Modeling atmospheric circulations with soundproof equations

Piotr K. Smolarkiewicz
National Center for Atmospheric Research (NCAR), Boulder, Colorado

Since the beginning of the 20th century, the anelastic approximations (including the classical incompressible Boussinesq model) have underlain the majority of research in low Mach number flows under gravity, such as atmospheres (planetary and stellar) and oceans. In this talk, I will discuss recent advances in the area of generalized anelastic approximations that filter out sound waves from the equations governing fluid motions. In particular, I will address the performance of anelastic models across a wide range of scales. While broader physical implications are indicated, theoretical considerations are illustrated with examples of atmospheric flows.

One common feature of anelastic models is the Boussinesq linearization of the pressure gradient force, resulting in a simplified representation of the vorticity dynamics. Among the existing soundproof models, Durran's pseudo-incompressible system is distinct. It represents thermal aspects of compressibility free of sound waves, yet the momentum equation is unapproximated. The latter admits unabbreviated baroclinic production of vorticity, thus facilitating separation of compressibility and baroclinicity effects per se. This distinct feature of the Durran system makes it a unique theoretical tool that complements both the standard anelastic and fully compressible models. Compared to other reduced fluid models, there is little cumulative experience with integrating the Durran system. In this talk I will compare consistent control-volume integrals of the Durran and the established Lipps-Hemler forms of anelastic equations. Because the resulting numerical model is build from a preexisting anelastic model of Lipps-and-Hemler, the consistency of the numerics is assured thus minimizing uncertainties associated with ad hoc code comparisons.