A semi-implicit time-splitting scheme for a regional atmospheric model

Andrei Bourchtein, Ludmila Bourchtein
Institute of Physics and Mathematics, Pelotas State University
Pelotas, Brazil
bourchtein@gmail.com

Key words: atmospheric model, Euler equations, semi-implicit scheme, time-splitting scheme

The atmosphere is a complex system supporting complex processes of different space and time scales. Accordingly, the complete 3D mathematical models of the atmosphere (Navier-Stokes or Euler equations) contain multi-scale solutions with fast and slow components. It is well-known that the fastest atmospheric waves are the acoustic ones, which do not contain any significant part of the atmospheric energy. The slower gravity waves are more energy valuable, while relatively slow advective processes and Rossby waves carry the main part of the atmospheric energy. Since differential approximations, which filter out fast waves, introduce distortions to the main physical modes, the problem of stiffness of the complete mathematical models of atmospheric dynamics should be addressed in design of numerical scheme.

In this study, a semi-implicit finite difference scheme is proposed for the nonhydrostatic atmospheric model based on Euler equations. The fast acoustic and gravity waves are approximated implicitly, while slow advective terms and Rossby modes are treated explicitly. Such time approximation requires solution of 3D elliptic equations at each time step. Efficient elliptic solver is based on decoupling in the vertical direction and then splitting in the horizontal directions. Stability analysis of the scheme shows that the time step is restricted only by the maximum velocity of advection and does not depend on speed propagation of the fast waves. The performed numerical experiments show computational efficiency of the designed scheme and accuracy of the predicted atmospheric fields.