are completely neglected in Boussinesq models. However, the effects of density stratifcation can be studied by using the anelastic approximation which - in contrast to fully compressible models - filters out fast time scales caused by sound waves.

In our anelastic approach we assume a perfect gas with the heat diffusion depending on the entropy instead of the temperature. Due to eliminating the pressure, the entropy is left as the only thermodynamic variable in the set of time-dependent equations. Furthermore we concentrate on the special case of constant dynamic viscosity while the entropy's turbulent diffusion coefficient is assumed inversely proportional to density keeping the Prandtl number constant.

As the governing equations of the anelastic system are very similar to the Boussinesq ones, we extent an existing Cartesian geometry spectral Boussinesq code to our anelastic model. In the horizontal direction the unknowns are expanded into truncated Fourier series. To allow for a vertical density stratification we apply finite difference formulas of arbitrary order of accuracy on grids with arbitrary spacing. The new models' code is kept very general. Consequently it can be used for 2D/3D and Boussinesq/anelastic simulations with different time stepping schemes.

So far we we sucessfully reproduced the results of a benchmark suggested by Lantz and Fan (The Astrophys. J. Supp., 121: 247-264, 1999) that tests the code's nonlinear dynamics. Further benchmarks are currently in progress.

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