Development of the nonhydrostatic dynamical core for SL–AV model

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The two-dimensional (in vertical plane) nonhydrostatic dynamical core was developed in the framework of the global finite-difference semi-Lagrangian model SL-AV [1].

The basic nonhydrostatic equations of the atmosphere as well as the general idea of their solution are similar to those of the semielastic semi-implicit semi-Lagrangian NH HIRLAM model [2], except that the momentum equation is replaced by the horizontal divergence equation. This approach provides an efficient numerical algorithm for solving the nonhydrostatic equations of the atmosphere.

The dynamical core employs vorticity-divergence formulation on the unstaggered grid (vorticity equation is absent for 2D vertical plane case). Furthermore, the SETTLS integration scheme [3] is applied instead of the classical two-time level semi-Lagrangian scheme used in NH HIRLAM. We also changed the geopotential calculation procedure from the midpoint rule to the trapezoidal rule. Another difference from the NH HIRLAM model is that we calculate the horizontal derivatives using the fourth–order scheme instead of the second–order algorithm.

A number of tests modeling the atmospheric processes with strong nonhydrostatic effects is carried out. The first test consists of a high–resolution adiabatic simulation with the artificial orography. The conditions of this experiment were as close as possible to those given in [4]. The time step was 6 s. For the vertical coordinate we used 101 layers (with constant $\Delta\sigma$) and the horizontal grid interval was 400 m covering a domain of about 160 km. The deviation of the horizontal wind from the basic state after 9000 s is shown in Fig. 1, left with the contour interval of 0.5 m/s. The area shown extends 20 km on each side of the center of the mountain and from 0 to 8 km in the vertical.

There are some differences in comparison with both analytical solution by Xue [4] (Fig. 1, right) and numerical solution by Janjic [5]. The reason of these differences is being investigated.

The numerical solution of the warm–bubble test [6] presented on Fig. 2 is in a good agreement with [5]. The time step in this experiment was 2 s (which can be compared to 0.3 s time step in [5]). The grid was represented by 101 vertical layers (100 m grid resolution from the Earth surface to 8 km) and by 400 horizontal nodes (100 m resolution). The maxima of the initial disturbance of the potential temperature from its neutral value of 300 K is 6.6 K. Initial position of disturbance is (0; 2750 m) with the diameter of 2500 m.

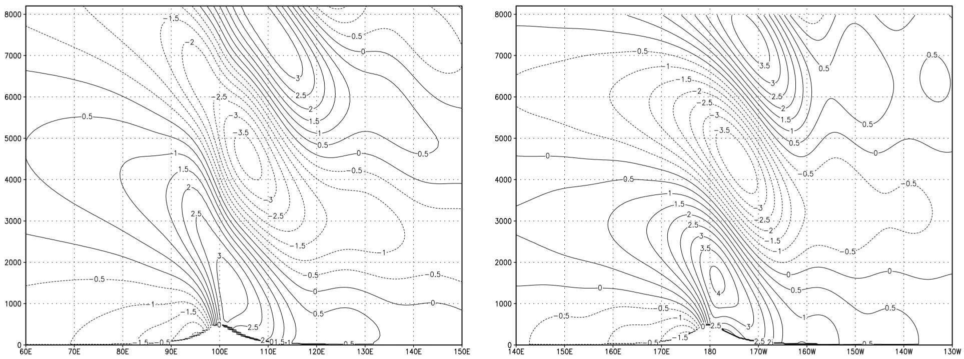

Figure 1: The deviation of the horizontal wind from its basic–state uniform value (10 m/s) after 9000 s. Left – numerical solution, right – analytical solution. The height of the bell shaped hill was 500 m, and its half–width was 2000 m. The Brunt–Vaisala stability parameter N is approximately 0.01 1/s.

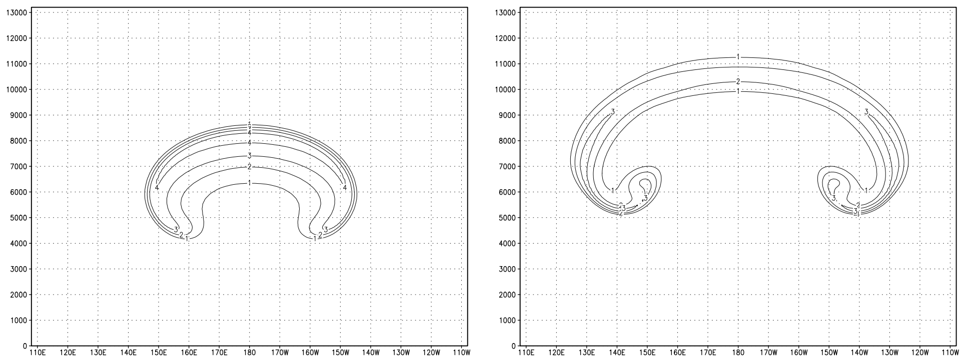

Figure 2: The potential temperature deviation after 900 s (left) and 1260 s (right) in the warm bubble test. The contour interval is 1 K.

References

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